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The effect swimming training intensity has on sleep, mood and recovery in elite swimmers

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453744

Dissertation submitted to the Faculty of Health Sciences; University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Medicine in the field of Biokinetics

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UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

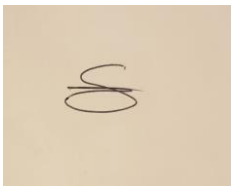
Centre for Exercise Science and Sports Medicine,

School of Therapeutic Sciences,

Johannesburg, 2020

DECLARATION

I Shandré Lee Pretorius declare that this dissertation is my own work. It is being submitted for the degree of Master of Science in Medicine in the field of Biokinetics at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.



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Shandré Lee Pretorius

_____14_____day of __September__ 2020

Date

DEDICATION

This dissertation is dedicated to my loving and supportive family and my partner for encouraging me.

ABSTRACT

BACKGROUND: Swimming is dynamic in nature and utilises both anaerobic and aerobic energy systems, and is a sport in which elite athletes often reach their peak physiological performance. Recovery has been found to encompass five factors; sleep, nutrition and hydration, psychological and emotional state, and active cooldown. Sleep forms one of the main components and if an athlete has poor sleep quality and quantity it may have a negative cascading effect on the physiology involved in the recovery process. Sleep quality and the components of the Total Quality Recovery (TQR) score are all interlinked and dependent on each other in the cycle of recovery. When an individual has slept for 8 hours and is in a positive mood during training and competitions the swimmers performance improves. Although recovery measures have been studied in elite swimmers, quantifying each factor at an individual level by using the TQR, mood and sleep measures will add to the knowledge of optimising swimmers performance.

OBJECTIVE: To determine the effect swimming training intensity has on elite swimmers by assessing sleep, mood, performance and recovery.

METHODS: A quantitative, explorative analytical study was conducted to assess the effect that swimming training intensity has on sleep, mood, performance and recovery in 15 elite swimmers between the ages of 13-21 years with a mean age of 16±2.09 years. Individuals were required to wear a Fitbit™ device on their non-dominant wrist for the duration of the 14 week study to measure daily calories expenditure, steps, active minutes, distance walked , total sleep time (TST), restless minutes, rapid eye movement (REM), none rapid eye movement (NREM), light and deep sleep, exercise and resting heart rate (RHR). In addition they completed the following questionnaires daily- Total Quality recovery (TQR) and Sleep Diary (SD), and weekly the Wellness Questionnaire and the Profile of Mood States (POMS). The Pittsburg Sleep Quality Index (PSQI), Sleep Hygiene Index (SHI) and Morningness-Eveningness Questionnaire (MEQ) were completed every four weeks and lastly the Sports Emotional Questionnaire (SEQ) was only completed when the athlete swam in an event. Participants completed self-reported questionnaires and Fitbit data was automatically collected. All data was collected by the researcher on a weekly basis. Statistical analysis was performed using Statistica version 10. The

demographics were expressed as mean, median and interquartile ranges and descriptive analysis was used to describe the interrelationships of the PSQI, SHI, MEQ, SD, TQR, training intensity and performance, in order to illustrate the relationship between sleep, performance, mood and recovery. A pilot study on 8 participants was conducted using a similar methodology used to optimise the main study, and in the main study the same model Fitbit in addition to a different model was used in the latter part: hence the two studies are analysed and reported separately.

RESULTS: 15 participants were included in the final analysis of the main study; with the mean age of participants 16±1.81 years with competitive swimming years mean of 6.7±2.71 years. Data analysis in the pilot study was performed on 8 participants, with a mean age of 16±2.78 years and mean of 6.5±3.33 years of competitive swimming. **DROPOUT RATE:** 11.76% drop out of participants was observed with 2 participants being excluded from the main study due to incomplete data. In the pilot study there was a dropout rate of 46.67% with 7 participants being excluded. **SLEEP:** A 52% and 13% decrease in FB TST was found in the main and pilot study. A steadily increase in sleep efficiency was observed in the main (60%) and pilot (46%) studies. SD TST compared to FB TST in the main ($p=0.006$) and pilot ($p=0.03$) study. **MOOD:** A progressive increase in depression and decrease in vigour was observed in the main (5%; 4%) and pilot (6%; 5%) studies. Participants experienced a pleasant mood state throughout the duration of the main and pilot studies. **PERFORMANCE:** An average RHR of 63.43 beats per minute (bpm) was found in the main study. Performance times during training and competitions improved in the main (1.345 seconds; 0.04 seconds) and pilot (3.545 seconds; 7.465 seconds) study. **RECOVERY:** Each TQR component fluctuated during the main and pilot studies. The only component that remained relatively steady in the pilot study was water consumption.

CONCLUSION: It was found that TQR recovery directly reflected a swimmers' performance, during training cycles with changes in training intensity. A strong assumption can be made that the sleep and mood factors can influence performance through recovery. This study could effectively link aspects of sleep quality and quantity to recovery and that mood had an effect on performance during training and competitions. Therefore, this study was able to find a relationship between sleep, mood, recovery and performance.

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With sincere appreciation

Shandré Pretorius

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LIST OF DEFINITIONS

ADL's: activities of daily living are activities that an individual does on a daily basis

Backstroke: is a swimming stroke also known as the back crawl, it is performed on the back and uses alternating and opposite arm movements. As one arm pulls through the water from an overhead position to the hip, the other arm recovers above the water from the hip to the overhead position and vice versa (Keller, 2020).

Breaststroke: is a swimming stroke swum with the body facing downwards and the body moves from a horizontal to a more inclined position with the arms performing a simultaneous and symmetrical semi-circular movement while the legs perform a frog kick (Keller, 2020).

Butterfly: is swum in a prone position, the body performs a wave-like undulation starting at the head, then chest, hips and legs move in the sequence. The hands exit the water at the hips and then circle forward above the water until they are extended forward again while the legs are held together and move up and down symmetrically with the feet extended in a dolphin kick (Keller, 2020).

Diuretic: a type of drug that promotes fluid loss in the body increasing urine production (Oxford English Dictionary, 2015) or increases excretion of electrolytes and water (Howley and Thompson, 2012)

Freestyle: is a swimming stroke also known as the front crawl that is swum in a horizontal position on the chest, the body rolls from side to side, turning to the side of the arm that is currently pulling in the water while the head remains in a neutral position, face down, except when breathing. The arms move continuously and alternately, when one arm pulls underwater from an extended forward position down to the hip, the other arm recovers above the water, from the hip to the extended forward position and the legs perform fast, compact movements, alternating up and down with outstretched feet in a flutter kick (Keller, 2020).

Periodisation: is the process of dividing the annual training plan into a series of manageable phases. It ensures appropriate overload and recovery in each phase (Howley and Thompson, 2012).

Recovery: the return to a normal state of health, mind or strength (Cook and Beaven, 2013)

Macrocycle: consist of a three month training period

Mesocycle: four weeks in duration with one week of recovery

Microcycle: one week of training

VO_{2max}: the maximum or optimum rate at which the heart, lungs and muscles can effectively use oxygen during exercise, used as a way of measuring a person's individual aerobic capacity (Oxford English Dictionary, 2015).

.

LIST OF ABBREVIATIONS

A

ADL's: activities of daily living

F

FB: Fitbit

I

IM: Individual medley

M

MEQ: Morningness-Eveningness questionnaire

N

NREM: Non Rapid eye movement

NSCA: National Strength and Conditioning Association

P

POMS: Profile of Mood States

PSQI: Pittsburg Sleep Quality Index

R

REM: Rapid eye movement

ROM: Range of motion

S

SD: Sleep Diary

SEQ: Sports Emotions Questionnaire

SHI: Sleep Hygiene Index

T

TQR: Total Quality Recovery

TQRact: TQR action scale

TQRper: TQR perceived recovery

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CHAPTER 1: PROBLEM STATEMENT

The topics that will be covered in this chapter include:

1.1 Introduction
1.2 Aim
1.3 Objectives
1.4 Research question
1.5 Structure of dissertation

1.1 Introduction

Being a highly competitive sport, elite swimmers often reach a peak in their physiological performance, which can be measured in VO_{2max}, blood lactate concentration, and resting heart rate (Costa *et al*., 2015).With these physiological measures reaching their individual limitations, this could lead to a plateau in swimming performance. Despite these limitations there are other strategies an athlete can implement to improve performance. A study conducted by Chalencon *et al.* (2012) found that swimming performance decreased due to fatigue and insufficient recovery from training sessions. Therefore if an athlete has a sufficient and holistic recovery they could improve and maintain their adaptations, subsequently leading to an improved performance (Nugent *et al*., 2016).

Swimming is dynamic in nature and utilises both anaerobic and aerobic energy systems. Although a swimmer's performance is often referred to in the context of training load, the physiological demands are dependent on both the individual athlete and the training schedule (Pyne and Sharp, 2014). Training load comprises of the volume, intensity and frequency of water-based and dry-land training (Mujika *et al*., 1998; Chatard and Stewart, 2011). The training load debate regarding high-intensity-low-volume training verses low-intensity-high-volume training for elite swimmers has been researched. A study done by Nugent *et al.* (2016) found that lower volumes of training at a higher intensity allowed for a greater adaptation response and more time to recover. In comparison to higher volumes of training at a lower intensity resulted in a greater energetics reserve, thus it takes less time for the athlete to recover, however the adaptations achieved in performance were marginal (Nugent *et al*., 2016). The different training intensities allow for specific physiological adaptations if the corresponding recovery is allowed.

Intensity continues to play a role in recovery as it was observed by Costill *et al*. (1988) that on lower intensity endurance swims the participants had less glycogen depletion compared to higher intensity sessions. This has been confirmed by a study conducted by Helge (2017) and Gibala (2017). Costill *et al.* (1988) reported that for the higher intensity training days a greater dietary glycogen supplement was required to allow for the restoration of muscle glycogen stores for an adequate subsequent performance. Swimming adaptations acquired through both training approaches are specific to the individual. Studies by Nugent *et al.* (2016) and Pyne and Sharp (2014) suggest that the key behind adaptations and performance lies within recovery methods.

Although minimal research has been conducted linking recovery to swimming performance, it has been found that an athlete's performance can be influenced by mood state during competition seasons (Swain, 2011). Berger *et al.* (1997) found in highly competitive swimmers that there was an increase in fatigue and decrease in vigour during long periods of training. This study observed athletes throughout their normal training cycle involving practice and competition seasons (Berger *et al.* 1997). They found that if individuals attained their target swimming times during practice they experienced a positive mood that may have influenced their competition performance (Berger *et al.,* 1997). This study therefore illustrates the relationship between mood and swimming performance.

For the purpose of this study, recovery can be defined as the "return to a normal state of health, mind or strength" (Cook and Beaven, 2013). This implies that restoration or an adaptation can occur from sport recovery, resulting in the same or an improved athletic performance (Cook and Beaven, 2013 and Nugent *et al.*, 2016). However, recovery in sport is another aspect related to performance which needs to be included.

Recovery is a subject of increasing importance in the elite athlete population (Halson, 2013). Every aspect of the athlete's performance is analysed to find areas for improvement and new ways to excel (Halson, 2013). The use of recovery tools in an elite swimming population is limited and could provide an avenue for improving individual performance.

Recovery has been found to encompass five factors; sleep, nutrition, hydration, psychological and emotional state, and stretching and active rest (Kenttä, and Hassmén, 1998; Meeusen *et al.*, 2006). These factors can be effectively measured using the Total Quality Recovery (TQR)

scoring (Kenttä, and Hassmén, 1998). In order to quantifiably measure recovery the TQR score (Cottrill, 2007; Osiecki *et al.,* 2015) can be utilised. In addition self-reporting through comprehensive sleep and wellness questionnaires may link the importance of sleep to recovery and performance. Analysis of such questionnaires should allow identification of correlations between aspects of recovery, sleep, mood and performance.

A study using this scoring done by Tee (2009) found that recovery is adversely affected by the training intensity. He also reported an inverse relationship between mood, resting heart rate (RHR) and recovery. As recovery encompasses both physiological and psychological aspects (Meeusen *et al.,* 2006; Scott *et al.,* 2006; Samuels, 2008), it is important to focus on a recovery method required to restore both of these aspects. Sleep has been found to play a recovery role in psychological and physiological aspects which cannot be substituted with any other recovery modality (Meeusen *et al.,* 2006; Scott *et al.,* 2006; Samuels, 2008).

Sleep has been defined as "the homeostatically controlled behavior state of reduced movement and sensory responsiveness" by Fullagar *et al*. (2015). Although sleep duration and sleep diaries have been utilised to understand sleep quantity in studies (Sargent *et al.,* 2014; Samuels and James, 2014; Fullagar *et al*., 2015), there have also been studies conducted on sleep quality (Nedelec *et al.,* 2018; O'Donnell *et al.,* 2018), however there are minimal studies on sleep quality in elite swimmers.

Sleep has three main factors. The first factor is sleep length comprising of the total number of hours of sleep obtained per night and any time spent napping (Samuels and James, 2014). The average adult individual should sleep approximately 8 hours per night to prevent neurobehavioural deficits from occurring (Van Dongen *et al.,* 2003; Halson, 2013). Less than 6 hours of sleep negatively affects the immune system, glucose metabolism and concentration (Sargent *et al.*, 2014). It has also been found that napping time should be a maximum duration of 30 minutes to be effective and forms part of total sleep time (Samuels and James, 2014). Sleep quality forms the second factor encompassing fragmented sleep patterns, having a calming and relaxed sleeping environment and the identification of any possible sleeping disorders such as insomnia (Samuels and James, 2014). This plays an important role in sleep quality, as having disturbed sleep affects an individual's activities of daily living (ADL's), thus showing how critical a regular sleeping pattern is. The last factor is sleeping phase which consists of the

circadian timing of sleep. The circadian system has been found to regulate individuals' sleepiness and wakefulness and this directly influences an athlete's performance (Samuels and James, 2014). The typical circadian cycle is divided into two states known as non-rapid eye movement (NREM) and rapid eye movement (REM) (Halson, 2013). The optimal average length for good quality sleep is 75-80% and 20-25% of total sleep time for NREM and REM respectively (Carskadon and Dement, 2005; The National Academy of Science, 2006; Harvard Medical School, 2007). Sleep quality and its components are all interlinked and dependent on each other in the cycle of recovery. It is possible that if there is a decrement in one of these links, there will be a negative cascading effect on the physiology involved in the recovery process.

The importance of sleep differs among athletes in comparison to non-athletes (Scott, 2002; Leeder *et al.,* 2012; Marshall and Turner, 2016). Due to training, athletes of all ages require more sleep compared to non-athletes, due to the importance of sleep for recovery (Scott, 2002; Leeder *et al.,* 2012; Marshall and Turner, 2016). Unfortunately sleep quality in elite swimming population is poorly understood (Halson, 2013). However, studies have found that sleep has a crucial role in psychological and physical recovery (Meeusen *et al.,* 2006; Scott *et al.,* 2006; Samuels, 2008), especially after high-intensity training (Samuels, 2008). Another study found that there is a relationship between sleep and post-exercise recovery (Samuels and James, 2014). Sleep quality and the components of the TQR are all interlinked and dependent on each other in the cycle of recovery. The mood state of an athlete has been found to influence sleep and performance in swimmers (Swain, 2011). It was reported that an increase in positive mood state aids in the recovery process (Lundgvist and Kentta, 2010).

Although recovery measures have been studied in elite swimmers, quantifying each factor at an individual level by using the TQR, mood and sleep measures will add to the knowledge of optimising swimmers performance, and also provide a base for further studies. Furthermore these measures could highlight possible inconsistencies and improper recovery strategies, with applicable outcomes. The research enables more convenient ways to monitor recovery in elite swimmers and understanding the effect swimming training has on the athlete.

Thus the aim of this research was to identify the relationship between recovery techniques and performance using validated recovery and sleep questionnaires.

1.2 Aim

To analyse the effect between swimming training, sleep, mood, recovery and performance in an elite swimming population.

1.3 Objectives

1) To determine how the training regime influences sleep, mood, performance and recovery in swimmers, using the sleep diary, Fitbit, total quality recovery and profile of mood states questionnaires.
2) To determine how mood can affect a swimmer's performance during competitions, using the profile of mood states and sports emotional questionnaires.
3) To determine if a relationship exists between sleep quantity, a swimmer's performance and recovery, using performance testing and sleep questionnaires.

1.4 Research Question

Can a strong correlation be established between performance and recovery by analysing the TQR, sleep, mood and wellness questionnaires?

1.5 Structure of dissertation

This dissertation is structured around six chapters (Figure 1.1). The contents of each chapter are detailed in the figure below:

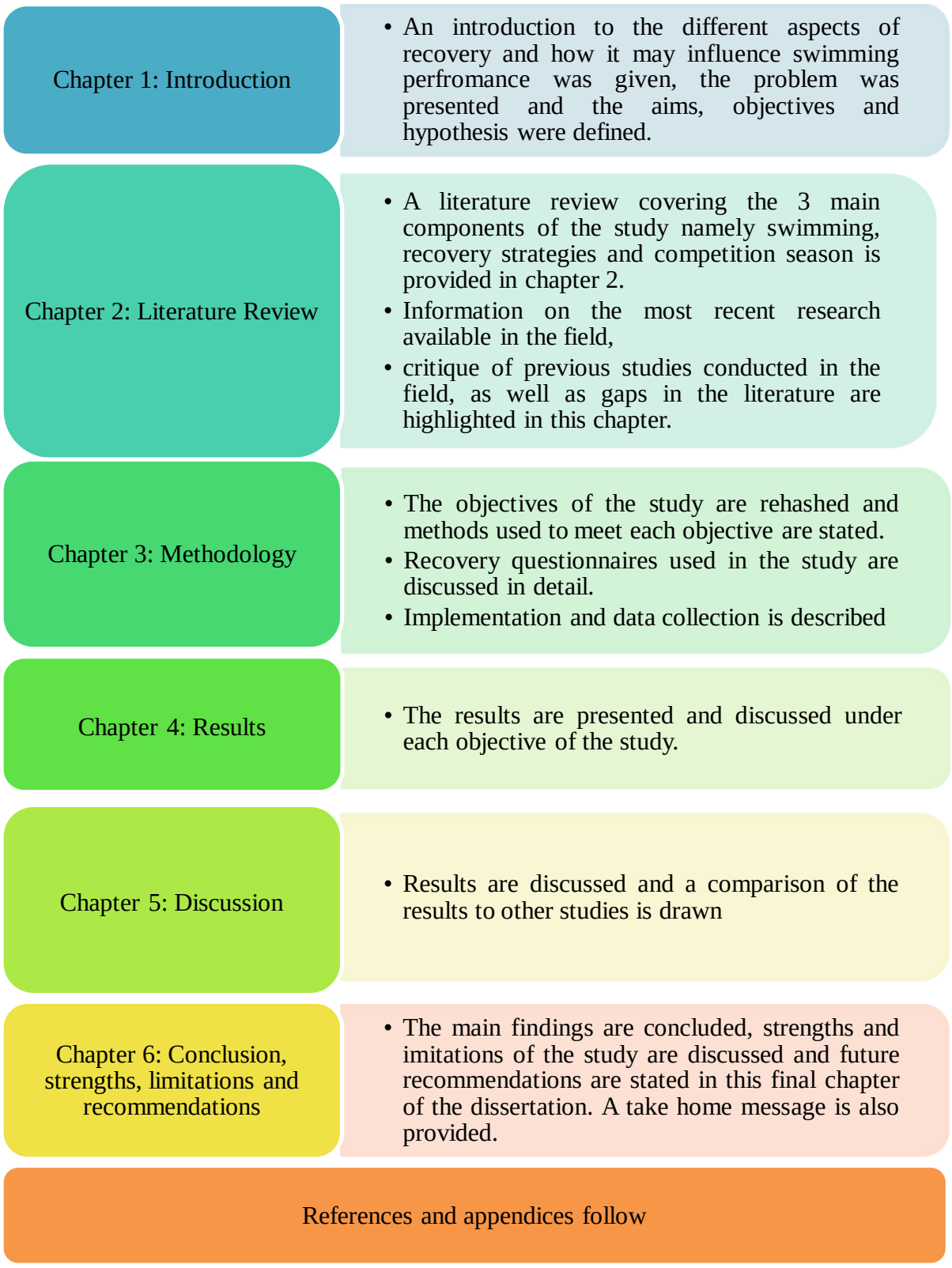


Figure 1.1: Structure of the dissertation

CHAPTER 2: LITERATURE REVIEW

The topics that will be covered in this chapter include:

2.1 Introduction
2.2 Swimming
2.3 Recovery in swimming
2.4 Recovery strategies
2.5 Summary

2.1 Introduction

The literature regarding the recovery in swimmers in general is minimal, especially within a South African population. Swimming is a demanding sport that requires the athletes to recover properly in order to reach their peak performance during competitions (Costa *et al.*, 2015). This study will contribute to the research conducted on swimmers in general but specifically in a South African context.

In this chapter, the three core components of this study are reviewed, namely: swimming, recovery and performance. Firstly, swimming is reviewed so that an understanding of the physical demands of the sport can be understood. The demanding training load and poor recovery strategies in swimmers leads to overtraining (Jones, 2017). The training regime consists of undulating volumes, intensity and frequency of water and land-based training (Mujika, 1998; Chatard and Stewart, 2011; Toubekis *et al.*, 2013); it incorporates full body strength training that is required for optimal performance in the water and is physiologically challenging on the individual (Costa *et al.*, 2015; Williams, 2017). This demanding training load with insufficient recovery methods can hinder a swimmers ability to attain their maximum peak performance.

Secondly, recovery is reviewed so an understanding of how different recovery factors can aid a swimmer to optimally recover. The TQR has been used to determine the rate of recovery within various athletic populations comprising of badminton players (Cottrill, 2007), soccer players (Osiecki *et al.*, 2015) and rugby players (Tee, 2009; Starling and Lambert, 2017). The TQR provides an insight into an athlete's general recovery (Cottrill, 2007). Two aspects of the TQR namely, sleep and mood was studied in more detail using questionnaires. Sleep is reviewed to

understand the effects it has on recovery and performance. Although, studies have found that sleep has a main role in physical recovery (Meeusen *et al.,* 2006). There is a limited amount of literature available relating to whether sleep quality or quantity is more responsible for recovery (Halson, 2013). The second aspect, mood is reviewed to understand the effect it has on a swimmers performance. It has been found that mood can affect an athlete's performance both during training and competitions (Berger *et al.,* 1997; Moller, 2020). Although sleep and mood were focused on in the study the other three remaining components are also essential to recovery.

Lastly performance (competition cycles) is reviewed to understand a swimmers training schedule and how the training affects the individuals recovery. The swimmers follow a tapering training load that is typically reduced by 50% to ensure proper recovery times are incorporated into the training regime (Mujika and Padilla, 2003; Plisk and Stone, 2003). The training load is arranged according to mesocycles as these cycles focus on competitions that occur throughout the year (Plisk and Stone, 2003).

2.2 Swimming

Swimming is known to be a competitive sport with a physically challenging water and land-based training load, which varies throughout the training cycle (Mujika *et al*., 1998; Chatard and Stewart, 2011). Competitive swimming requires athletes to swim a certain distance in the shortest time with correct technique despite being fatigued, under pressure and in pain (Dingley *et al.,* 2015; Goldsmith, 2018).

Water has three unique properties that can facilitate a swimmers strength training namely; buoyancy, physiologic assistance through hydrostatic pressure and natural resistance (Becker, 2009). There are two types of water-based training namely; hydrotherapy which is a passive, supportive form of training by immersing the body in water (Mooventhan and Nivethitha, 2014) and secondly water therapy is used to train and condition muscles by utilising the properties of water in an active manner (Becker, 2009). Active water-based training prepares the individuals for the different lengths of races by utilising the aerobic and anaerobic metabolic systems (Jones, 2007; Pyne and Sharp, 2014). During water-based training swimmers practice time based trials during the mesocycles in order to improve their performance time within various strokes (Jones, 2017), which consist of the breast, back, freestyle and butterfly strokes. Water-based training

differs from land-based training as it enables the swimmers to practice and correctly execute the previously mentioned strokes under time constraints and develop their cardiorespiratory system (Jones, 2017). Continuous water-based training enables the swimmers to adapt physiologically to the metabolic energy demands and decrease recovery time (Jones, 2017). Performing water-based plyometrics was found to increase force production, balance and isokinetic strength in the swimmers quadriceps and hamstrings compared to land-based plyometrics (Colado *et al*., 2010; Kobak *et al*., 2015). A study conducted by Junior *et al.* (2016) found that individuals improved their 25 metre freestyle performance times with water-based training. This shows that water-based training should be documented in studies as it forms an integral part of a swimmers training regime and preparation for competitions.

Land-based training enables the individuals to develop the necessary muscle strength and power to aid them in the three different phases of a swim (Jones, 2017; Williams, 2017). This comprises of the push off from the platform, strength in the shoulder muscles to follow through with the stroke and lastly push off from the turnaround during races (Jones, 2017; Williams, 2017). Faigenbaum *et al.* (2013) and Legerlotz *et al.* (2016) found that resistance training reduces injuries and can improve performance in young athletes. Land-based training forms the foundation of the strength of the individual so that they may have the necessary upper and lower body muscle strength and core stability to compete in swimming galas. In a study done by Aspenes *et al.* (2009) found that swimming speed improved in the 400 metre freestyle with an increase in upper body strength. This was corroborated by Garrido *et al.* (2010) which reported that strength training improved 25 and 50 metre freestyle swimming performance, by improving the muscular strength of the swimmers. Another study by West *et al.* (2011) found that lower body strength and power were important at the start of a 50 metre freestyle race. A swimmers' time can be improved with plyometric training that focuses on extension of the hip, knee and ankle joints (Bishop *et al.,* 2009; 2013; Monu; 2013). A study by Weston *et al.* (2015) reported a 2% improvement in the 50 metre freestyle swimming performance of junior swimmers after a twelve week core training programme. Core stability is essential for swimmers to maintain movement in the water and for correct posture, balance and alignment during swimming strokes; which is necessary for improving swimming performance (Fig, 2005; Willardson, 2007).

The combination of water and land-based training enabled swimmers to improve the 50 metre (Girold *et al.*, 2007), 400 metres (Aspenes *et al.*, 2009) and freestyle performance times (Garrido *et al.*, 2010; West *et al.*, 2011; Weston *et al.*, 2015). A study done by Brady *et al.* (2008) found that after rotator cuff surgery combination training increased the range of motion in the joint. Gibson and Shields (2015) reported that combination training after hip and knee arthroplasty improved joint range of motion and odema. The use of combination training in swimmers improves the athlete's cardiovascular system, overall strength and power output, which enables the individual to perform optimally in the water (Jones, 2017; Williams, 2017). However, due to the high training volumes swimming professionally is physiologically taxing on the individuals body (Costa *et al.*, 2015); this usually results in overtraining and possible injury which can hinder a swimmer's maximum performance (Jones, 2017).

2.2.1 Swimming training regime

Training in elite swimmers focuses on improving physiological abilities by incorporating land and water-based training (Jones, 2017; Williams, 2017). Both land and water-based training are important to ensure that the athlete is able to develop the necessary physiological capacity (Glowacki *et al.*, 2004; Jones, 2017) to competitively compete in the sprints, middle or long distance races.

Due to the focus of land and water-based training swimmers need to develop the necessary adaptations in order to perform optimally. This optimal performance can be obtained using periodisation. Periodisation can be defined as "a training plan whereby peak performance is brought about through the potentiation of biomotors and management of fatigue and accommodation" (Mateyev, 1972; Turner, 2011). The use of periodisation enables the athletes to train at an optimal level with a gradual weekly increase in the training load, which aids in preventing muscle fatigue (Mujika, 2009; Chalencon *et al.*, 2012).

Periodisation training progresses from a high volume low intensity towards a lower volume and higher intensity training regime (Plisk and Stone, 2003). The training regime comprises of three different cycles (Figure 2.1) namely, macrocycles, mesocycles and microcycles (Plisk and Stone, 2003).

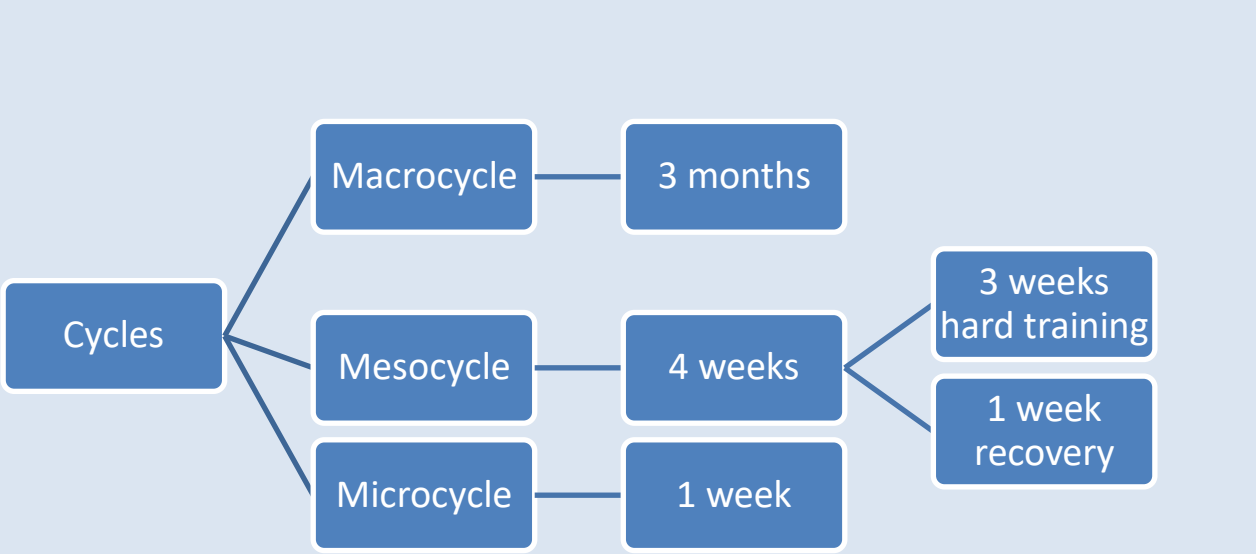


Figure 2.1: The training cycle regime (Plisk and Stone, 2003)

These cycles allows the swimmer's to understand the training regime set by their coach and progress towards individually set goals. During competitive swimming season's, mesocycle training is utilised (Plisk and Stone, 2003) (Figure 2.1), due to the gradual increase in training intensity with one recovery week (Plisk and Stone, 2003). This form of training attempts to ensure that swimmers' are at their peak during the competition seasons (Plisk and Stone, 2003). Enabling the athletes to training optimally, developing the necessary strength required to compete in the competition without the fatigue experienced from overtraining (Plisk and Stone, 2003; Haff, 2004).

Three of these mesocycles form one of four main macrocycles that occur throughout the year. Athletes can be tested at the beginning of each macrocycle, by performing time based tests and comparing the times to the previous cycle. Individuals will be able to see distinctive adaptations and improvements within strength, a decrease in muscle fatigue, increased endurance ability and performance times when comparing cycles.

The mesocycle training enables the physiological adaptations to gradually develop throughout the cycle (Plisk and Stone, 2003; Haff, 2004). Swimmers will notice a difference within their performance times and can compare the previous cycle to the current one and use it as a

motivation to push for qualifying in galas or Olympics. However, this is not always the case and due to the high demands of training and expectations of a professional swimmer the body adapts over a period of time and some individuals may experience overtraining or injuries (Haff, 2004) despite gradual progress.

Periodisation has been used for years in various sporting disciples worldwide (Houmard *et al*., 1990; Houmard *et al.,* 1994; Banister *et al.,* 1999; Toubekis *et al.,* 2013) and not only in swimming (Plisk and Stone, 2003). These types of cycles have been used internationally (Vorontsov, 2002; Maglischo, 2003; Barnier, 2012; Vergnoux, 2014; Hellard, 2019) by coaches and are important to assist athletes to gradually develop physiological adaptations while concurrently attempting to prevent overtraining and swimming related injuries (Plisk and Stone, 2003; Haff, 2004). The training cycles have been adapted within a South African setting by Swimming South Africa (2012) where coaches are utilising it as part of the training program to enable swimmer's to reach their peak performance for competitions.

2.3 Recovery in swimming

The use of recovery tools such as the TQR can help to understand the different aspects of recovery and how each link to one another. It can highlight the areas of importance within this elite swimming population and possibly improve individual recovery strategies.

It has been found that the body undergoes a flux between adaptation and maladaptation which is seen with changes in the training volume intensity and recovery during the training cycle (Cottrill, 2007). Fatigue, recovery and performance all go hand-in-hand. Recovery in the context of this study will be demarcated by sleep, TQR, mood and the time between training sessions. Full recovery between training sessions would allow for the same or an improved performance in succeeding sessions. If there is a decrement in performance this would be classified as fatigue due to an incomplete recovery (Nédélec *et al.,* 2012). To minimise the effects caused by fatigue recovery modalities such as rest and active recovery (Nédélec *et al.,* 2012 and Thorpe *et al.,* 2017) may be utilised. Swimming is a demanding sport with high volumes and frequencies of training (Jones, 2017), which makes recovery an essential mode of maintaining and improving performance.

2.4 Recovery strategies

Various recovery strategies are utilised by athletes in different sporting disciplines (Crowther *et al.* 2017) and is essential for athletic performance. Studies by Cook and Beaven (2013) and Nugent *et al.* (2016) found that a relationship exists between recovery and performance; therefore an overall understanding of how different components of recovery can affect a swimmer's performance is necessary if an individual wants to improve their performance.

There are different forms of recovery methods including stretching, massage, sleep, cold water immersion, contrast water therapy, active recovery and combined therapy (Hing *et al.,* 2010; Venter *et al.,* 2010; Halson, 2013; Crowther *et al.,* 2017). Crowther *et al.* (2017) found the preferred three recovery methods in team sports were, stretching, cold water immersion and cold water therapy. In a study done by Hing *et al.* (2010) contrast water therapy was the preferred form of recovery in New Zealand athletes, while Simjanovic *et al.* (2009) found that Australian athletes used nutrition, stretching, active recovery and cold water therapy as forms of recovery. The French soccer team combined active recovery, massage, stretching, compression and electrical stimulation with either cold water therapy or cold water immersion (Nédélec *et al.,* 2013). A study conducted by Van Wyk and Lambert (2009) found that 83% of elite South African rugby players preferred using the combination of stretching and cold water immersion while 74% used active recovery and cold water immersion. Venter (2014) reported that South African team sport athletes used sleep, fluid replacement or socialising as a form of recovery.

Currently the literature states that ice baths are the best form of recovery for swimmers' (Walker, 2016), however there is limited literature regarding recovery methods for South African swimmers'. A study conducted by Nogueira *et al.* (2015) found that juvenile swimmers' obtained a well recovered score of 14 on the TQR, with a higher score obtained in phase two of training. This corresponded with a decrease in the training load and improved recovery; however it is expect that an elite group of swimmers' will score higher than juvenile due to individuals being more mature and using other recovery strategies.

Recovery incorporates many aspects and one way of measuring recovery is by using the Total Quality Recovery (TQR) questionnaire.

2.4.1 Total Quality Recovery (TQR) as a recovery tool

Although there is minimal research available on TQR and sleep quality in a general and South African swimming population, it has been used in other sports (Cottrill, 2007; Tee, 2009; Osiecki *et al.,* 2015; Starling and Lambert, 2017). A study done on elite badminton players does however find the categories and their weightings appropriate for the athlete's needs (Cottrill, 2007). Another study done in a soccer population showed a strong relation between TQR scores and muscle damage biomarkers thus showing the connection between recovery physiology and performance (Osiecki *et al.,* 2015). A study conducted by Starling and Lambert (2017) in rugby players found that using the TQR, individuals were able to monitor training fatigue. The TQR has been found to be a valid and reliable tool for an athletic population (Tee, 2009) and each component will be discussed below.

2.4.2 Components of TQR

The Total Quality Recovery questionnaire (Appendix A) is a questionnaire that is used to assess overall recovery in an athletic population (Cottrill, 2007, Osiecki *et al*., 2015; Starling and Lambert, 2017). This questionnaire was chosen for the study as it comprises of five recovery categories namely: nutrition, hydration, sleep and rest, relaxation and emotional status and lastly stretching and active rest (Kentta and Hassmen, 1998) which will be elaborated on in the following subsections.

i. *Nutrition*

During endurance and high intensity exercise, such as swimming, glycogen provides energy for sustained movement. Thus during recovery these stores need to be replenished in order to be ready for the next bout of exercise and to use as energy for adaptations to occur (Burke and Mujika, 2014). This refuelling of glycogen comes from a dietary source of carbohydrates (Burke and Mujika, 2014; Pyne and Sharp, 2014). A study by Vanheest *et al.* (2014) focused on elite junior female swimmers found that energy-deprived swimmers had a 10% decline in speed. Intense bouts of swimming will cause micro-trauma to the muscles (Burke and Mujika, 2014), and to repair and create new myofibrillar tissue for adaptations to take place, protein synthesis needs to occur, and this is sourced in the diet. These processes are accurately generalised - for a

broad population, but recovery is individualised and thus needs a specific dietary intake per person (Pyne and Sharp, 2014).

There is a limited amount of literature available on South African swimmers' nutrition; however interviews with the athletes were found (Scheepers, 2012; Sunday Times, 2012; Pressreader, 2014; Heslop, 2015). An interview by Pressreader (2014) with Roland Schoeman a South African sprint swimmer found that he prefers a Banting diet supplemented with more carbohydrates and less fat to aid with his anaerobic recovery and to replenish the muscle glycogen stores. The correct diet is important for a swimmer although it is individualised and specifically tailored to energy demands for endurance or sprint competitions. South African swimmers Cameron van der Burgh (Sunday Times, 2012), Kathryn Meaklim (Scheepers; 2012) and Marlies Ross (Heslop, 2015) all have diets that suit the performance requirements but there is no specific mention of the nutritional intake.

ii. Hydration

Inadequate fluid intake can lead to a decrement in performance and recovery (Arnaoutis *et al*., 2015; Baron *et al.,* 2015) as water is required to utilise the body's stored carbohydrates (Kentta and Hassmen, 1998). This category is based on the body's homeostasis and a balance between hydration and dehydration. Hydration is defined as optimal water concentration for body functioning and homeostasis (Arnaoutis *et al*., 2015; Baron *et al.,* 2015), while dehydration is the loss of body water (Popkin *et al*., 2010). Dehydration can cause early fatigue, decreased response times, increase the risk of injuries and lastly increase the risk of muscle cramps (Buchanan, 2017). Within the same study by Buchanan (2017) it was found that the consumption of alcohol and caffeine increased the production of urine which leads to water loss. Therefore swimmer's need to compensate for fluid loss by consuming approximately 125-150% of their fluid deficit to ensure that proper recovery is obtained (Burke and Mujika, 2014). Sheila (2005) recommends individuals consume 3.7 and 2.7 litres of water per day for men and women respectively. Regrettably there is minimal literature on the hydration status of both South African and international swimmer's. A study by Nogueira *et al.* (2015) analysed the overall TQR score instead of reporting on the individual hydration component in juvenile swimmers.

The TQR utilises urine colour as its method for determining hydration, which can be limited due to urine colour being affected by illness, diet, and medications (Baron *et al.*, 2015; Kavouras *et al*., 2015). However urine colour is appropriate for determining hydration status as there is a linear relationship between urine colour and urine osmolality (Baron *et al.*, 2015; Kavouras *et al*., 2015).

iii. Sleep and rest

Sleep is a controlled behaviour state with a reduction in movement and sensory responsiveness (Fullagar *et al*., 2015) and has been found to affect an athlete's rate of physical recovery (Meeusen *et al.*, 2006). Samuels and James (2014) observed a relationship between sleep length, sleep quality and sleep phase and post-exercise recovery.

The current elite swimming training regime involves morning and evening sessions and disrupts the amount of sleep athletes obtain (Sargent *et al.*, 2014), which is detrimental to the recovery process. Athletes in individual sports such as swimming acquire a sleep deficiency known as sleep debt, which can be decreased when an individual naps; therefore increasing the hours spent sleeping (Lastella *et al.*, 2014). However, the effectiveness of sleep is not only dependent on duration but also sleep quality. The parameters for quality sleep are: falling asleep within 20-30 minutes, sleeping through the night with brief awakenings and spontaneously waking up feeling refreshed in the morning (Samuels and Alexander, 2013). These factors can be disrupted by lifestyle influences and environmental sleep disturbances (Samuels and Alexander, 2013). It is therefore evident that varying sleeping hours and quality will affect performance. Halson (2014) reported that sleep can also be monitored effectively using actigraphy. Actigraphy involves using a non-invasive method of measuring an individual's wakefulness (Halson, 2014).

There is minimal literature available on South African athletes sleeping patterns however a study conducted by Venter *et al*. (2010) found that 33% of 890 elite South African hockey, netball, rugby and soccer athletes have irregular sleeping patterns and 41% have trouble falling asleep. Nogueira *et al.* (2015) conducted a study on juvenile swimmers using the TQR, however there was no data reported on the sleep and rest component of the TQR but rather an overall recovery score.

iv. Relaxation and emotional status (mood)

An altered mood state and a high level of stress can lead to fatigue (Swain, 2011). The Profile of Mood States (POMS) (Appendix B) and the Sports Emotions Questionnaire (SEQ) (Appendix C) is used to monitor the mood state of the individual during competition seasons (Swain, 2011; Chennaoui *et al.,* 2016; Vacher *et al.,* 2017). Athletes may experience more negative emotions during an increase in the training cycle compared to the tapering periods of the cycle (Vacher *et al*., 2017), and emotional exhaustion has been found to be related to higher stress levels and poor recovery (Lazarus, 1993; Kellmann and Gunther, 2000). Hu *et al.* (2015) found that the human stress-coping mechanism causes an increase in cortisol levels, which can affect an individual's sleep cycle. Within the same study it was reported that massage, naps, and family and peer support helped athletes attain relaxation and emotional stability (Hu *et al.,* 2015).

However, emotional status and modes of relaxation are hard to standardise, as these are highly subjective. There is minimal literature available on the relaxation and emotional status of South African swimmers' although a study conducted by O'Neil and Steyn (2007) found that non-elite endurance athletes coped with environmental stress by identifying the stress, changing the perception of the stressor and strategies to cope with the stress. A study by Nogueira *et al.* (2015) used the TQR on a group of juvenile swimmers', but analysis was on the overall TQR recovery score and not the relaxation and emotional status alone**.**

v. Stretching and active rest

Active recovery has many benefits including aiding the return of the body to homeostasis (Brukner *et al*., 2012). According to research conducted by National Strength and Conditioning Association (NSCA) (2017) stretching decreases blood flow; and increases joint ROM and decreases muscle stiffness. This is contradictory when compared to another study conducted by Evjenth *et al.* (1985) which found that stretching increases blood flow to the muscles which in turn improves an athlete's recovery.

There is minimal literature on stretching and active rest within a South African swimming population. Therefore this current study will provide insight into the stretching and active rest literature applicable to a South African elite athletic population.

2.5 Performance

A study done by Bächlin and Troster (2009) found that a swimmer's stroke technique is directly related to the individual's performance in training and competitions. Another study conducted by Pyne *et al*. (2004) reported that swimmers should improve performance by 1% in competitions and 1% per year closer to the 2000 Olympics; this ensures that the individual's performance times improve. Performance of swimmer's may also depend on the reduction of training closer to competitions (Houmard and Johns, 1994; Mujika and Padilla, 2003; Mujika *et al*., 2004; Bosquet *et al*. 2007). Therefore understanding how a swimmer's performance can be influenced is important to ensure that individuals are training appropriately and developing the necessary physiological adaptations required for competitions (Pyne *et al.*, 2004; Costa *et al*., 2010).

2.5.1 Factors relating to performance

There are various factors that affect an athlete's performance but for the purpose of this study the five components of the TQR and how each affect a swimmer's performance will be discussed below.

i. Nutrition

An athlete's performance can be affected by inadequate ingestion of carbohydrates (Shaw *et al.*, 2014). Carbohydrates provide energy during endurance sports, such as in swimming (Burke and

Mujika, 2014; Pyne and Sharp, 2014). A 10% decline in the speed of elite junior female swimmers were found to be related to energy-deprivation (Vanheest *et al*., 2014) Shaw *et al.* (2014) found that athletes with inadequate amounts of carbohydrates as part of their diet presented with muscle soreness, fatigue and inability to complete training programs. These studies show that inadequate intake of nutrition can affect a swimmers performance.

ii. Hydration

Hydration is important for swimming performance as individuals dehydrate during training. A study done by Briars *et al*. (2017) found that individual swimmers performances differed when athletes consumed water and sports drinks. Within this study rehydration after training was observed by an increase in urine output from participants (Briars *et al*., 2017). Illustrating that during training swimmers are required to rehydrate. Studies conducted by Arnaoutis *et al*. (2015) and Baron *et al.* (2015) reported a decline in performance with inadequate fluid intake which lead to a decrement in performance and recovery.

iii. Sleep and rest

An athlete's decrease in performance can be directly linked to sleep deprivation. Shapiro *et al*. (1981) reported during competition seasons athletes sleep patterns changed, these findings were similar to Sargent *et al*. (2014) which reported that athletes sleep less prior to training days in comparison to rest days. Within the same study it was observed that athletes who obtained less than 6 hours of sleep had a lack of concentration (Sargent *et al*., 2014). Therefore when an individual is sleepy and drowsy, it directly hinders an athlete's performance (Samuels and James, 2014).

iv. Relaxation and emotional status (mood)

An athlete's mood has been found to directly influence performance during training and competitions (Swain, 2011). The same study found that poor performance was directly related to a negative mood in comparison to a positive mood with improved performance times. The study by Swain (2011) also reported that athletes who had a positive mood performed better during training which enabled the athletes to improve their performance time during competitions. However, mood alone is not the only factor that can affect an individual's performance, the

emotional status also plays a role (Hu *et al.,* 2015). When an athlete is stressed and unable to manage the pressure and feels overwhelmed, the individual's hypothalamus is unable to cope causing the individual to become exhausted, resulting in a decrease in concentration, motivation and performance (Hu *et al.,* 2015).

v. Active recovery and warm down

Intense bouts of exercise can result in the increase of metabolites such as lactate (Ali *et al.,* 2012). Therefore when an athlete has inadequate active recovery and warm down it increases the feelings of fatigue due to poor lactate clearance (Ali *et al.,* 2012). Within the same study it was found that performance was improved when athletes used active recovery compared to passive or warm-down recovery; due to an increase in the removal of lactate from the muscles, it also promoted muscle protein re-synthesis. Toubekis *et al.* (2008) reported that athletes whom used five minutes of active recovery improved their performance compared to those individuals who only used warm-down.

Although the above five factors influence performance it is also important to understand how swimming performance is measured.

2.5.2 Measurement of performance

It is important to understand how swimming performance is measured in both the international and national setting to ensure a standard is maintained. Internationally swimming performance has been documented according to time based trails (Lavoie and Montpetit, 1986; Alberty *et al.,* 2006). Lavoie and Montpetit (1986) tested individuals mean velocity over a 400 metre swim. In comparison to Alberty *et al*. (2006) whom determined the endurance of swimmer's by letting them swim for a duration of five times and calculated the longest distance covered during that time period.

Within a South African context swimming performance is also measured according to time based trials. A study by Bosch (2008) measured performance according to 25 metre split lap laps and three timed strokes. Therefore, this shows that swimming performance both nationally and internationally is measured according to time based trials.

CHAPTER 3: METHODOLOGY

The topics that will be covered in this chapter include:

3.1 Introduction
3.2 Study design
3.3 Site of study
3.4 Sample population
3.5 Testing procedures and equipment
3.6 Data collection
3.7 Statistical analyses
3.8 Ethical considerations
3.9 Amendments made from the pilot to the main study

3.1 Introduction

Literature regarding recovery in athletes incorporates various aspects, which include; sleep and rest, nutrition, hydration, psychological and emotional state, and lastly active recovery. In elites swimmers these factors are individualised and by using various questionnaires to obtain data for each aspect, recovery in this elite swimming population can be understood.

The main study succeeded a pilot study.

3.2 Study design

The pilot and main studies are classified as a quantitative, explorative, analytical study.

3.3 Site of study

Screening, briefing and data collection occurred at two sites.

Pilot study:

The study occurred over a 16 week training period at the Mandeville Swimming Club in Johannesburg.

Main study:

The study occurred over a 14 week training period, at the Waterborne Swimming Club in Randburg.

3.4 Sample population

3.4.1 Sampling and sample size

Individuals in both the pilot and main study were provided with an information sheet and invited to participate in the study (Appendix A). Parents of individuals, who were below the ages of 18 years, were also given an information sheet (Appendix A). Prior to the commencement of the study, a biographical questionnaire (Appendix B) was completed.

A sample of convenience was used because the number of elite swimmers in Gauteng is unknown. A South African study conducted by Bosch (2008) on the efficacy of a modified tapering protocol on swimming performance only had a total of 12 participants compared to an international study by Nogueira *et al*. (2015) which was performed on 17 juvenile swimmers to identify how external and internal loads affect recovery and performance.

Pilot study:

The sample initially consisted of 15 elite swimmers, which included female (n=8) and male (n=7) swimmers mean age of 15±2.29 years and 18±2.23 years respectively.

As illustrated by Figure 3.1 there were five participants who dropped out from the study, two female and three male individuals. Due to the lack of data obtained from one female and one male participant these individuals were also excluded. The results of these seven individuals were excluded from the findings of this study. At the end of the study a total of five female and three male elite level swimmers data were analysed.

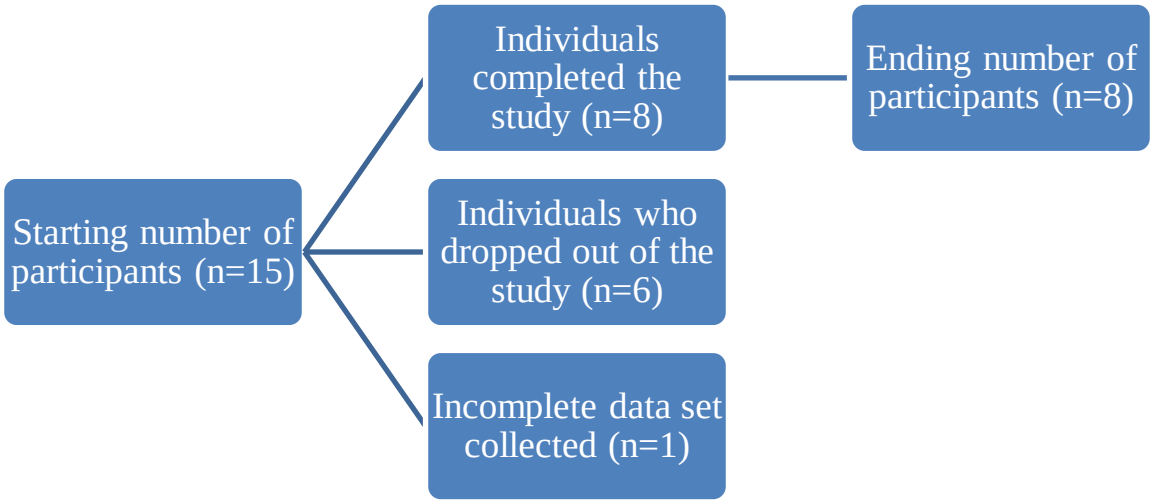


Figure 3.1: Participation of participants in the pilot study

Main study:

The sample initially consisted of 17 elite swimmers, which included female (n=8) and male (n=9) swimmers with a mean age of 15±1.58 years and 17±1.59 years respectively.

As illustrated by Figure 3.2 there were seventeen participants, two male swimmers dropped out of the study. At the end of the study a total of eight female and seven male elite level swimmers data were analysed.

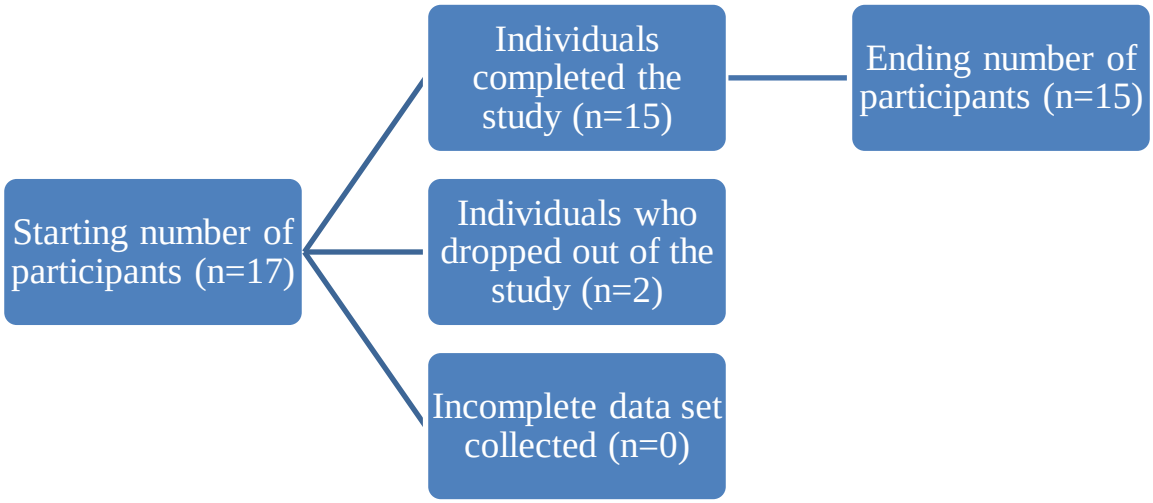


Figure 3.2: Participation of participants in the main study

3.4.2 Inclusion criteria

Male and female swimmers aged 13-24 years and having been competing at a national level of competition for a minimum of 2 years was included in the pilot and main study.

3.4.3 Exclusion criteria

The following criteria excluded an individual from participating in the pilot and main study:

i. A current musculoskeletal injury like a muscle strain or tendinopathies, which can hinder swimming participation and performance.
ii. Heart or metabolic condition that may affect their participation
iii. Individuals who have colour blindness, this can influence the correct analysis of urine samples for the total quality recovery questionnaire.

3.5 Testing procedures and equipment

The objectives of the study and how the objectives were met using the various questionnaires are described below. An in-depth look at how the study was conducted follows.

1) **To determine how the training regime influences sleep, mood, performance and recovery in swimmers, using the sleep diary, Fitbit, total quality recovery and profile of mood states questionnaires.**

   Pilot study*: Training regime was correlated with calories to determine the training intensity and correlations were made between training intensity, sleep and mood. Performance testing was conducted intermittently and due to insufficient consecutive data, it was omitted.*

   Main study*: Training regime was correlated with calories to determine the training intensity and correlations were made between training intensity, sleep and mood. Performance testing was conducted on a weekly basis and correlated with the training regime and total calorie and swimming calorie expenditure.*

2) **To determine how mood can affect a swimmer's performance during competitions, using the profile of mood states and sports emotional questionnaires**

   Pilot study: *A case study was used to identify if mood influenced a participant's performance during two competitions.*

   Main study: *A case study was used to identify if mood influenced a participant's performance during competitions and weekly performance tests were compared to performance and mood during competitions.*

3) **To determine if a relationship exists between sleep quantity, a swimmer's performance and recovery.**

   Pilot study: *Sleep quality and quantity were assessed using the PSQI, Fitbit Flex 2 and sleep diary.*

   Main study: *Sleep quality and quantity were assessed using the PSQI, Fitbit Flex 2 and sleep diary. The Fitbit Flex 2 was used for data collection between weeks 1 to 7 and the Fitbit Inspire HR for weeks 8 to 14 of data collection.*

An explanation of the participants training regime is explained below.

3.5.1 Training intensity

The normal prescribed training regime of the athletes were not altered or interrupted. The participant's schedule was a combination of land and water-based training arranged into a mesocycle comprising of four weeks. The first three weeks of the cycle gradually increased in training load with the last week being the recovery week. This four week mesocycle allows for the swimmers to gradually adapt to the training and helps to prevent overtraining from occurring.

The first mesocycle served as the control to the other three, allowing for comparisons to be made. Included within these cycles were race days which were categorised as an independent intensity.

Pilot study:

The main difference between the training weeks was the volume of gym or land-based training, namely consisting of one set compared to two sets of a prescribed gym workout routine. It was noted that the same land-based workout was performed daily. Training intensity and Fitbit total calorie expenditure during the "easy/recovery and hard" training weeks were measured.

Performance tests were conducted intermittently and were omitted due to lack of consistency.

Main study:

The difference between training weeks was the volume of gym or land-based training however, it should be noted that everyday participants had a different land and water-based training session. Training intensity and Fitbit total calorie expenditure during the "easy/recovery and hard" training weeks were measured.

Performance tests were conducted on a weekly basis and the Fitbit swimming calorie expenditure were recorded.

The individual questionnaires will now be discussed in detail:

3.5.2 Total Quality Recovery (TQR)

The TQR score presented by Kentta and Hassmen (1998), analyses recovery through the use of four categories, each with their own points system (Table 3.1) (Appendix C), with nutrition and hydration being classified together. The score is recorded every 24 hours with a higher score associated with a better total recovery.

Table 3.1: Breakdown of the TQR scoring

TQR category	Description	TQR score
Nutrition and hydration	Nutrition: full breakfast, lunch and dinner. Having a pre and post workout snack Hydration: clear pre and post urine	10
Sleep and rest	Slept for 8 or more hours and taken a nap	4
Relaxation and emotional support	Fully relaxed and having no psychological stress	3
Stretching and warm down	Adequate active cool down and stretched after training	3
Total score	Most beneficial recovery 17-20 points Adequate recovery is 15-16 points Change of recovery methods required is 14 and below points	20

The TQR has two subdivisions (Kentta and Hassmen, 1998). The first subdivision is TQR perceived recovery (TQRper), which is a subjective points system based on how well the athlete has perceived recovery over a 24 hour period. The TQR action scale (TQRact) is the second

subdivision and encompasses the categories mentioned above. The TQR action scale is the focus out of the 2 in this study, as the perceived recovery was recorded in the format of the wellness questionnaire. A urine colour chart (Appendix D) (Ting, 2017) was used to determine colour of the urine for hydration pre and post-training.

3.5.3 Mood state

The Profile of Mood States (POMS) (Appendix E) (McNair *et al*., 1971) consists of 67 questions that can be categorised into tension, anger, fatigue, vigour, depression and confusion with a composite mood score (total mood disturbance, TMD) computed by summing the negative variables, subtracting the vigour score and adding a constant of 100. The higher scores indicated poorer mood states. This questionnaire was completed on a weekly basis and has been validated and reliable in illustrating a relationship between mood and performance (Verger *et al*., 1997). The Sport Emotional Questionnaire (SEQ) (Appendix F) consists of 22 questions that identify the mood state of the individual prior, intra and post competitions (Swain, 2011; Chennaoui *et al.*, 2016; Vacher *et al.*, 2017). The combination of these two questionnaires aided in identifying the emotional factors that influenced performance and recovery in the participants during training and competitions.

Pilot study:

One participant competed in two competitions throughout the duration of the study, one in September and October. Therefore, only two SEQ questionnaires were used throughout the study.

Main study:

Participants competed in two competitions, the Winter gala and the CGA senior gala throughout the duration of the study. Only two SEQ questionnaires were used during the study.

3.5.4 Sleep quality

i. Pittsburgh Sleep Quality Index (PSQI)

An accurate mode of obtaining sleep quality has been developed in the form of the PSQI (Appendix G). This questionnaire has previously been used in a clinical setting and has been found to provide valid data in a swimming population (Elbayoumy and Elbayoumy, 2015). This method is commonly combined with a sleep diary to increase accuracy (Nishiyama *et al.*, 2014). An important factor included in the PSQI is caffeine consumption; this has been linked to sleeping disturbances (Halson, 2014). The PSQI is a questionnaire that looks at several sleep components consisting of sleep quality, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication and daytime functioning. Each of the 7 components gives a score; the total should be <5 to show good sleep quality. The 7 categories include; (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleep medication, (7) day-time functioning.

ii. Sleep Hygiene Index (SHI)

The SHI (Appendix H) was used to identify an individual's normal sleeping routine (Mastin *et al.*, 2006), and consists of 13 questions. The total score for the SHI is out of 52, with a score closer to 52 indicating poor sleeping habits (Mastin *et al.*, 2006).

iii. Morningness-Eveningness Questionnaire (MEQ)

The MEQ (Appendix I) identified the participant's circadian phenotype; this classified the individual as a lark, owl or a combination of the two categories (Horne and Ostberg, 1976; Terman and Terman, 2005) and confirmed a participant's sleep routine. The questionnaire consists of 19 questions scoring the MEQ out of 86. Individuals who scored 16-30 were definite evening, 31-41 moderate evening, 42-58 intermediate, 59-69 moderate morning and 70-86 were definite morning individuals (Terman and Terman, 2005).

iv. Sleep Diary

The sleep diary (The National Sleep Foundation) (Appendix J) encompasses the major factors relating to sleep quality. These include; sleep duration, sleep hygiene, sleep efficiency, day-time sleepiness, naps, exercise, and activities 1-3 hours prior to bed, mood, and consumption of caffeinated beverages. This was in the format of a table which the participants would complete in the morning and in the evening.

In addition to the sleep diary athletes were required to complete two questionnaires consisting of; a wellness questionnaire (Appendix K) and the PSQI (Appendix G).

v. Wellness questionnaire

The wellness questionnaire (Appendix K) provided subjective information pertaining to the individual's activities and training for the week, compared to the PSQI which identified the sleep quality of the individual throughout the duration of the study.

vi. Fitbit™

Participants were required to wear a Fitbit Flex 2 or Fitbit Inspire HR wristwatch (Fitbit Incorporated, Designed in San Francisco, California, United States of America, Manufactured in China) (de Zambotti *et al.*, 2015; Ferguson *et al.*, 2015) on their non-dominant wrist and complete a sleep diary comprising of recording their start, end, date and time of all sleep activities and related questions (Appendix O). The wrist monitors were worn at all times including during showering/bathing and swimming. The following data was obtained from the Fitbits™; sleep efficiency, sleep duration- total sleep time (TST), naps, bed-time, distance, activity levels, and calories. However with the Fitbit Inspire HR used in the main study, in addition to the above, rapid eye movement (REM), none rapid eye movement (NREM), light and deep sleep, resting heart rate (RHR) and heart rate during exercise was also obtained.

3.6 Data collection methods

Pilot study:

Screening, briefing and data collection occurred over a 16 week period at the Mandeville Dolphins Swimming Club in Johannesburg.

Main study:

Screening, briefing and data collection occurred over a 14 week training period, at the Waterborne Swimming Club in Randburg.

3.6.1 Start of the study

The biographical questionnaires were collected along with the consent and assent participant forms before commencing the study.

3.6.2 Weekly data collection

A booklet (Appendix L) containing the TQR, SD, PSQI, SHI, MEQ and wellness questionnaires were distributed and collected on a weekly basis.

Once a week, participants were required to submit the readings from the Fitbit™ to the researcher. If participants were unable to submit the Fitbit readings, the researcher manually collected the data from each of the participants on a weekly basis when collecting the other questionnaires.

Pilot study:

Performance testing was conducted intermittently and due to insufficient consecutive data, it was omitted.

Main study:

Performance testing data was collected on a weekly basis.

3.6.3 Competition session

SEQ were issued a week prior to participation in a competition and collected the following week.

Performance times during competitions were recorded by the participant.

3.7 Statistical analysis

Data analysis was performed using Statistica (Version 10; Dell software, Statasoft, United States of America) for both the pilot and main study.

For qualitative data, descriptive data was used to describe the interrelationships of the PSQI, SHI, MEQ, TQR, training intensity, and performance using mean, plus minus standard deviation, median and inter-quartile ranges. For quantitative statistics, to ensure data was normally distributed for the PSQI, SHI, MEQ, Fitbit (FB) Total sleep time (TST), Sleep diary (SD) sleep efficiency and TQR histograms were drawn. Non-parametric simple student paired t-test was conducted to compare significance of changes in performance tests. Statistical significance was accepted at 95% ($p \leq 0.05$).To identify correlations a Pearson's test was conducted.

3.8 Ethical considerations

Pilot study:

Ethics clearance was obtained prior to conducting the pilot study from the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, ethics certificate number: M180279 (Appendix M).

A letter of permission was obtained from the coach to conduct the pilot study at the Mandeville Dolphins Swimming Club in Johannesburg (Appendix N).

Main study:

Additional ethical clearance was obtained prior to conducting the main study indicating a change and addition of site (Appendix O) and an additional Fitbit device (Appendix P).

A letter of permission was obtained from the coach to conduct the main study at the Waterborne Swimming Club in Randburg (Appendix Q).

Pilot and Main study:

Individuals in the study were provided with an information sheet and invited to participate in the study (Appendix A). Parents of individuals, who were below the ages of 18 years, were also

given an information sheet (Appendix A). Prior to the commencement of the study, a biographical questionnaire (Appendix B) the individuals 18 years and older signed a participant consent form (Appendix R) and individuals younger than 18 years signed a participant assent form (Appendix S) and the parent/legal guardian signed the participant consent form (Appendix T).

The information that was obtained during the course of the pilot and main study was kept confidential and participants were not criticised or penalised in any way if they withdrew from the study. All participants were given a participant number and this number remained confidential between the relevant participant and researcher involved. Following the study, individual feedback was given to participants, if requested

The main study succeeded a pilot study. Minor adjustments to the methodology following the pilot study are described below.

3.9Amendments made from the pilot to the main study

The pilot study's limitations were identified and consisted of the following. Firstly, the study initially had 15 participants but due to poor compliance and drop out, the study ended with a sample size of 8 participants. Partial and/or incorrectly completed questionnaires were collected and excluded from data analysis.

Secondly, the training regime of the participants had no variation except for an increase in the number of sets for land-based training and an increase in the distance swam per week according to a "hard or easy" training week. Information collected was limited to similar exercises and swimming programmes being prescribed daily and weekly during the course of the study and this limited data analysis.

Thirdly, the coach did not conduct weekly performance tests on the participants resulting in a lack of performance data. The performance data that was collected during the study was directly from individuals who recorded their times during two competitions that took place throughout the duration of the study and lastly, the Fitbit Flex 2 device was unable to record resting heart rate (RHR). These two limitations resulted in the lack of performance data recorded to determine recovery.

The above mentioned limitations lead to four main amendments made in the main study which included; a larger sample size of 17 participants were used to accommodate for poor compliance and dropping out of individuals during the course of the study. Weekly reminders were sent out to the coach to ensure participants completed the questionnaires; and during weekly data collection the researcher would check that individuals understood how to correctly complete the questionnaires, this prevented incomplete questionnaires from being collected and unnecessary data exclusion.

Secondly, the land and water-based training program set by the coach were required to vary between days and weeks according to the training cycles. This constant variation in both land and water-based training programs ensured that during data analysis that the training regime could illustrate how the training regime influenced the participants sleep, mood, performance and recovery.

Thirdly, the coach was required to conduct weekly performance tests for the participants. The weekly performance testing combined with the competition data recorded by the participants ensured that all performance data was collected during the main study and lastly; the main study used another device (Fitbit Inspire HR) that could measure RHR and could be worn during water-based training. The Fitbit Inspire HR allowed for the capturing of HR, swimming and performance data during water-based training and rest.

CHAPTER 4: RESULTS

The topics that will be covered in this chapter include:

4.1 Introduction
4.2 Section A: Pilot study
4.3 Section B: Main study

4.1 Introduction

Results will be presented in two main sections: section A shows the demographic information, dropout of participants and results of the pilot study. In section B the demographic information, dropout of participants and the results corresponding to each objective for the main study will be reported; after which a discussion of the results will follow.

4.2 Section A: Pilot Study

i. Baseline Data

a. Demographic information

In the study there was a total of 15 participants with female (n=9) and male (n=6), 62.5% of the participants were female. Table 4.1 below shows the mean chronological age and number of years individuals competitively competed in swimming. The mean chronological age for the participants was 16±2.78 years and the mean number of years competitively competing in swimming was 6.5±3.33 years. At the end of the study a total of 8 participants comprising of females (n=5) and males (n=3) with mean ages of 15±2.29 and 18±2.23 years respectively remained.

Table 4.1: Mean baseline chronological age and number of years competitively swimming (n=8).

Anthropometry	Mean±SD	Median and interquartile range
Age (years)	16±2.78	16(13.5-17.5)
Competitively swimming (years)	6.5±3.33	6.5(4-8.5)

b. Dropout

Figure 4.1 below illustrates the dropout of the participants throughout the duration of the study. At the start of the study 15 participants were recruited, and during the course of the study, due to poor compliance the sample size was reduced to a total of 8 individuals at the end of the study. Figure 4.1 shows the participant dropout during the course of the pilot study. The dropout of participants was due to incomplete questionnaires and individuals dropping out of the study. It was observed that the male participant numbers decreased by 42.85% compared to the female participants.

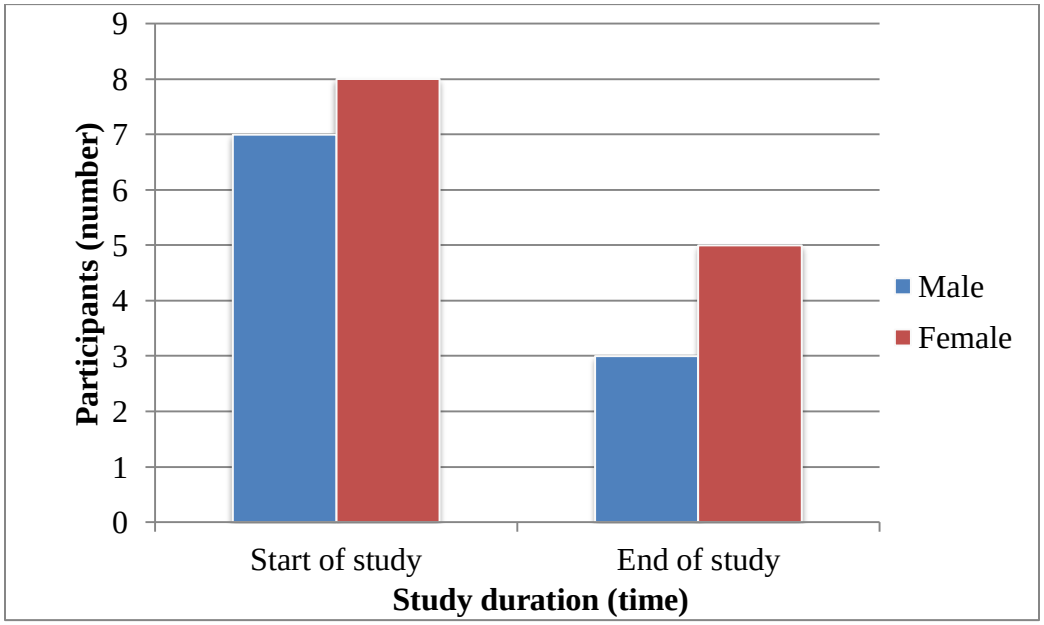


Figure 4.1: Overall swimmer dropout during the course of the 16 week pilot study (n=15).

ii. Data obtained from the study

1) Objective 1

To determine how the training regime influences sleep, mood, performance and recovery in swimmers, using the sleep diary, Fitbit, total quality recovery and profile of mood states questionnaires.

Various questionnaires relating to recovery were used and related to the training regime over a 16 week period consisting of 4 training cycles.

Data will be discussed according to the mesocycle training regime. Each mesocycle is subdivided into four weeks consisting of one recovery week and three weeks of hard training. Four mesocycles were observed during the study and comparisons were made between cycles 1 to 4.

i. Calories versus training

Calories can relate to the training regime and is illustrated by Figure 4.2. Calories include an estimation of an individual's basal metabolic rate (BMR) based on physical data - sex, age, height and weight. The BMR was combined with the activity tracked by the Fitbit and any activity logged by the participant, the calorie counter was reset every day at midnight. In Figure 4.2 in eight participants it was observed that 50% of the recovery week total calories were lower in comparison to the other three hard weeks across the four cycles, there is no significance difference between the four cycles ($p=1.00$). However, it was found that during cycle 1 and 4 that recovery was increased compared to the following hard week.

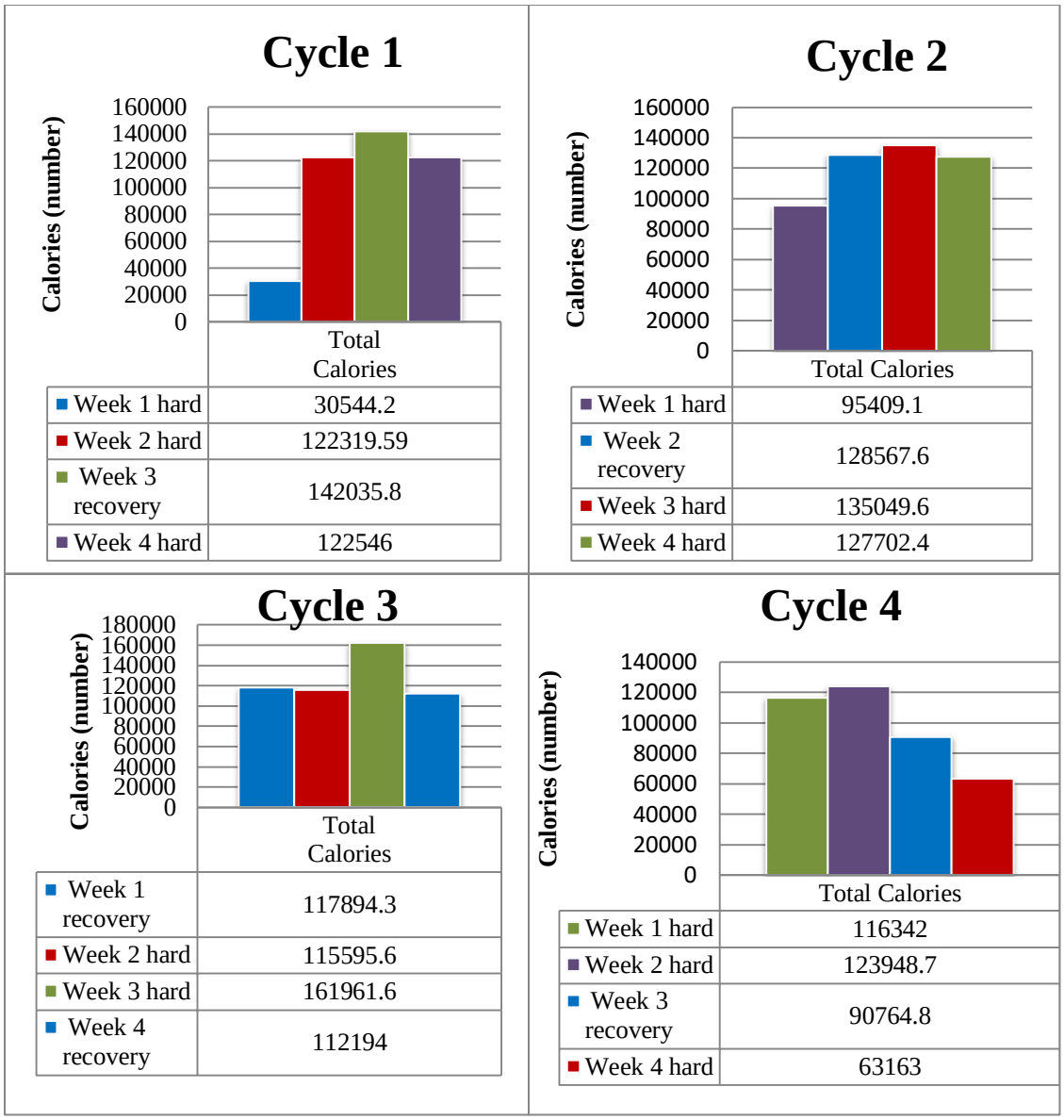


Figure 4.2: Training intensity per week versus total calorie expenditure in swimmers between cycle 1 to 4 over a 16 week period (n=8).

ii. Sleep versus training

Sleep can relate to training intensity which can be seen in Figure 4.3. Sleep was measured in minutes and recorded in the sleep diary (SD) and by the Fitbit (FB). Figure 4.3 illustrates eight participants sleep times in the form of percentages comprising of average sleep diary naps (SD naps), average sleep diary total sleep time (SD TST) and average Fitbit total sleep time (FB TST). It was found that the recorded SD TST increased by 12% as individuals progressed

through the cycles. However, the inverse was found with FB TST gradually decreasing by 13% throughout the duration of the study while naps fluctuated between each cycle.

The SD TST and FB TST were found to be significant (p=0.03) however, a Pearson's correlation test found no correlation between the SD TST and FB TST (-0.99). There was no significance difference found between SD naps and SD TST (p=2.41).



* SD naps ave- Sleep diary averge nap time, SD TST ave- Sleep diary average total sleep time, FB TST ave- Fitbit average total sleep time **Sleep was measured in minutes and converted to a percentage for each mesocycle.

Figure 4.3: Three components of sleep compared across four training cycles in swimmers (n=8).

iii. TQR sleep and training

TQR sleep and training intensity can be observed in Figure 4.4. The TQR sleep score was subdivided into average total sleep, 8 hours, 7-8 hours, 6-7 hours and naps. Figure 4.4 shows each sleep component of the TQR namely average sleep, 8 hours, 7-8 hours, 6-7 hours and naps fluctuated throughout the duration of the study in eight participants. The sleep average and nap times were equal when comparing cycle 1 and 4. Average total sleep decreased by 11% between cycle 1 and 2 and increased by 17% between cycle 1 and 3 compared to naps with an increase observed between cycle 1 and 2 by 3% and a 2% increase between cycle 1 and 3. The TQR sleep average and TQR nap average was significant (p=0.00). A decrease in TQR time for 8 hours, 7-8 hours, 6-7 hours and nap averages were observed between cycle 2 and 3.

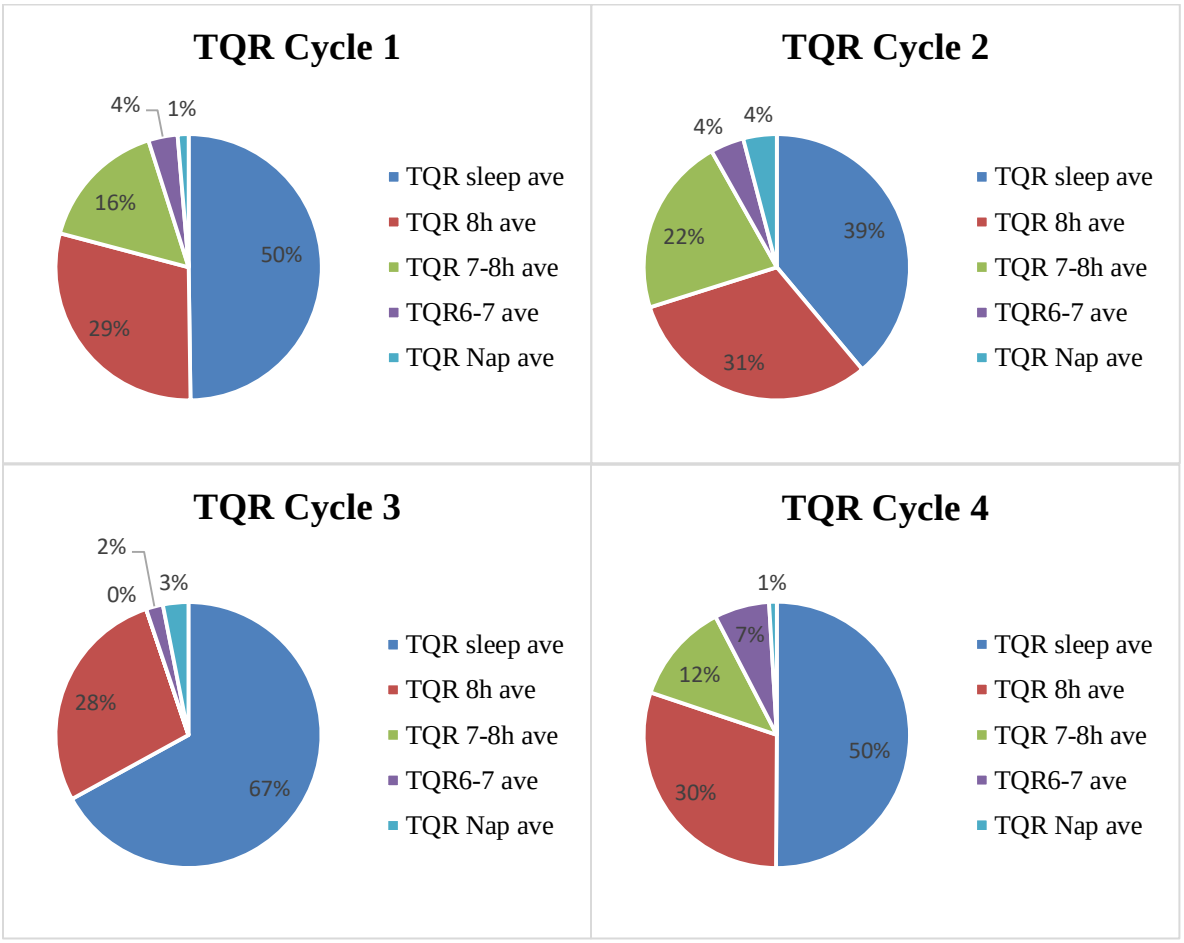


Figure 4.4: TQR sleep score in percentage occurring across four mesocycles in swimmers (n=8).

iv. Mood versus training

Each mood factor of the POMS questionnaire comprising of tension, anger, fatigue, depression, vigour and confusion and its relation to training cycles can be observed in Figure 4.5. Figure 4.5 illustrates the score in percentage of six mood states that were experienced on a weekly basis obtained from the POMS questionnaire for eight individuals. Anger was the only emotion that gradually increased by 3% from cycle 1 to 3 and remained the same in cycle 4. Depression had a similar trend with a gradual increase of 6% observed between cycle 1 and 3 and decreased between cycle 3 and 4 by 2%. The inverse was observed when comparing depression and vigour. There was a gradual decrease by 5% between cycle 1 and 3 and an increase of 2% observed between cycle 3 and 4. Tension decreased between cycle 1 and 2 and cycle 3 and 4 by 2% and 3% respectively and increased by 2% between cycle 2 and 3. The inverse was found with confusion, an increase of 1% was observed between cycle 1 and 2 and a decrease of 2% between cycle 2 and 3 with a further decrease observed between cycle 3 and 4 by 1% and 2%.

Overall within emotions anger, fatigue and depression an increase in scores was found between cycle 1 and 4 with the inverse being observed in tension, vigour and confusion between the same cycles. There was no significant difference found for each of the six emotions from the start to the end of the study ($p=0.50$).

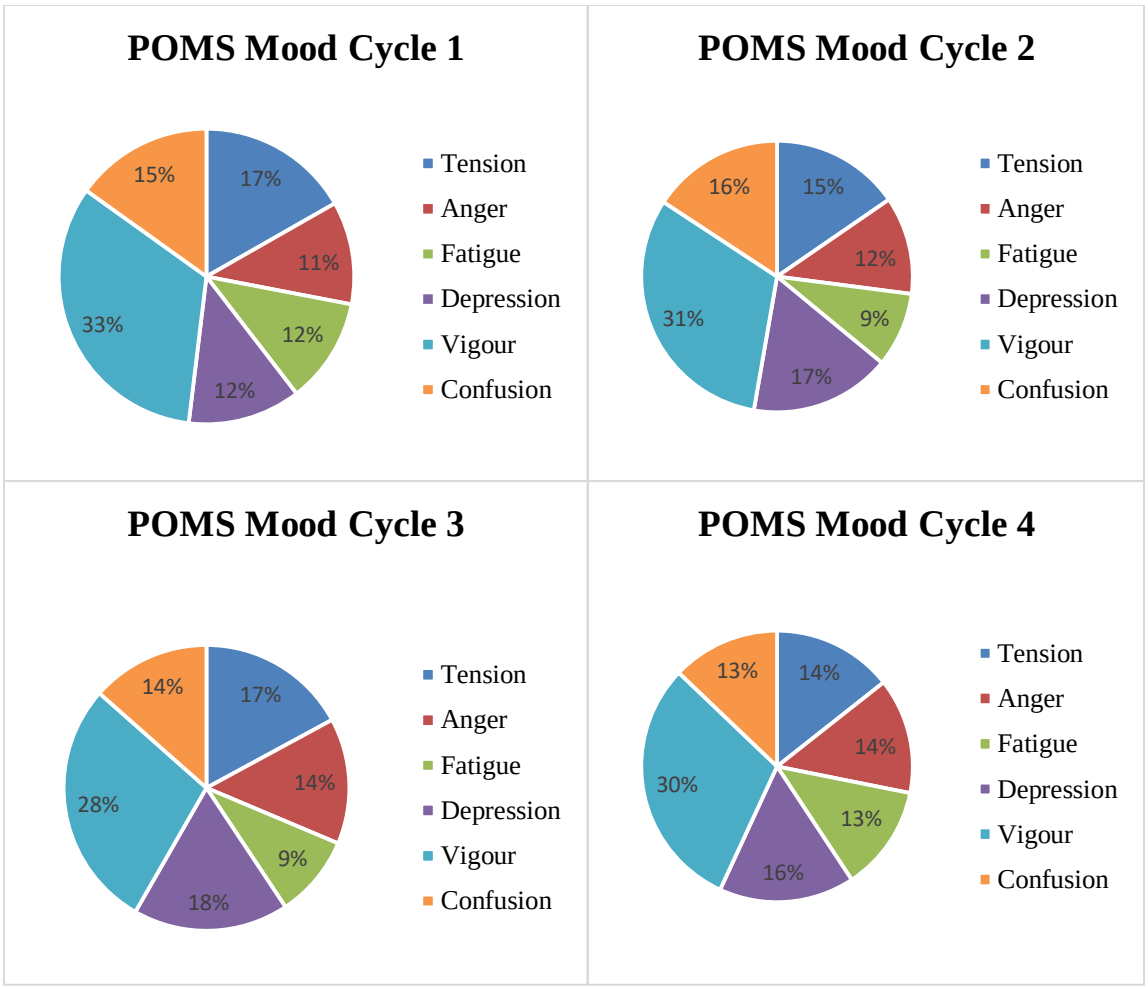


Figure 4.5: Profile of mood states scores separated into the six different mood states that swimmers experienced over a 16 week cycle (n=8).

Further a summary of the sleep diary mood throughout the course of the study can be found in Figure 4.6. Figure 4.6 illustrates the sleep diary mood states comprising of very pleasant, pleasant and unpleasant that 8 participants experienced during four training cycles. It was found that the unpleasant mood decreased between cycle 1and 3 by 25% and increased by 13.13% between cycle 3 and 4. The opposite was found in the very pleasant mood with an increase of 16.97% between cycle 1 and 3 and a decrease of 6.05% between cycle 3 and 4. It was observed overall that the pleasant mood remained elevated throughout the study when compared to a very pleasant and unpleasant mood. No significant differences were observed from the start to the end of the study for all three SD mood states (p=0.50) and no correlations were found using the

Pearson's test for pleasant mood compared to very pleasant (-0.96) and pleasant compared to unpleasant mood state (-0.94).

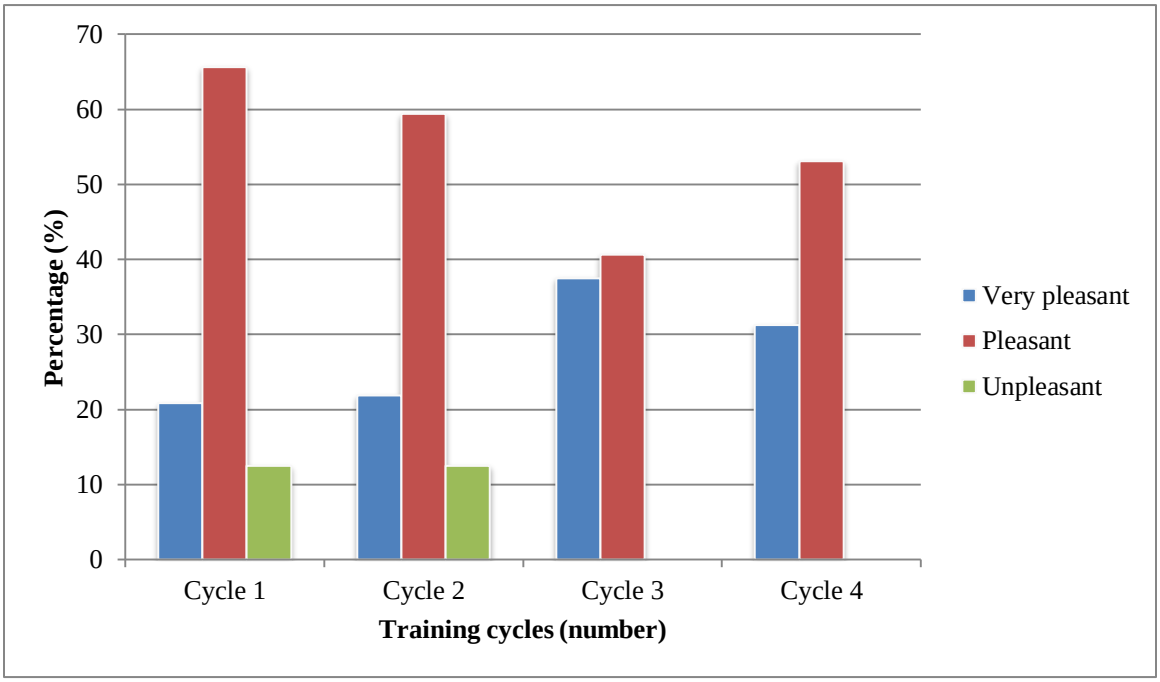
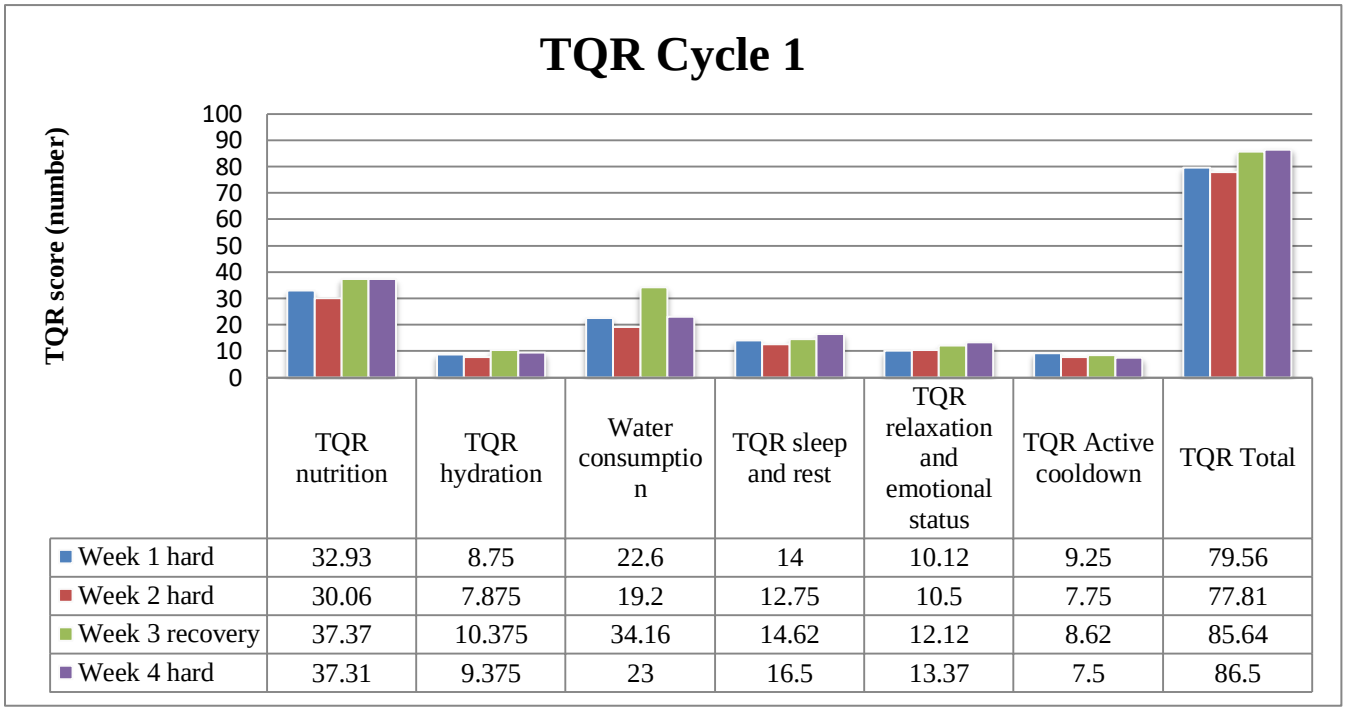


Figure 4.6: Three sleep diary mood states that occurred during the course of four swimming training cycles (n=8).

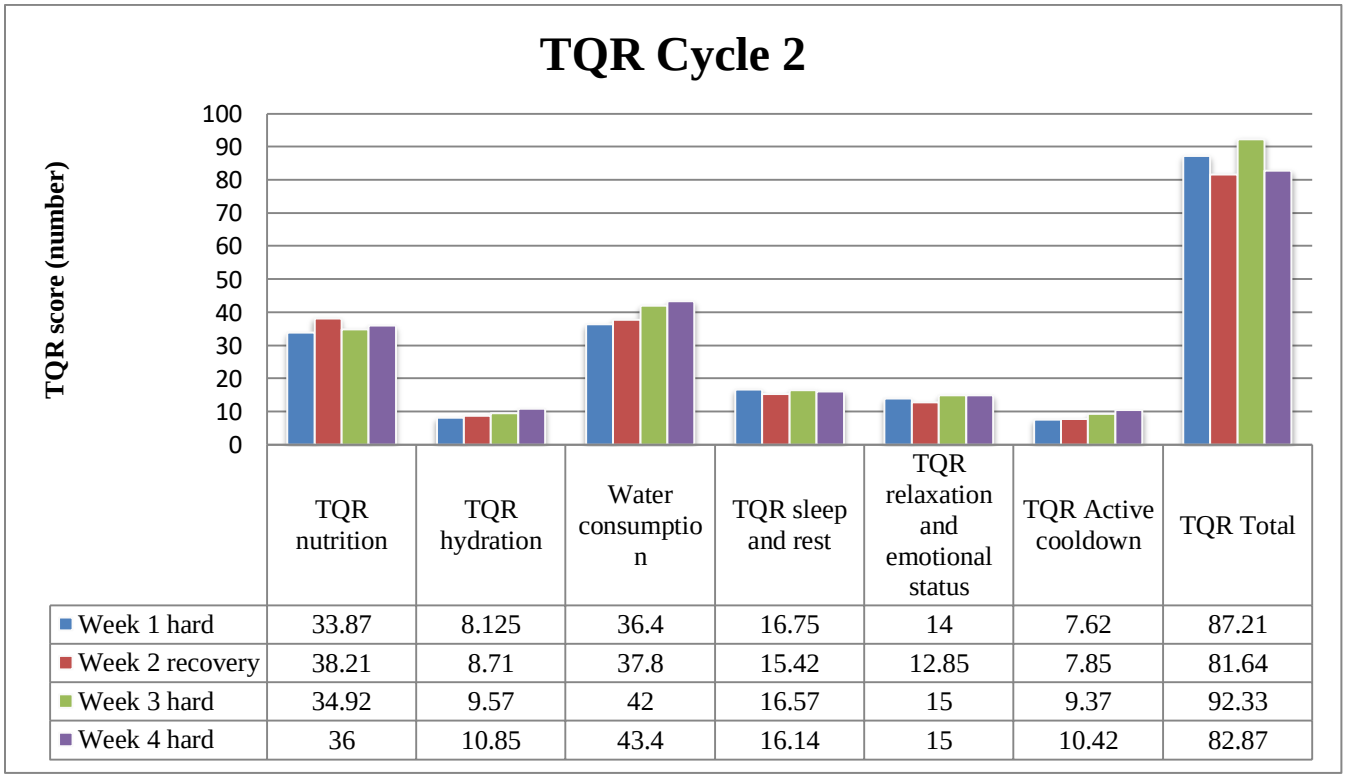
v. Recovery (TQR) versus training

The four components of the TQR consisting of nutrition and hydration, sleep and rest, relaxation and emotional status and stretching and active rest scores can be seen in Figure 4.7. In addition to these components, the total TQR score and water consumption in litres can be found in Figure 4.7. Figure 4.7 shows each component of the TQR and water consumption in eight participants over four cycles. The highest TQR score was found the week after the recovery week during cycle 1 to 2 and 4 compared to cycle 3 where the highest score was two weeks after the recovery week. TQR nutrition was the highest during the recovery week between cycles 1 to 3 compared to the sleep and rest which was the highest the week after recovery week during all four cycles. Overall a steady decline in each TQR component score can be observed except in water consumption, there was no significant difference (p=0.50). However, this increase in water consumption is due to the lack of compliance, during cycle 1 and 2 all participants completed the

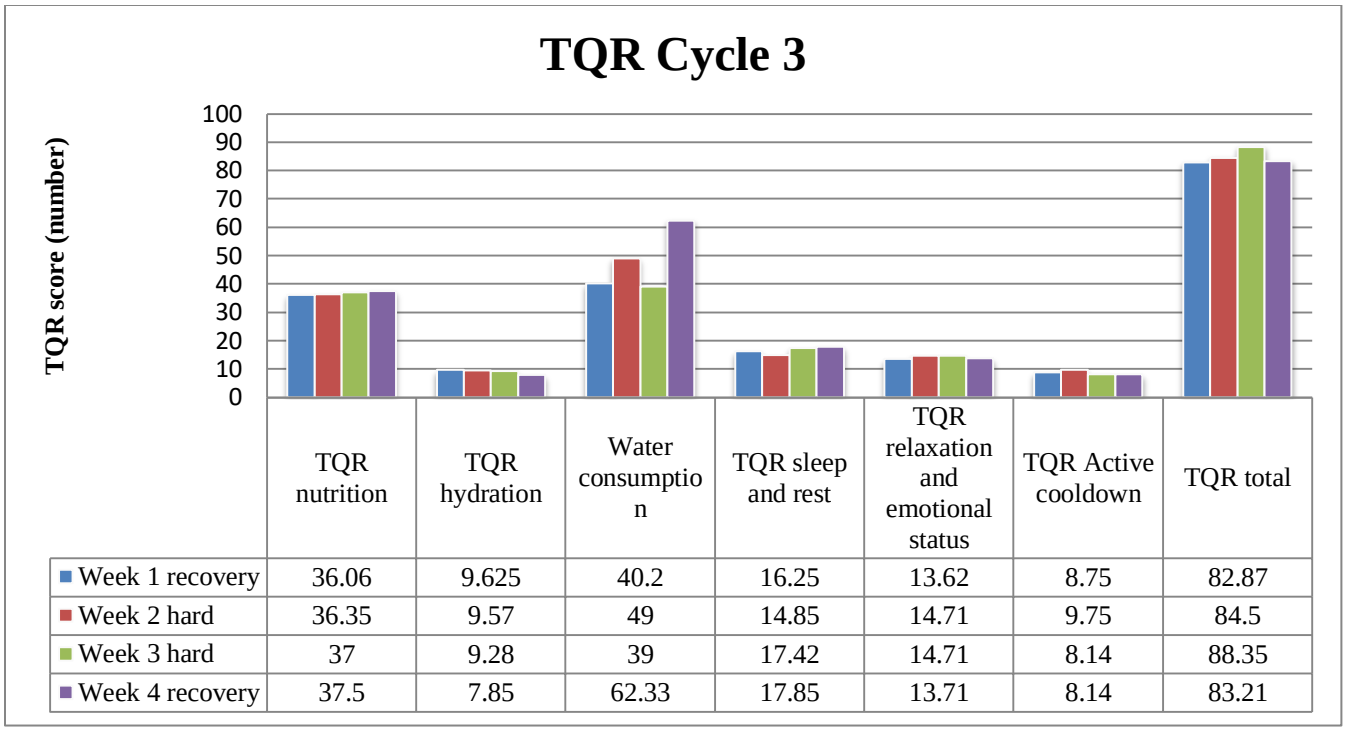
water consumption compared to cycle 3 and 4 where five and three participants completed the section respectively.



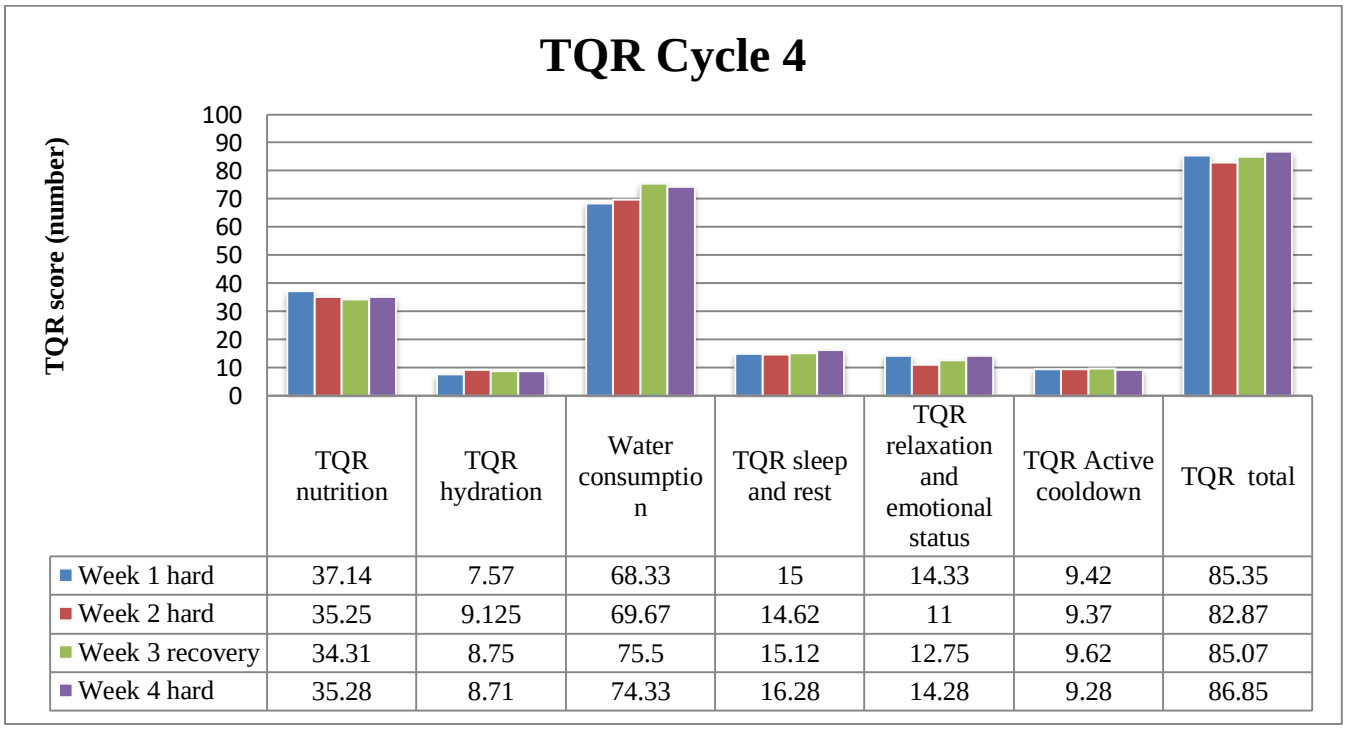
	TQR nutrition	TQR hydration	Water consumption	TQR sleep and rest	TQR relaxation and emotional status	TQR Active cooldown	TQR Total
Week 1 hard	32.93	8.75	22.6	14	10.12	9.25	79.56
Week 2 hard	30.06	7.875	19.2	12.75	10.5	7.75	77.81
Week 3 recovery	37.37	10.375	34.16	14.62	12.12	8.62	85.64
Week 4 hard	37.31	9.375	23	16.5	13.37	7.5	86.5



	TQR nutrition	TQR hydration	Water consumption	TQR sleep and rest	TQR relaxation and emotional status	TQR Active cooldown	TQR Total
Week 1 hard	33.87	8.125	36.4	16.75	14	7.62	87.21
Week 2 recovery	38.21	8.71	37.8	15.42	12.85	7.85	81.64
Week 3 hard	34.92	9.57	42	16.57	15	9.37	92.33
Week 4 hard	36	10.85	43.4	16.14	15	10.42	82.87



	TQR nutrition	TQR hydration	Water consumption	TQR sleep and rest	TQR relaxation and emotional status	TQR Active cooldown	TQR total
Week 1 recovery	36.06	9.625	40.2	16.25	13.62	8.75	82.87
Week 2 hard	36.35	9.57	49	14.85	14.71	9.75	84.5
Week 3 hard	37	9.28	39	17.42	14.71	8.14	88.35
Week 4 recovery	37.5	7.85	62.33	17.85	13.71	8.14	83.21



	TQR nutrition	TQR hydration	Water consumption	TQR sleep and rest	TQR relaxation and emotional status	TQR Active cooldown	TQR total
Week 1 hard	37.14	7.57	68.33	15	14.33	9.42	85.35
Week 2 hard	35.25	9.125	69.67	14.62	11	9.37	82.87
Week 3 recovery	34.31	8.75	75.5	15.12	12.75	9.62	85.07
Week 4 hard	35.28	8.71	74.33	16.28	14.28	9.28	86.85

Figure 4.7: Component scores of the TQR in relation to training across four training cycles in eight swimmers (n=8).

2) Objective 2

To determine how mood can affect a swimmer's performance during competitions, using the profile of mood states and sports emotional questionnaires.

Two validated questionnaires namely the profile of mood states and sports emotional questionnaires were correlated to the participant's performance over a 16 week period consisting of 4 training cycles.

Due to poor compliance, the second objective of the study could only be presented in the form of a case study (Appendix U), for more details please refer to the limitations section. The information pertaining to the case studies individual's performance and mood can be found in Figures 4.8-4.11.

Figure 4.8 illustrates the training times of one participant during a two month period between September and November 2018. There is a distinctive overall decrease within the performance times of all three swimming strokes from September till November. The greatest improvement was a 4.59 second decrease in the freestyle stroke performance time from 33.59 seconds to 29 seconds during training. In addition to the increase in performance time of the freestyle, the participant also improved the time for the back and fly swim strokes by 2 seconds. A Pearson's test was performed on each of the three swimming strokes performance times between the two month period and were found to be positively correlated (0.99), however the data was found not to be significantly different ($p=0.12$).

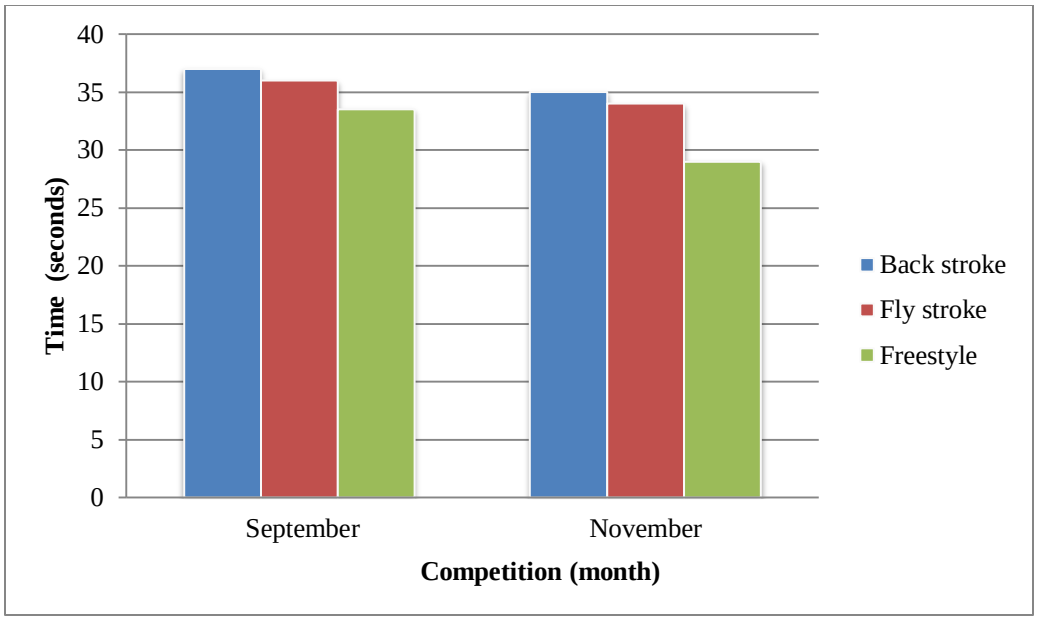


Figure 4.8: The training times obtained for back, fly and freestyle swimming strokes over a two month period during two competitions in one individual (n=1).

Due to the improved performance times observed during training, it was found that the participant's performance times decreased during competitions in 50 metre race (Figure 4.9) and a 200 metre race (Figure 4.10).

Figure 4.9 illustrates the back and breast stroke performance times of the participant during September and October in a 50 metre race. There was an improvement of 1.93 seconds for the back stroke from 0.36.23 to 0.34.22 seconds and breast stroke improved by 2 seconds from 0.40.22 to 0.38.22 seconds. A Pearson's test was performed on the back and IM swimming strokes performance times between the two competitions and were found to be positively correlated (1.00), however the data was found not to be significantly different (p=0.48).

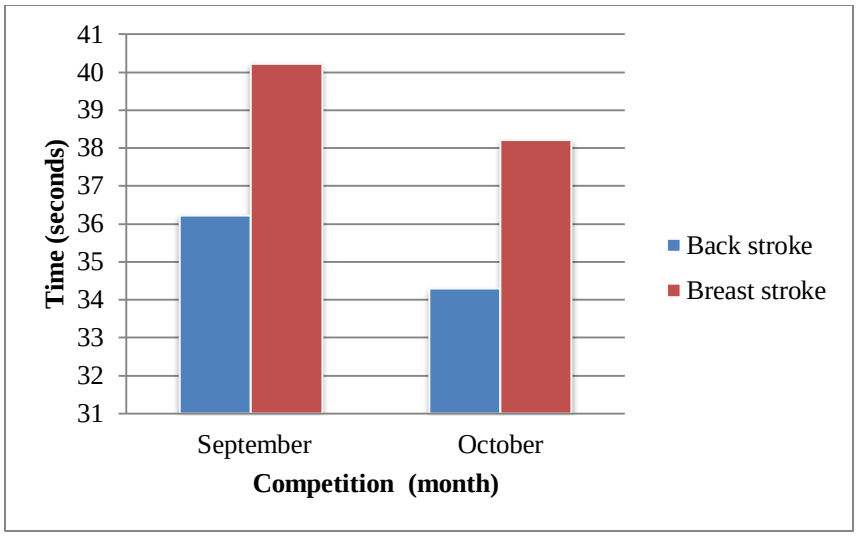


Figure 4.9: The performance times for one swimmer for a 50 metre race obtained for two competitions occurring between September and October 2018 (n=1).

The performance times for one participant in two 200 metre races can be found in Figure 4.10 below. In Figure 4.10 illustrates the performance times during a 200 metre race during September and October. There was a marked improvement in performance times observed for both the back and IM races by 12.7 and 9.73 seconds respectively. The back stroke performance time decreased from 00.37.00 minutes to 00.34.30 seconds and the IM decreased from 2.51.00 to 2.41.27 minutes. A Pearson's test was performed on the back and IM stroke over one month and the data had a positive correlation (1.00), but was not significant (p=0,.8).

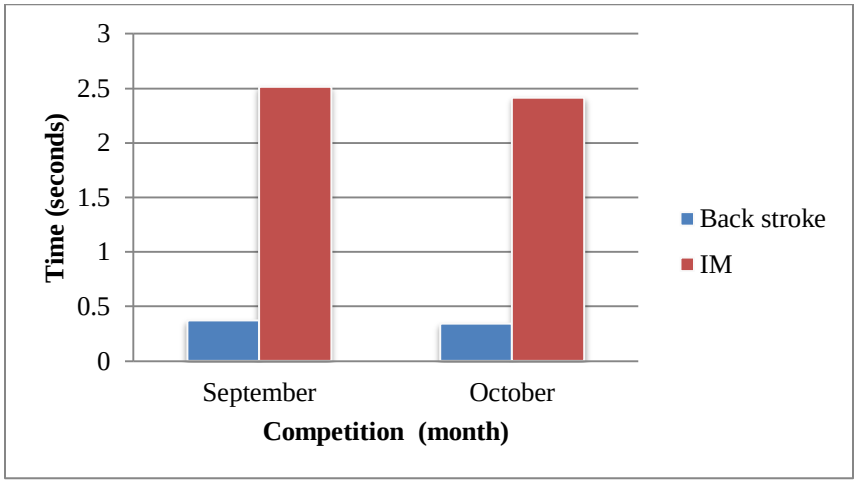


Figure 4.10: The competition times obtained for two swimming strokes between two different competitions over two months in one swimmer (n=1).

The performance times of the individual can also be affected by the mood state during competitions which can be observed in Figure 4.11. Figure 4.11 shows the different scores of the mood involved during the course of the study occurring during competition times. At the start of the study individuals were preparing for the competition season with scheduled galas and towards the end of the year individuals competed in important competitions. From the figure below, a general increase can be observed for the pre competition mood and a decrease in the post competition mood with a significant difference (p=0.04). In comparison to the intra competition mood, in general out of 8 competitions, presented with a 50% elevated intra competition mood score compared to 37.5% being below the pre competition score, with mood not being significant (p=0.15) and 12.5% showing no mood score relating to no stress experienced during the competition.

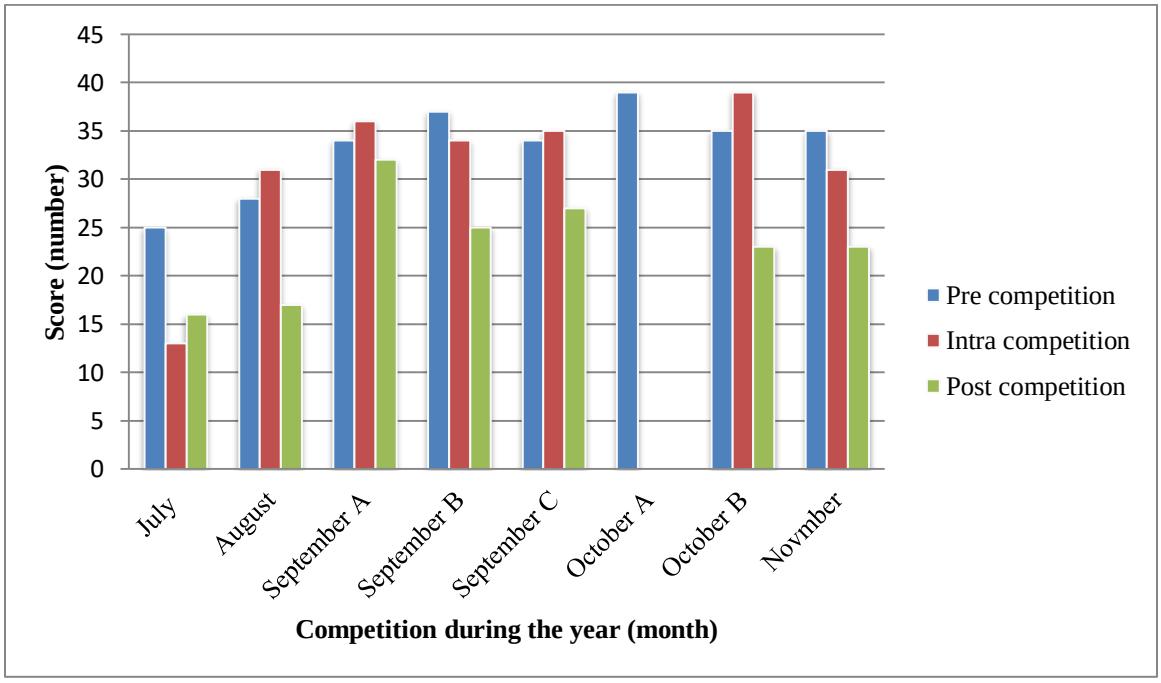


Figure 4.11: The pre, intra and post competition moods scores obtained from the Sports Emotional Questionnaire between the periods of July 2018 and November 2018 of one swimmer (n=1).

3) Objective 3

To determine if a relationship exists between sleep quantity, a swimmer's performance and recovery, using performance testing and sleep questionnaires.

Sleep questionnaires were utilised to compare the different aspects of the TQR and sleep quality to the individual's performance

i. Sleep efficiency

Sleep efficiency can be classified into three components, waking up refreshed, slightly refreshed or fatigued according to the sleep diary and can observed in Figure 4.12 across four cycles. Figure 4.12 shows each component of the sleep efficiency that was recorded by the sleep diary. It was observed that waking up feeling refreshed remained consisted at the start and end of the study with a 47% decrease occurring between cycle 1 and 2 and a gradual increase by 46% between cycles 2 to 4. When comparing feelings of slightly refreshed and fatigued it was found to correlate (0.08) and be significant (p=0.03). It was also found when doing a paired t-test that feeling of refreshed and fatigue were significant (p=0.00).

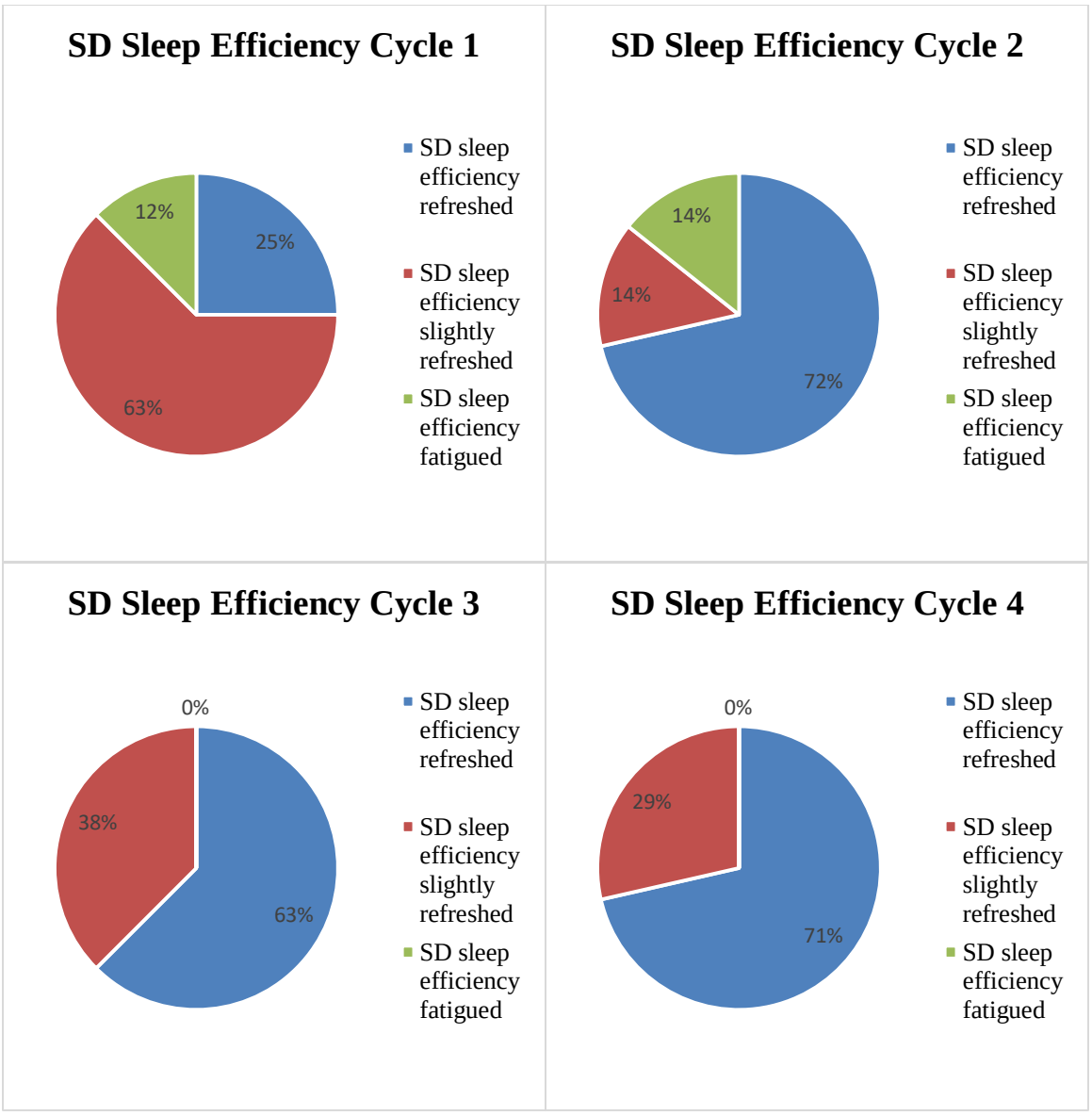


Figure 4.12: Comparison of sleep diary sleep efficiency percentage during each of the four training cycles occurring during the course of 16 weeks of eight swimmers (n=8).

ii. PSQI scores

In addition to the sleep efficiency recorded by the sleep diary an additional sleep questionnaire was used to identify the sleep quality of the participants during each mesocycle, this can be observed in Figure 4.13. Figure 4.13 shows the PSQI scores of 8 participants throughout four training cycles. A gradually increase of sleep quality scores can be observed from cycle 1 to 3, with cycle 2 having the highest score of 4.5. There was a decrease of PSQI scores by a score of 2.3 between cycle 3 and 4. The PSQI scores were not significant (p=0.28) from the start to the end of the study and no correlation was found using the Pearson's test (-1.00).

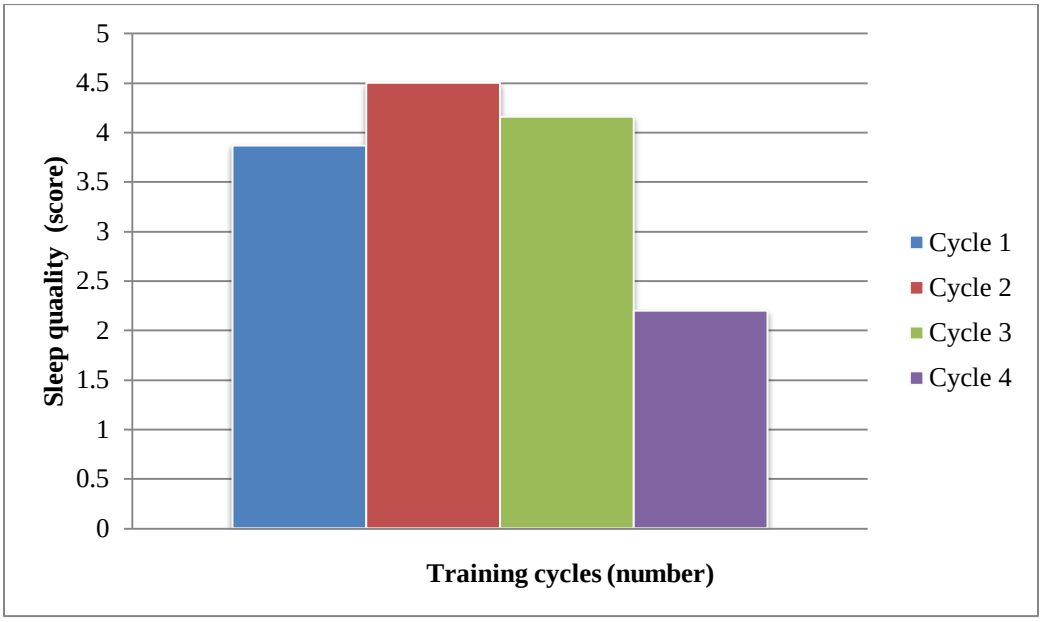


Figure 4.13: The PSQI scores over four swimming training cycles throughout the duration of the study (n=8).

Another aspect of sleep that was observed throughout the study was the sleep hygiene of participants.

iii. Sleep Hygiene Index

In Figure 4.14 shows the SHI scores of 8 participants occurring throughout the duration of the study. It was found that the SHI score increased by a score of 3.46 between cycles 1 and 2. A decrease in the SHI score was observed between cycles 3 and 4, which decreased by 3.71. From the start to the end of the study there was a 0.25 decrease in score. The SHI scores between the start and end of the study were not significant (p=0.40) and did not correlate (-1.00).

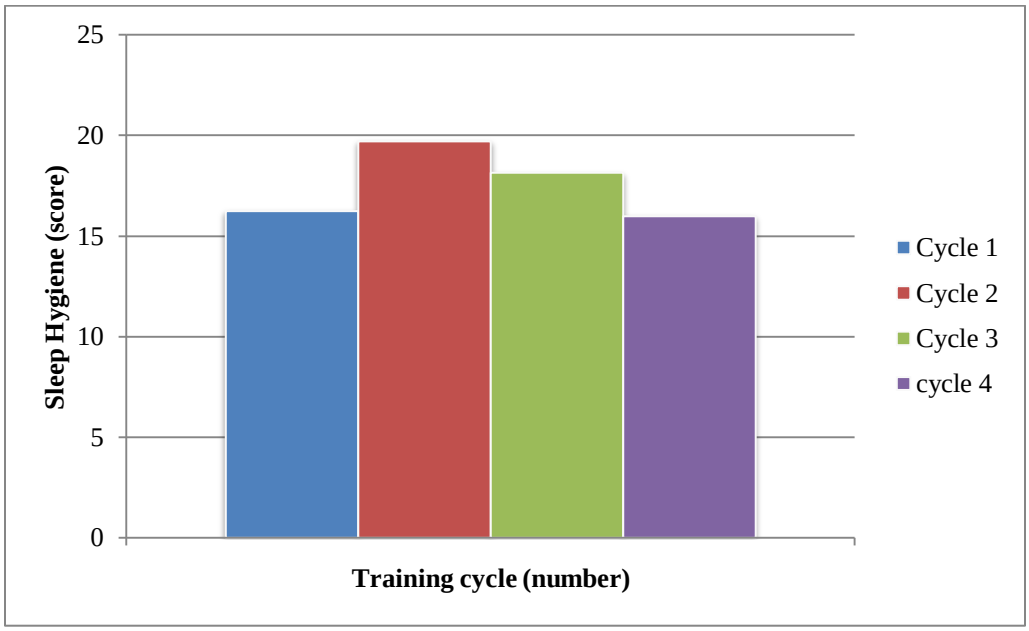


Figure 4.14: The SHI score of eight swimmers during four training cycles (n=8).

The last aspect of sleep that was studied used the Morningness-Eveningness questionnaire to determine if a participant was a morning or evening person.

iv. Morningness-Eveningness Questionnaire

Figure 4.15 illustrates the MEQ scores of participants over the four training cycles. It was observed that MEQ scores fluctuated throughout the study with the lowest score being observed during cycle 2. However, it was found that when comparing cycle 1 and cycle 4, there was a decrease of 0.25% from 58.25 to 56.Showing that at the end of the study participants sleeping pattern changed from individuals being an owl to a lark. The Pearson's correlation test showed

that the data correlated (1.00) between the start and end of the study; however the data was not significant (p=0.29).

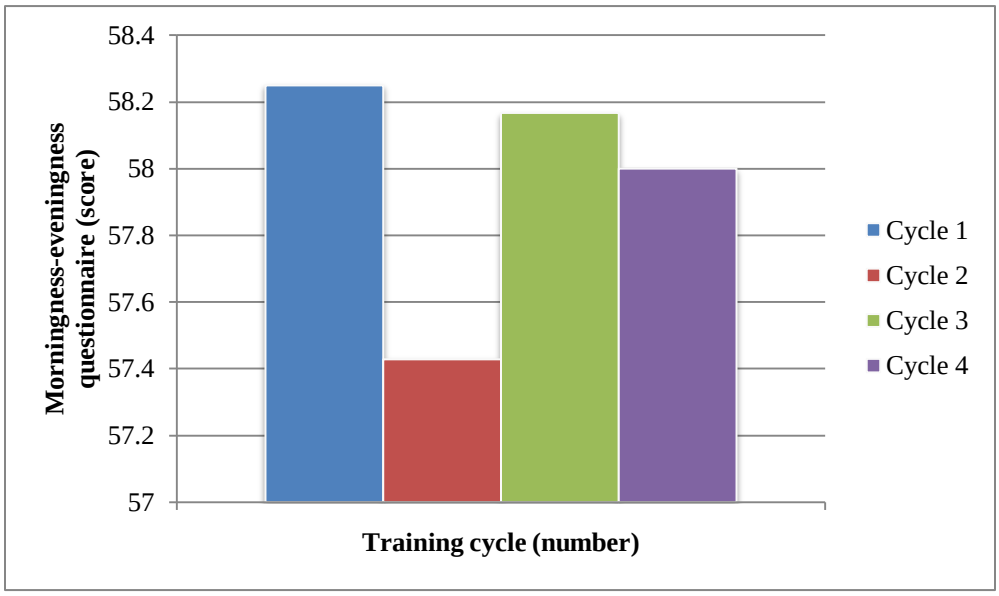


Figure 4.15: The MEQ scores of eight swimmers occurring during four training cycles (n=8).

A summary of all sleep components used during the study can be found below.

v. Summary of sleep questionnaire and sleep efficiency

In figure 4.16 shows the combined sleep questionnaire scores of the MEQ, SHI and PSQI and sleep diary sleep efficiency for the four training cycles. Overall the MEQ score remained at 58 except for cycle 2 when it dropped to 57. The SHI score fluctuated between the lowest score of 16 during cycle 4 and the highest score of 19.71 occurring in cycle 2. The PSQI scores were observed to be the inverse of the SHI score, with cycle 2 having the highest score of 4.5 and cycle 4 having the lower of 2.2. Therefore, sleep quality and sleep hygiene were at the highest during cycle 2 and the lowest MEQ score was during cycle 2. The PSQI and SHI was found to be significant (p=0.00) and the Pearson's correlation test was positive (0.77). No significance was found between PSQI and MEQ (p=2.87) and SHI and MEQ (p=3.53) and no correlation was found between each with values of -0,3 and -0,8 when using the Pearson's test. Overall the SD sleep efficiency showed that refreshed was the highest when compared to slightly refresh and fatigued during each cycle. The lowest score was during cycle 3 and the highest was during cycle

4. Therefore when sleep hygiene and quality were at the lowest individuals woke up feeling more refreshed. All data between PSQI and sleep efficiency (refreshed, slightly refreshed and fatigued) were significant (p=0.00, p=0.00; p=0.00). The only positive correlation that was found between the PSQI and feeling fatigued with a value of 0.58. Positive Pearson's correlations were found between SHI and refreshed sleep efficiency (0.48) and SHI and fatigue (0.34). The last positive Pearson's correlation found was between MEQ and feeling slightly refreshed (0.86).

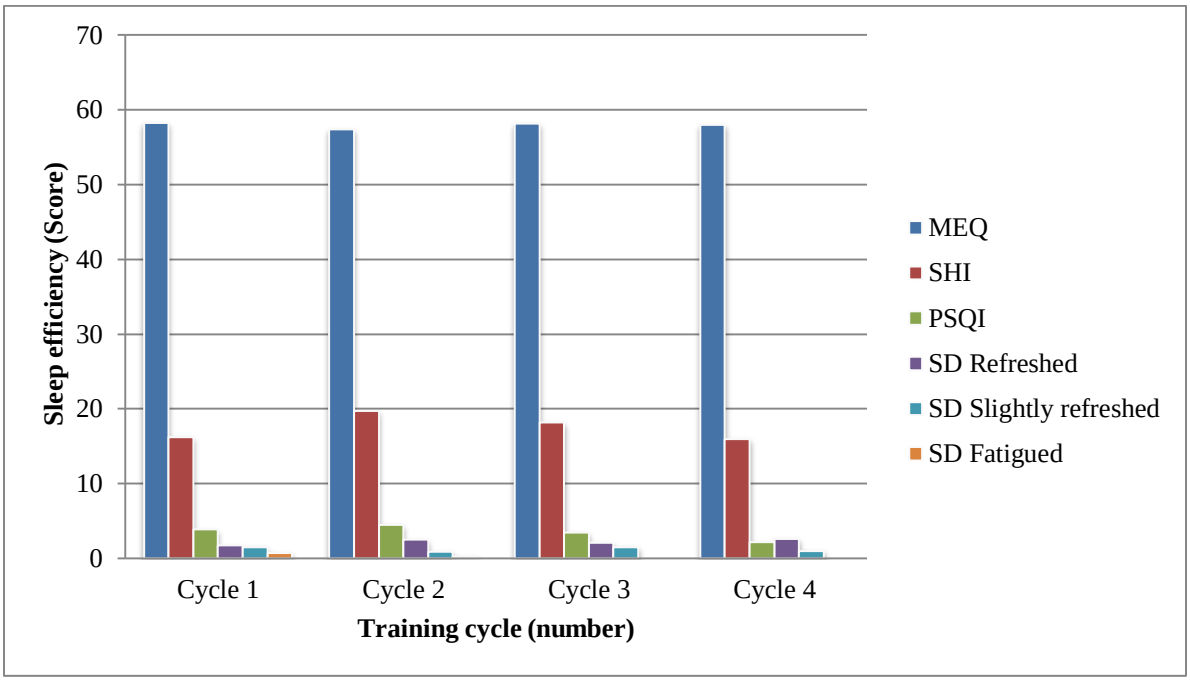


Figure 4.16: Summary of the sleep scores from the MEQ, SHI and PSQI sleep questionnaires and sleep diary sleep efficiency over four training cycles occurring over the duration of a 16 week period (n=8).

4.3 Section B: Main Study

i. Baseline Data

a. Demographic information

In the study there was a total of 17 participants consisting of female (n=8) and male (n=9), 53.33% of the participants were female. Table 4.2 below shows the mean chronological age and number of years competing in swimming. The mean chronological age for the participants was

16±1.81 years and the mean number of years competing in swimming was 6.7±2.71 years. At the end of the study a total of 15 participants comprising of females (n=8) and males (n=7) with mean ages of 15±1.8 and 17±1.59 years respectively.

Table 4.2: Mean baseline chronological age and number of years competing in swimming (n=15).

Anthropometry	Mean±SD	Median and interquartile range
Age (years)	16±1.81	16 (15-17)
Competitively swimming (years)	6.7±2.71	7 (4-10)

b. Dropout

Figure 4.17 below illustrates the dropout of the participants throughout the duration of the study. At the start of the study 17 participants were recruited, due to the lack of compliance during the study the sample size was reduced to a total of 15 individuals at the end of the study. Figure 4.17 shows during the course of the main study individual dropout decreased due to participants dropping out of the study or incomplete questionnaires. It was found that the male participant dropout declined by 17.64% in comparison to the female participants. An unpaired student t-test was done and data was found not to be significant (p=0.77).

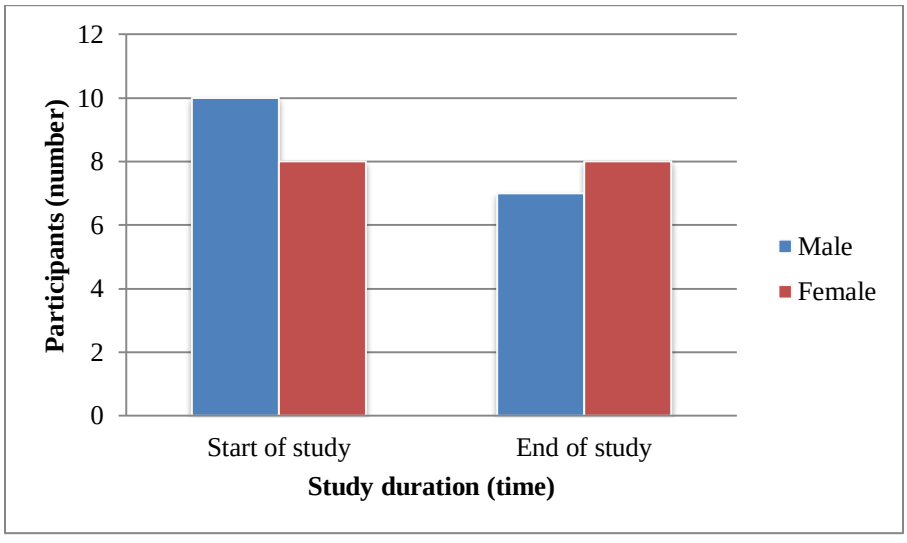


Figure 4.17: Overall participant dropout during the 16 week main study (n=17).

ii. Data obtained from the study

1) Objective 1

To determine how the training regime influences sleep, mood, performance and recovery in swimmers, using the sleep diary, Fitbit, total quality recovery and profile of mood states questionnaires.

Various questionnaires relating to recovery were used and related to the training regime over a 16 week period consisting of 4 training cycles.

Data will be discussed according to the mesocycle training regime, during the course of the study four mesocycles were observed, and comparisons were made between cycles 1 to 4.

i. Calories versus training

Total calories can relate to training regime and is illustrated by Figure 4.18 below. Calories comprise of the BMR, Fitbit activity and activity logged by the participant. Figure 4.18 shows in 6 participants that during four swimming training cycles the recovery week total calories were 25% lower compared to the other hard weeks, there was no significant difference ($p=0.50$). It was also found that during cycle 2 and 4 that recovery was increased compared to the following hard week. There was a positive Pearson's correlation between the recovery weeks over the four cycles and data was found to be significant ($p=0.03$).

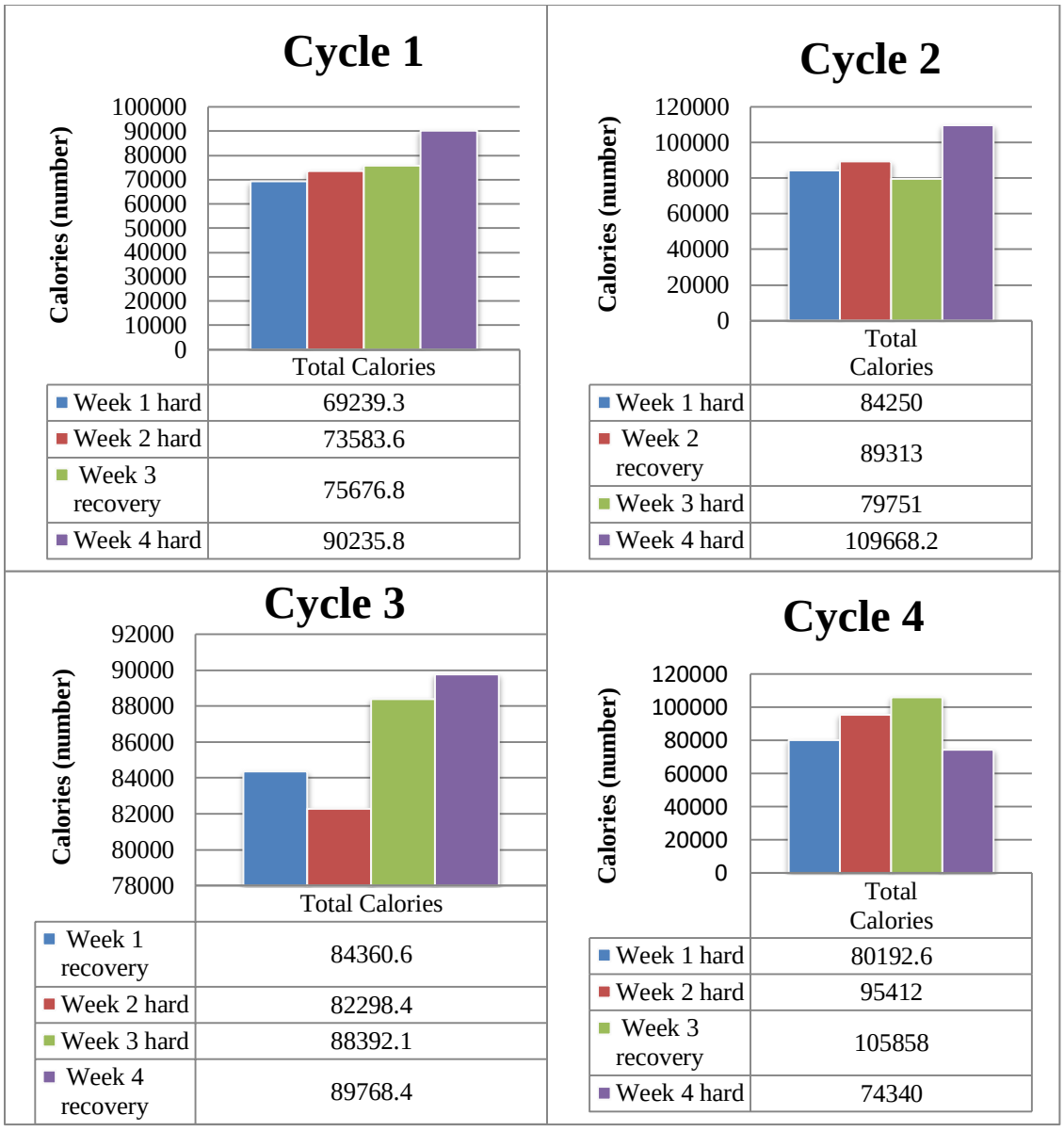


Figure 4.18: The training intensity and total calorie expenditure of six swimmers between training cycles 1 to 4 over a 16 week period (n=6).

Calories are burnt during swimming training and relate to the training intensity of the mesocycle week. The calorie expenditure occurring during swimming training can be seen in Figure 4.19 below. Figure 4.19 shows total swimming calorie expenditure of seven participants over four training cycles. It was observed that 75% of the swimming calories were higher during the recovery week compared to the other hard training weeks during four training cycles, the data during the recovery week was found to be significant (p=0.01).The lowest swimming calorie

expenditure during the recovery week was only found in cycle 2 compared to cycle 3 and 4 which found the lowest calorie expenditure occurring the week after the recovery week, and lastly Cycle 1 lowest calorie expenditure occurred before the recovery week. It was observed in cycle 1 and 2 that the recovery swimming calories increased by 95.68% and 91.92%respectively compared to the following hard week. There was no correlation found between the four cycles (-1.00).

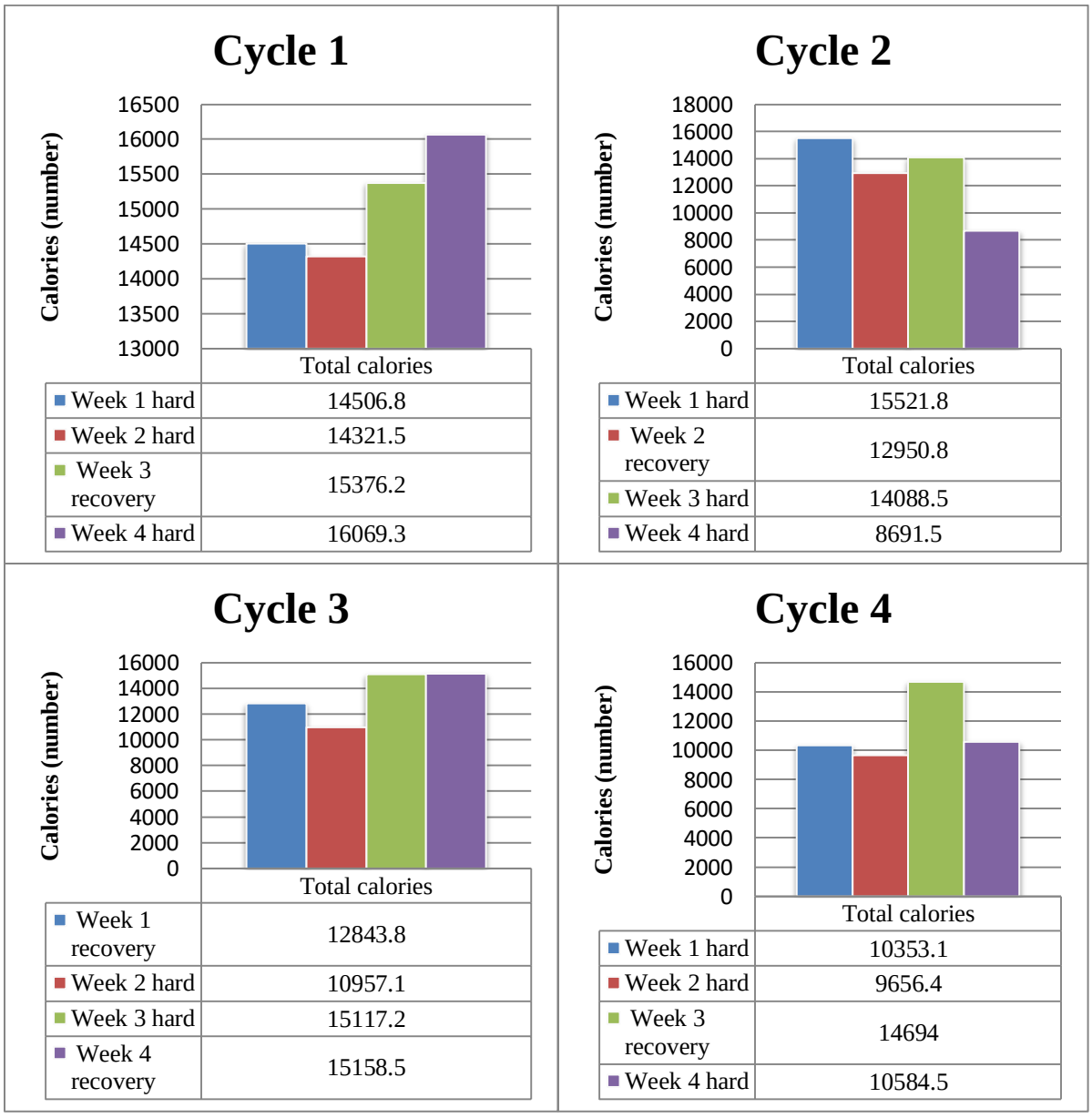


Figure 4.19: Total swimming calorie expenditure and its relation to training intensityover a 16 week period (n=7).

ii. Sleep versus training

Total sleep time was measured in minutes by the SD and FB and can relate to training intensity which can be seen in Figure 4.20 below. Figure 4.20 illustrates that the TST recorded by the Fitbit (n=6) and the SD (n=8). The TST recorded by the Fitbit are lower compared to the TST recorded in the sleep diary. It can be observed that the Fitbit TST gradually increased by 92.91% as individuals progress from cycle 1 to 3 and decreased by 21.42% between cycle 3 to 4, in comparison to the gradual increase in sleep from cycle 1 to 2 by 85.31% and a decrease of 86.81% from cycle 2 to 3 and another increase of 98.38% between cycle 3 to 4.

The SD TST and FB TST were found to be significant (p=0.00) over the four training cycles using a unpaired student t-test however, a Pearson's correlation test found no correlation between the SD TST and FB TST (-0.65).

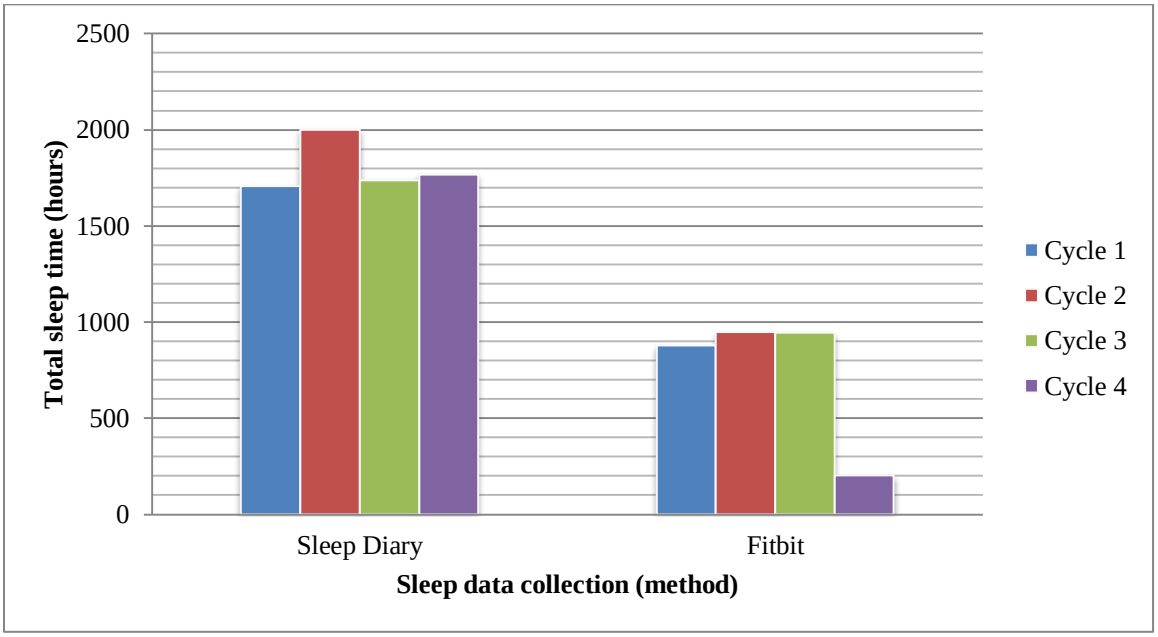


Figure 4.20: Total sleep time from the sleep diary and Fitbit versus training over four training cycles taking place over a 16 week period (n=8; n=6).

Sleep has been further subdivided into the first 2 cycles and the last two cycles due to the change in device from the Fitbit Flex 2being used during week 1 to 7 to the Fitbit Inspire HR; which was used from week 8 to 14. Figures 4.21-23 showing the sleep results obtained from the two devices can be found below. Figure 4.21 shows the restless time in minutes during the course of

a 7 week training period of 6 participants when the Fitbit Flex 2 device was used. During the course of the first 7 weeks of the study it was observed that the FB Flex 2 restless minutes increased between week 1 to 4 from 691 to 1145 minutes and then gradually started to decreased by 67.51% from week 4 to 7. Data between training week 1 to 7 was positively correlated using a Pearson's test (1.00).

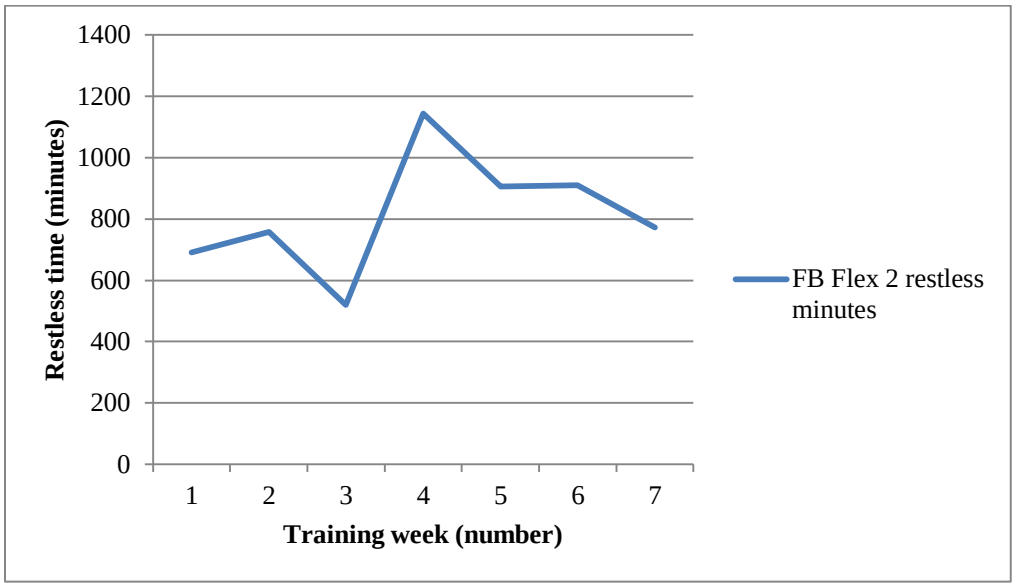


Figure 4.21: Fitbit Flex 2 restless minutes during week 1 to 7 of the training regime (n=6).

The Fitbit Flex 2 was then collected and participants used the Fitbit Inspire HR from weeks 8 till 14 of data collection. The FB Inspire awake minutes can be found in Figure 4.22. Figure 4.22 shows that awake minutes recorded by the Fitbit Inspire HR between trainig weeks 8 to 14 of the swimming training regime for 9 participants. It was observed that awake minutes fluctuated during the course of the study. It was found between week 8 and 9 the awake minutes decreased by 77.75% and then gradually increased between week 9 and 10 by 36.12%, then decreased by 61.34% between week 10 to 11, increased by 56.29% between week 11 and 12. At week 12 it decreased again from 1897 to 1311 minutes and then increased slightly towards the end of the study by 0.99% between week 13 and 14 of data collection. All awake minutes between week 8 to 14 were found to be positively correlated using a Pearsons test (1.00).

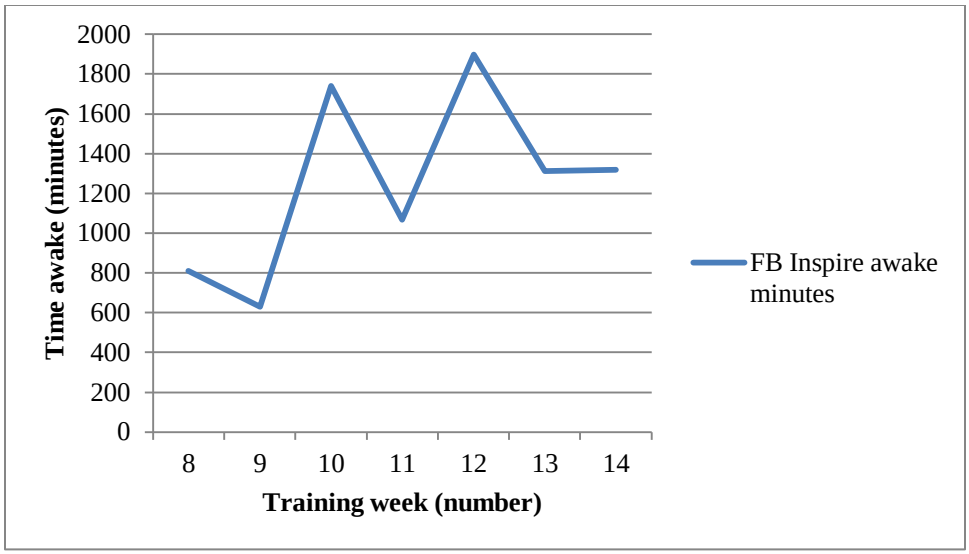


Figure 4.22: Fitbit Inspire HR awake minutes recorded during week 8 to 14 of the training regime for nine swimmers (n=9).

Overall sleep data that was recorded by the Fitbit Inspire HR between week 8 to 14 can be found in Figure 4.23 below. Figure 4.23 provides an overview of the different sleep patterns that were recorded in 5 participants during weeks 8 to 14 of data collection. It can observed that individuals obtained more light sleep compared to REM, with no significance (p=0.42) and deep sleep, a significant difference (p=0.00) and positive Pearson's correlation (0.00) was found during the course of the study. However, participants obtained more REM sleep than deep sleep over the seven week period and data was found to be positively correlated (0.00) and significant (p=0.00).

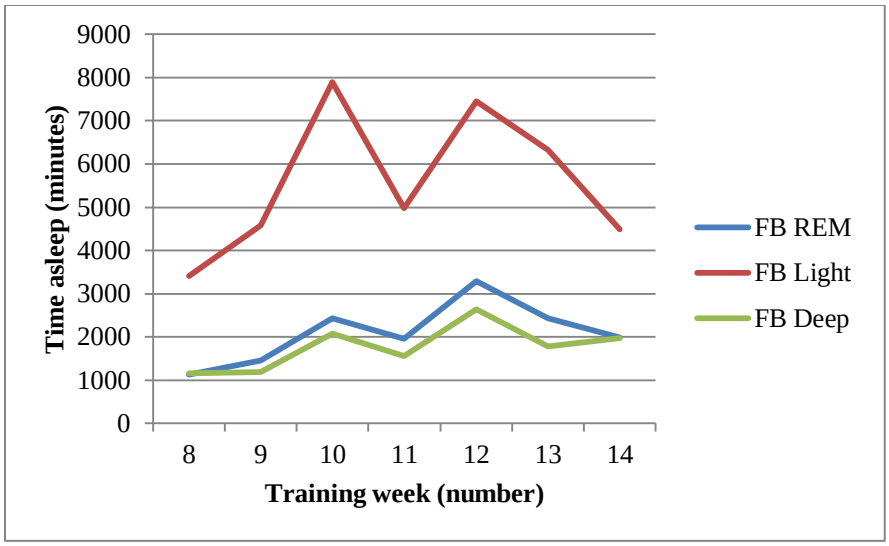
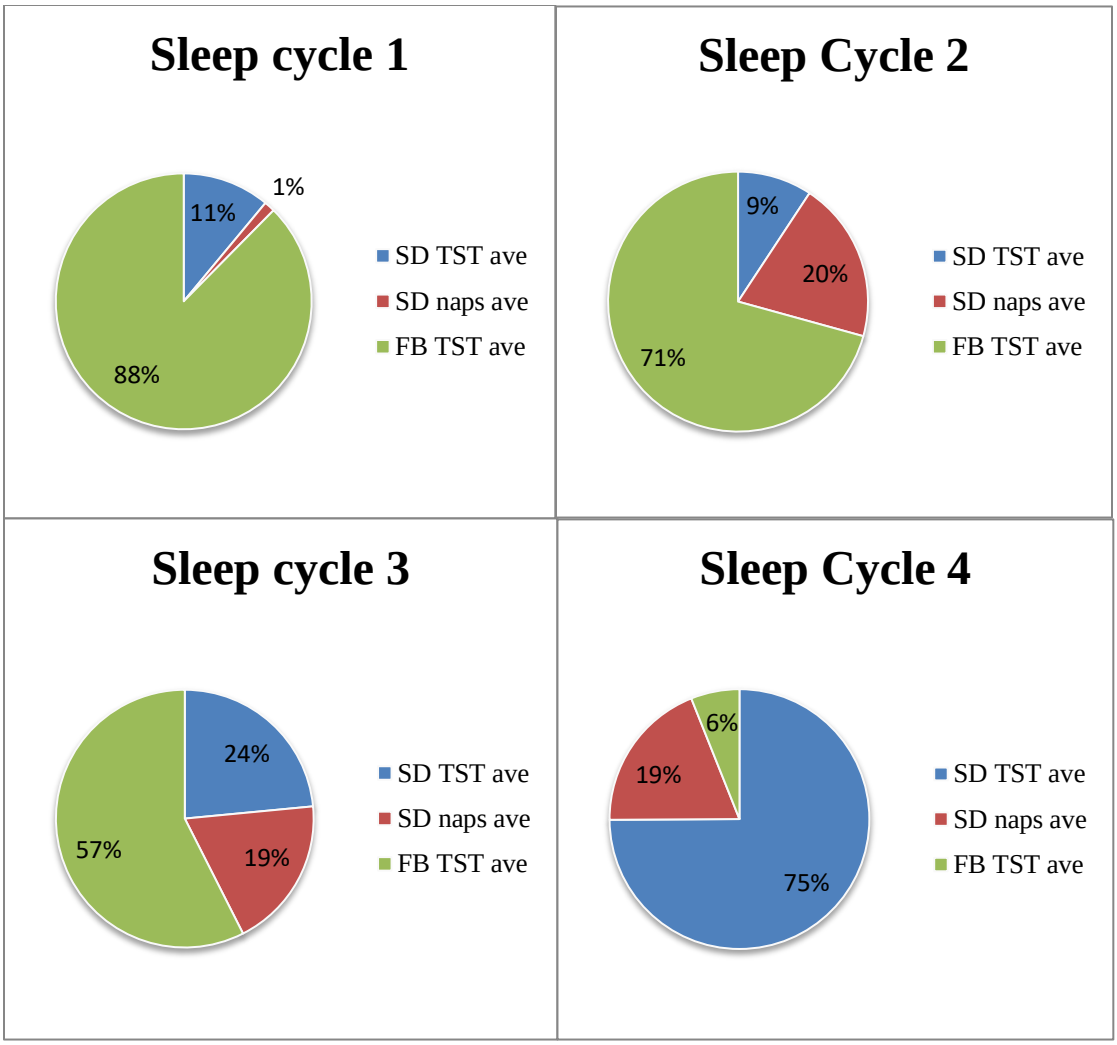


Figure 4.23: Summary of Fitbit Inspire HR sleep pattern measured in minutes during training weeks 8 to 14 of data collection in swimmers (n=5).

In addition to the use of the FB devices, participants manually recorded sleep in minutes within a sleep diary and relate to training intensity which can be seen in Figure 4.24 below. In Figure 4.24 sleep was compared across the four mesocycles which included the average SD naps (n=9), SD TST (n=8) and FB TST (n=6). It was found that the recorded average FB TST steadily decreased by 33% between cycles 1 to 4. Average SD TST increased between cycles 1 to 2 from 56% to 59% and then increased by 30% between cycles 2 to 4. However, it was found that SD naps average remained the same between cycles 1 to 2, then decreased from 1% to 0% between cycles 2 to 3and then increased by 1% between cycles 3 and 4.

The SD TST and FB TST were found not to be significant (p=0.08) using an unpaired student t-test and a Pearson's correlation test found no correlation between the SD TST and FB TST (-0.97) over the six week period. There was no significance difference found between SD naps and SD TST (p=0.38), however the Pearson's test found a positive correlation (0.37) between week 8 and 14 of the training cycle.



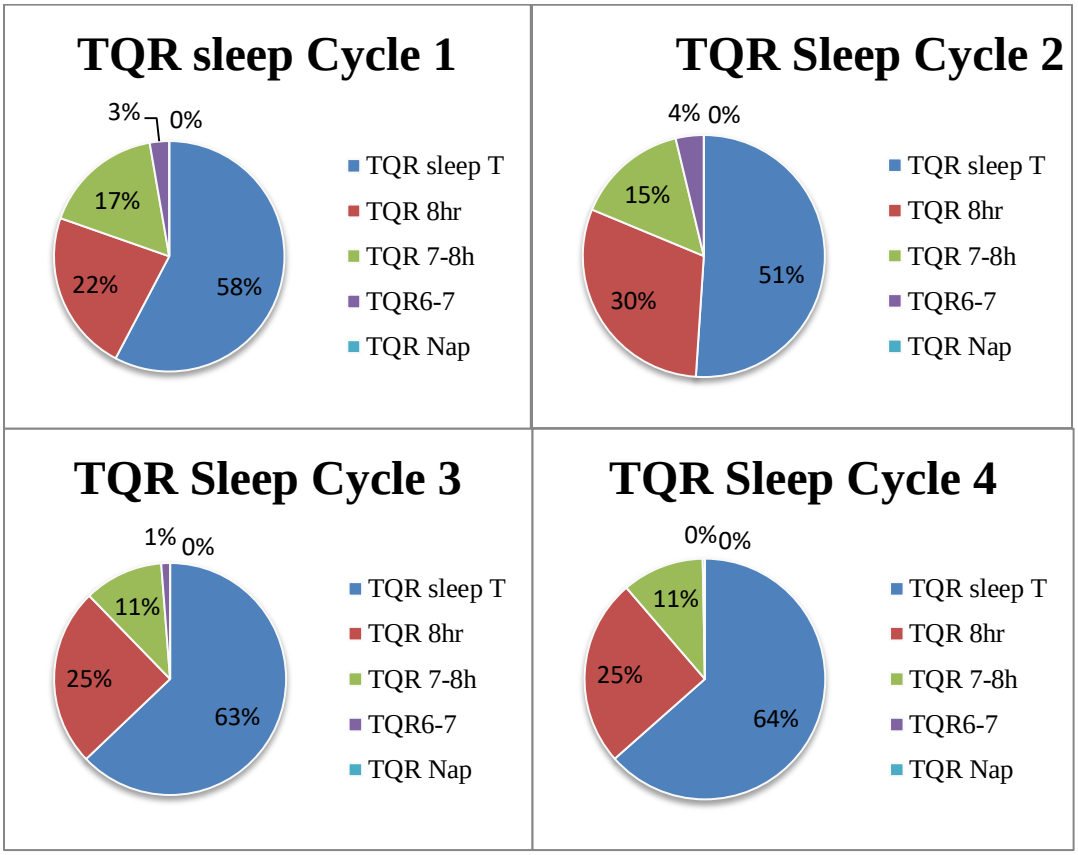
*SD naps ave- Sleep diary averge nap time (n=9), SD TST ave- Sleep diary average total sleep time (n=8), FB TST ave-Fitbit average total sleep time (n=6) **Sleep was measured in minutes and converted to a percentage for each mesocycle.

Figure 4.24: Summary of sleep and training over four swimming training cycles (n=9;n=8;n=6).

iii. TQR sleep and training

TQR sleep score comprised of the different aspects of sleep and related it to training intensity which can be seen in Figure 4.25. Figure 4.25 shows each sleep component of the TQR that fluctuated during the course of the study in 11 swimmers. TQR TST increased by 4% between cycles 1 to 2 and gradually increased by 11% between cycles 2 to 4, but overall increased by

15% between cycles 1 to 4. TQR naps remained at 0% throughout the study between cycles 1 to 4. The TQR sleep average and TQR nap average was significant (p=0.00) with no correlation found using a Pearson's test. TQR 8 hours of sleep increased by 9% between cycle 1 to 2 and further decreased by 6% between cycle 2 and 3. Overall from the start to end of the study there was a 6% increase. A TQR score for 7-8 hours of sleep increased between cycles 1 and 2 by 4% and then by a further 4% for the remainder of the study. Therefore overall there was a 1% decrease in TQR 7-8 hours of sleep between the start and end of the study. It was observed that TQR 6-7 hours decreased by 17% during cycles 1 and 2, but overall presented with a 20% decreased throughout the duration of the study from 20% to 0% between cycles 1 and 4.The TQR data across the four training cycles were not significant (p=0.50).



*TQR sleep T= TQR total sleep

Figure 4.25: TQR sleep occurring across the four training cycles of eleven swimmers (n=11).

iv. Mood versus training

The POMS questionnaire consists of six mood factors and the relation it has to the four training cycles can be found in Figure 4.26. Figure 4.26 illustrates the six types of moods that were experienced on a weekly basis across four mesocycles from the POMS questionnaire in 14 swimmers. All six emotions namely anger, tension, fatigue, depression, vigor and confusion fluctuated throughout the duration of the main study. Tension increased by 1% between cycles 1 and 2 and decreased by 4% between cycles 2 and 4. Anger decreased by 2% between cycles 1 and 2 and gradually increased by 2% between cycles 2 and 4, anger scores remained the same between cycles 1 and 4. It was found between cycle 1 and 2 that fatigued remained equal at 11%, then increased by 2% between cycle 2 and 3 and decreased by 4% between cycles 3 and 4, when comparing cycle 1 to cycle 4 a decrease of 2%. Depression increased between cycles 1 and 4 by 5%, decreased by 1% between cycles 1 and 2 and gradually increased between cycles 2 and 4 by 6%. Vigour increased between cycles 1 and 2 by 8% and gradually decreased by 12% between cycles 2 and 4. Confusion increased between cycles 1 and 2 by 2% and decreased by 2% between cycles 2 and 3 and remained equal between cycles 3 and 4.

Overall within emotions the only one that gradually decreased by 4% throughout the study was vigour. Tension and fatigue decreased from the start and end of the study by 3% and 2% respectively compared to anger and confusion remaining the same throughout the study. There was no significant difference found for each of the six emotions from the start to the end of the study using an unpaired student t-test ($p=0.50$). Overall the total score increased by 4% from the start to the end of the study, with no significant difference ($p=0.39$) and no correlation being found (-1.00).

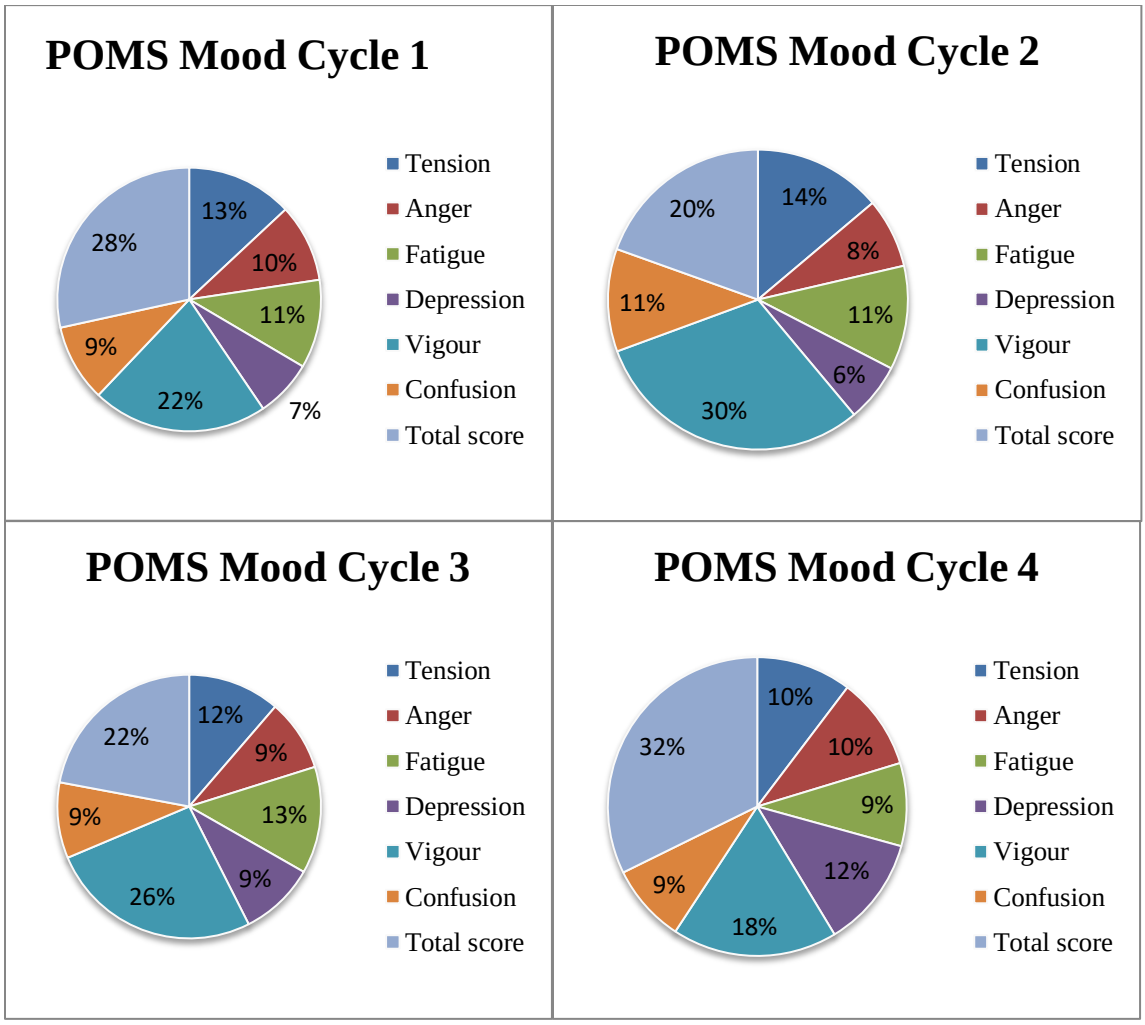


Figure 4.26: Profile of mood states separated into the six different mood states that fifteen swimmers experienced over a 16 week cycle (n=15).

Addition to the POMS questionnaire mood was measured daily using the sleep diary which can be found in Figure 4.27 below. Figure 4.27 illustrates the three types of moods that were experienced on a weekly basis across four mesocycles from the sleep diary in 11 swimmers. It was found that participants only experienced an unpleasant mood during cycle 1 when compared to the other three cycles. The overall mood experienced by participants was pleasant throughout the study cycles except in cycle 4 which was the lowest. An increase in the SD very pleasant mood was observed between cycles 3 and 4 by 19% and remained consistent from cycle 1 to cycle 3.

Over the four cycles no significant difference (p=0.50) was observed in all three SD mood states and no correlations were found using the Pearson's test for pleasant mood compared to very pleasant (-1.00) and pleasant compared to unpleasant mood state (-1.00), however a positive correlation was found between very pleasant and unpleasant mood state (1.00) throughout the duration of the study.

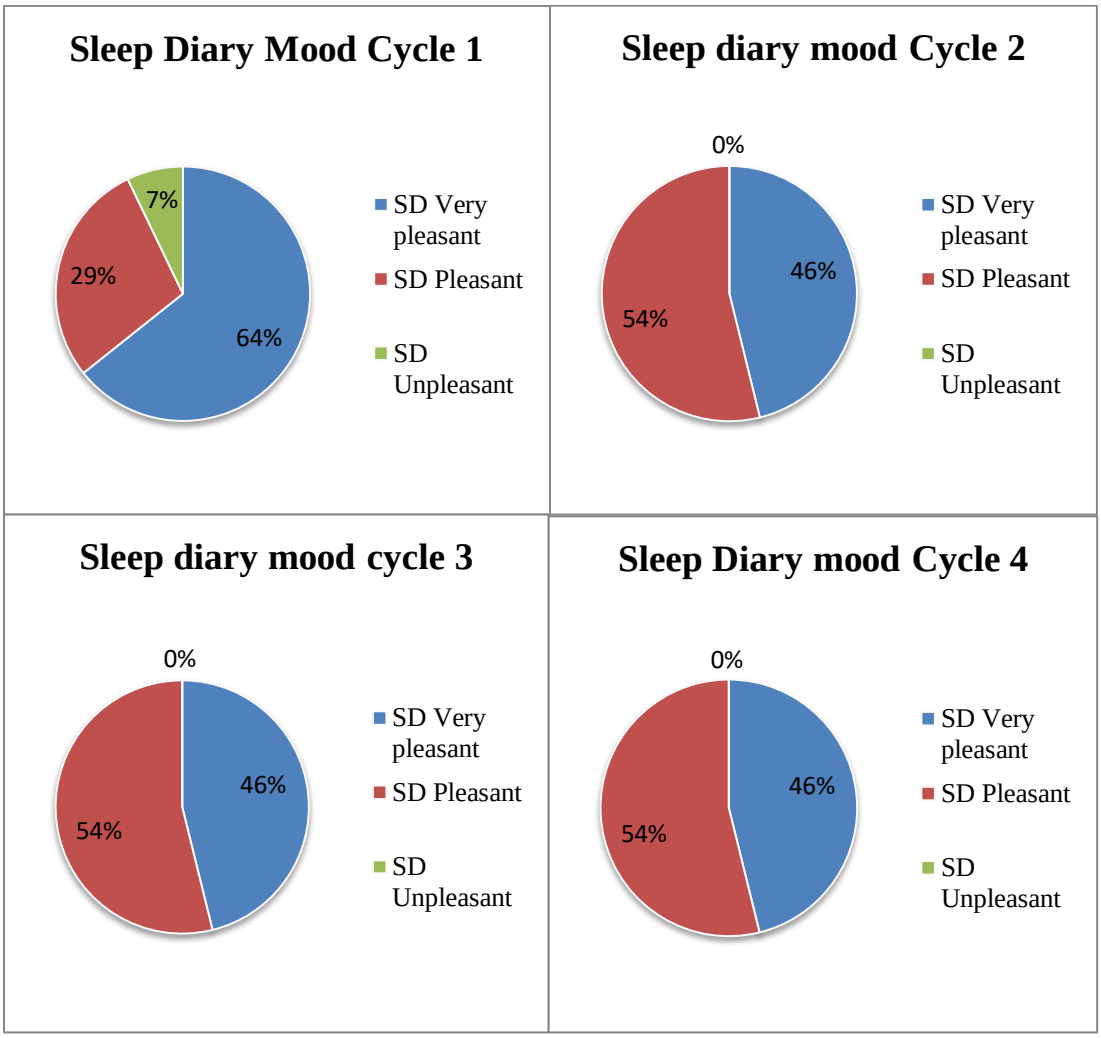
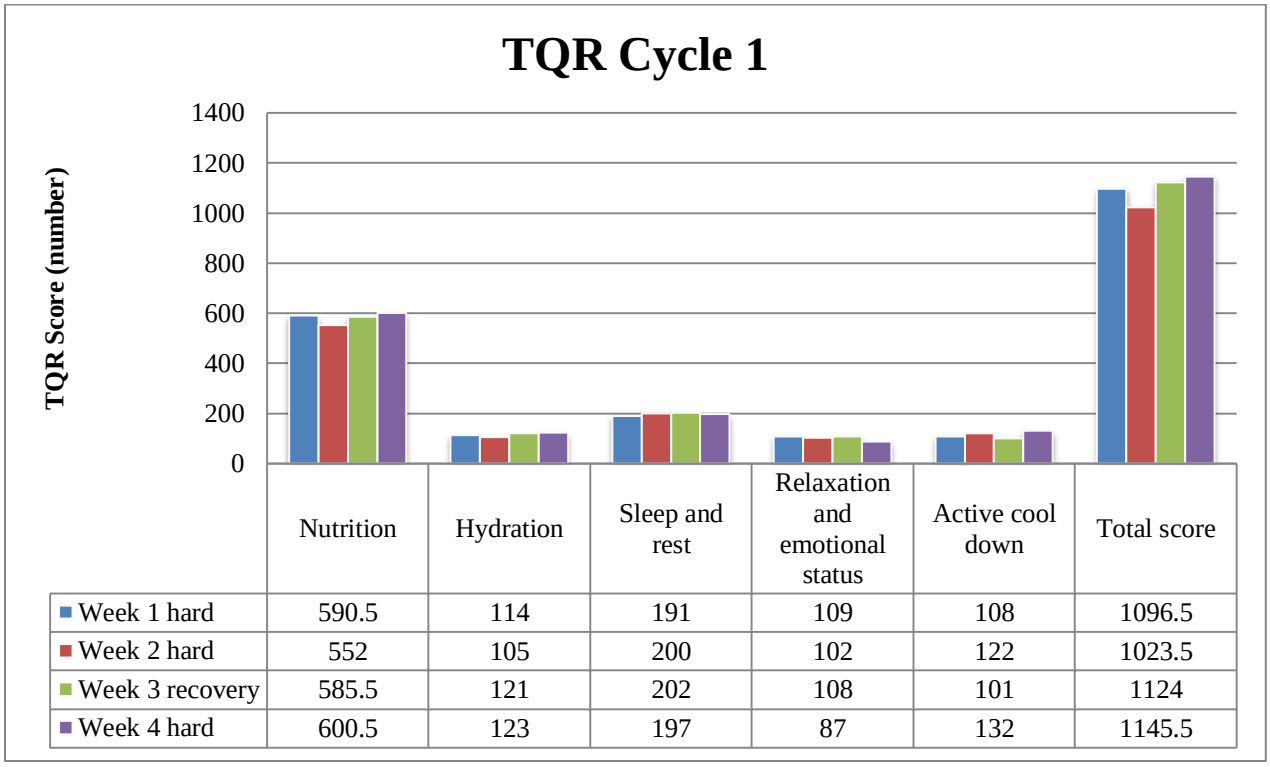


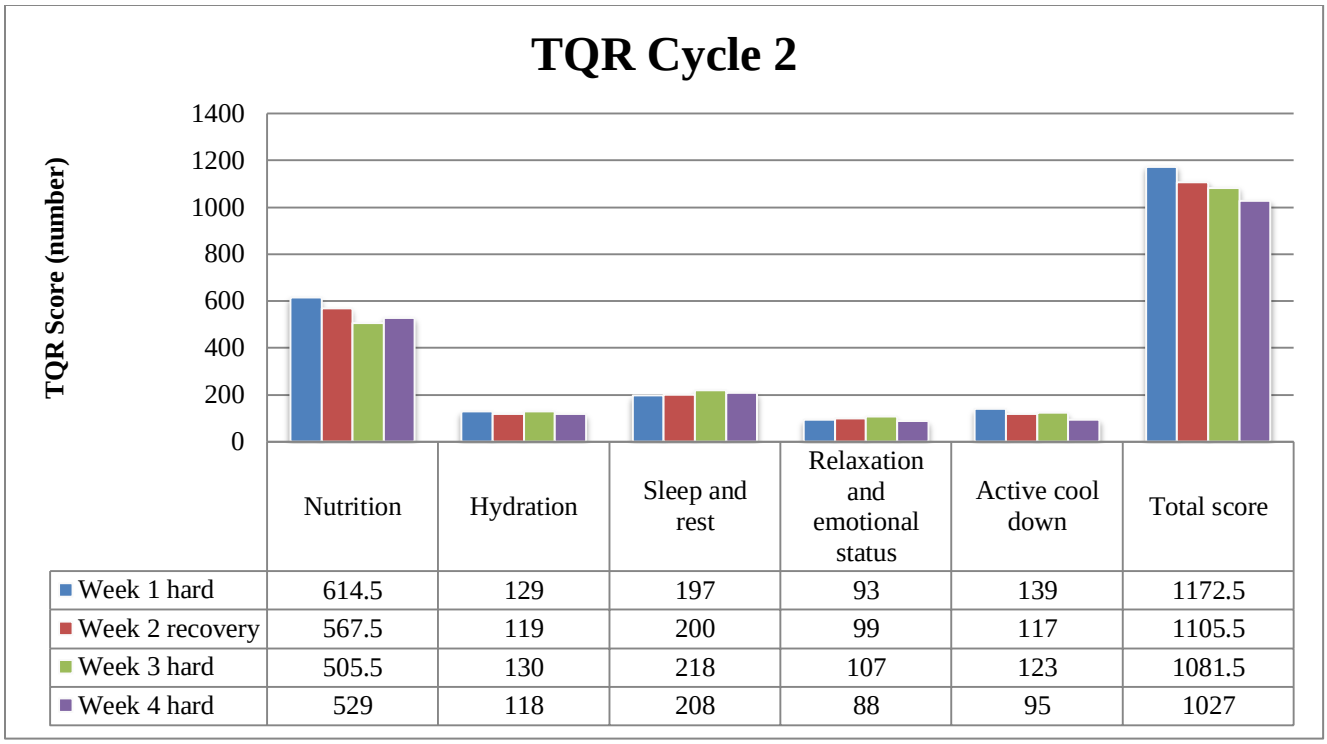
Figure 4.27: Sleep diary mood divided into three categories that eleven participants experienced over a 16 week swimming cycle (n=11).

v. Recovery (TQR) versus training

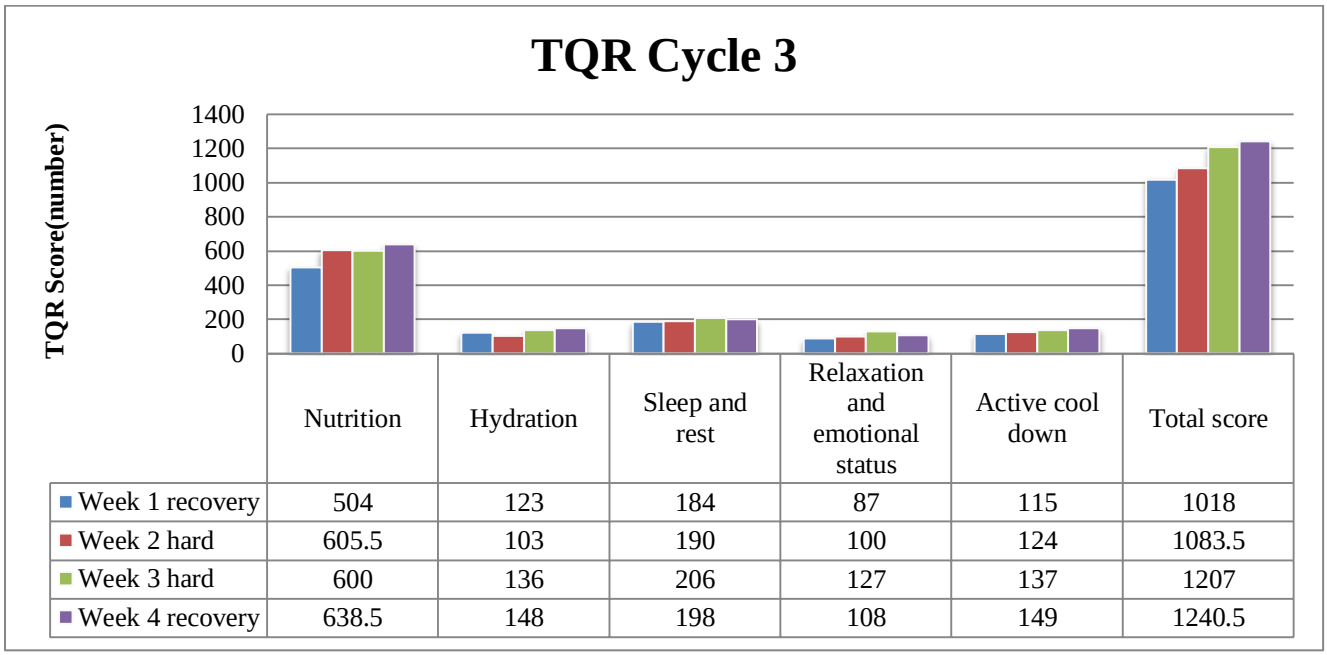
Each component of the TQR can be found in Figure 4.28. Figure 4.28 shows each component of the TQR in 13 participants. The highest total TQR score was found in cycle 3 and 4 during the recovery week and in cycle 1 and 4 the highest score was the week after the recovery week, there was no significance (p=0.50). TQR nutrition was the highest during the recovery week for cycles3 and 4 and the week before the recovery week for cycles 2 and 4. The highest TQR sleep and rest score was observed in cycles 2 and 4 after the recovery week. It was found that TQR active cool down remained relatively steady with the highest scores being found in the hard week for cycles 1, 2 and 4. Overall there was no significant difference observed for each of the TQR cycles (p=0.50, p=0.50, p=0.28, p=0.50).



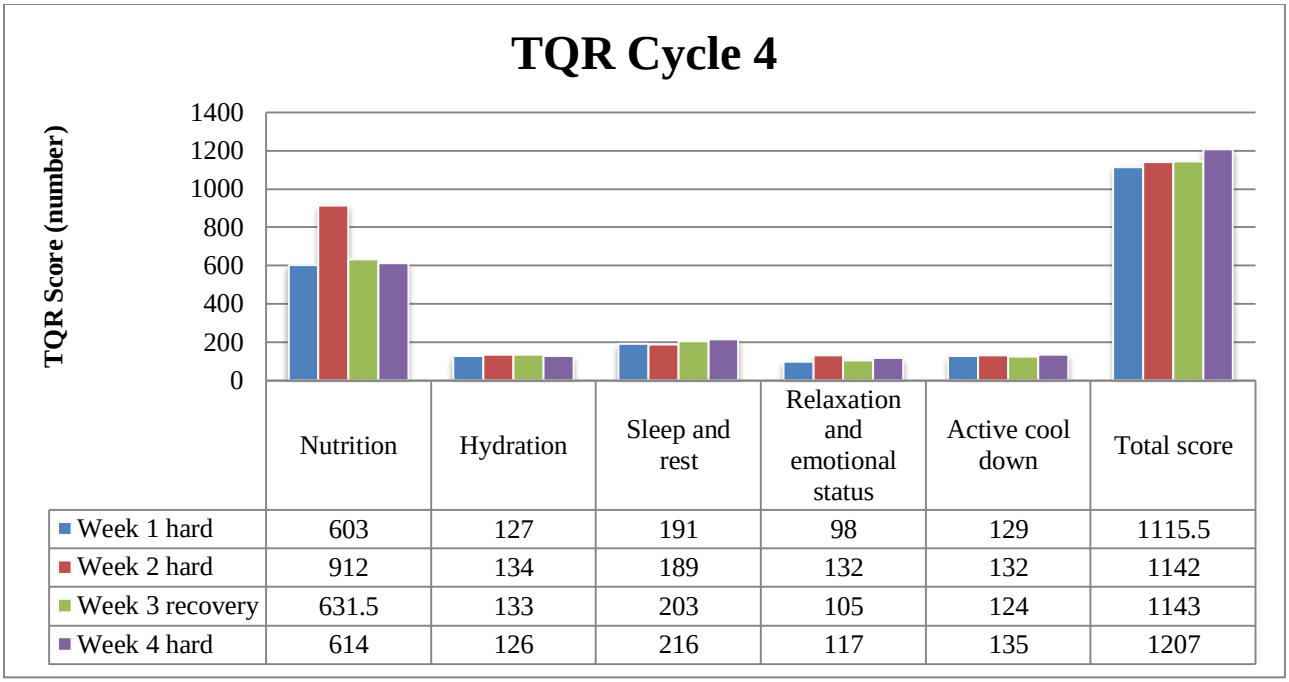
	Nutrition	Hydration	Sleep and rest	Relaxation and emotional status	Active cool down	Total score
Week 1 hard	590.5	114	191	109	108	1096.5
Week 2 hard	552	105	200	102	122	1023.5
Week 3 recovery	585.5	121	202	108	101	1124
Week 4 hard	600.5	123	197	87	132	1145.5



	Nutrition	Hydration	Sleep and rest	Relaxation and emotional status	Active cool down	Total score
Week 1 hard	614.5	129	197	93	139	1172.5
Week 2 recovery	567.5	119	200	99	117	1105.5
Week 3 hard	505.5	130	218	107	123	1081.5
Week 4 hard	529	118	208	88	95	1027



	Nutrition	Hydration	Sleep and rest	Relaxation and emotional status	Active cool down	Total score
Week 1 recovery	504	123	184	87	115	1018
Week 2 hard	605.5	103	190	100	124	1083.5
Week 3 hard	600	136	206	127	137	1207
Week 4 recovery	638.5	148	198	108	149	1240.5



	Nutrition	Hydration	Sleep and rest	Relaxation and emotional status	Active cool down	Total score
Week 1 hard	603	127	191	98	129	1115.5
Week 2 hard	912	134	189	132	132	1142
Week 3 recovery	631.5	133	203	105	124	1143
Week 4 hard	614	126	216	117	135	1207

Figure 4.28: Components of the TQR in relation to training across four cycles over a 16 week period in swimmers (n=13).

2) Objective 2

To determine how mood can affect a swimmer's performance during competitions, using the profile of mood states and sports emotional questionnaires.

Two validated questionnaires namely the profile of mood states and sports emotional questionnaires were correlated to the participant's performance over a 16 week period consisting of 4 training cycles.

Objective 2 will be answered in two parts, the first in the form of a case study (Appendix U) of one participant Ms. Y that competed in two competitions during the course of the study and secondly, using the weekly performance times of four swimmers.

i. Mood states during gala

Ms. Y that competed in two competitions during the course of the study which can be found in Figure 4.29. Figure 4.29 illustrates the SEQ scores during two competitions namely, the winter and CGA senior gala for Ms. Y. Within the winter gala the scores were higher by 70.21%and 66.66% for the pre and intra competitions compared to the CGA senior gala. The intra competition scores of 51 and 34 were higher compared to the post competition scores of 27 in both the winter and CGA senior galas. The data was found to be significant (p=0.00) using an unpaired student t-test and a positive Pearson's correction was found (0.99) between the Winter and CGA senior gala's.

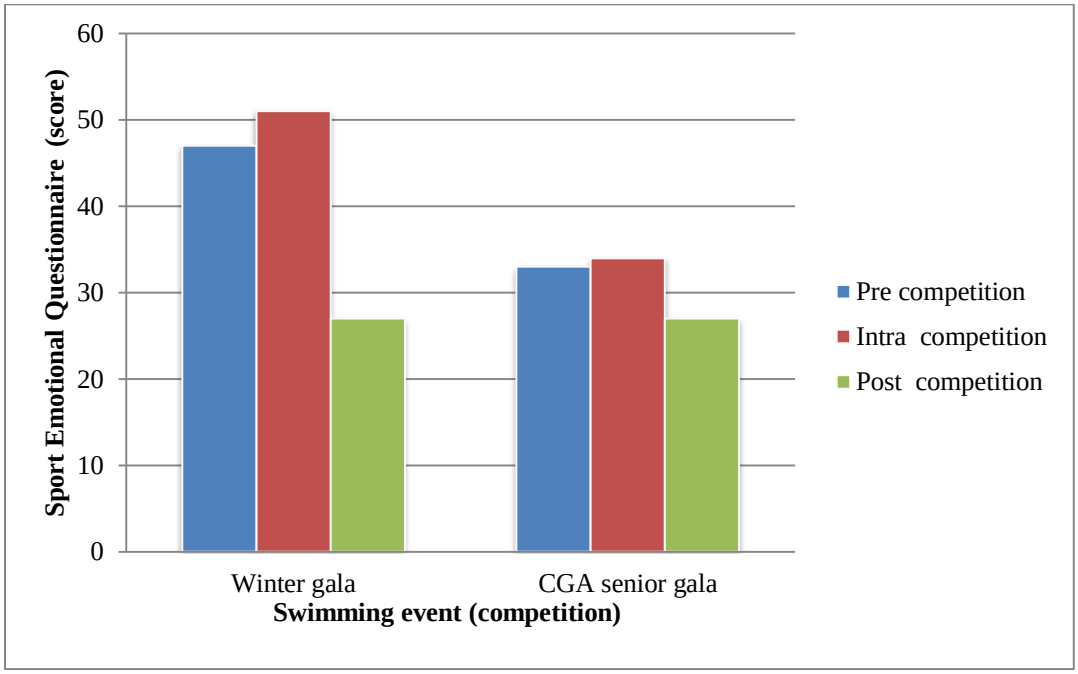


Figure 4.29: Sports Emotional Questionnaire scores pre, intra and post competition during the winter and CGA senior galas for Ms. Y (n=1).

ii. Performance times during two competitions

In the main study only one participant, Ms. Y competed in both the winter and CGA senior galas, her performance times can be found in Figure 4.30 below. Figure 4.30 illustrates the performance times of Ms. Y in different races. It was found that during the individual's time decreased in the 200 metre freestyle from 2:32.6 to 2:32.2 minutes between the winter and CGA senior gala. However, the times increased by 0.2 seconds in the 100 metre freestyle from 1:08.1 to 1:10.1 minutes and 200 metre backstroke the time increased by 6 seconds from 2:41.6 to 2:47.6 minutes. A Pearson's correlation test was done on the performance times between the two competitions and it was found to be positively correlated (0.9), however it was not significant (p=0.47).

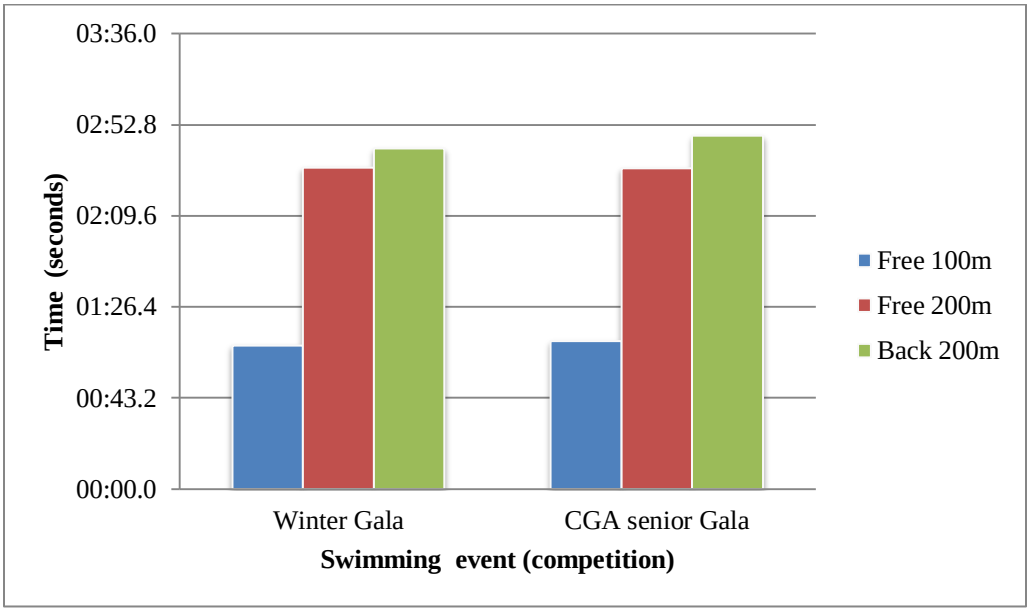


Figure 4.30: The competition times obtained from the Winter gala and CGA senior gala for Ms. Y (n=1).

A case study will be used to show Ms. Y performance times during the course of the study (Appendix V). The information pertaining to the case studies individual's performance and mood can be found in Figures 4.31-4.33.

Figure 4.31 shows the performance times of different strokes of Ms. Y throughout the duration of the study between two months. It was observed that performance times in the100 metre fly

improved by 2.65 seconds from 1.20.9 to 1.18.25 minutes and 100 metre freestyle time decreased by 0.04 seconds from 1.12.6 to 1.12.56 minutes. A Pearson's test was performed and the data was positively correlated (1.00) but no significant difference was found (p=0.40).

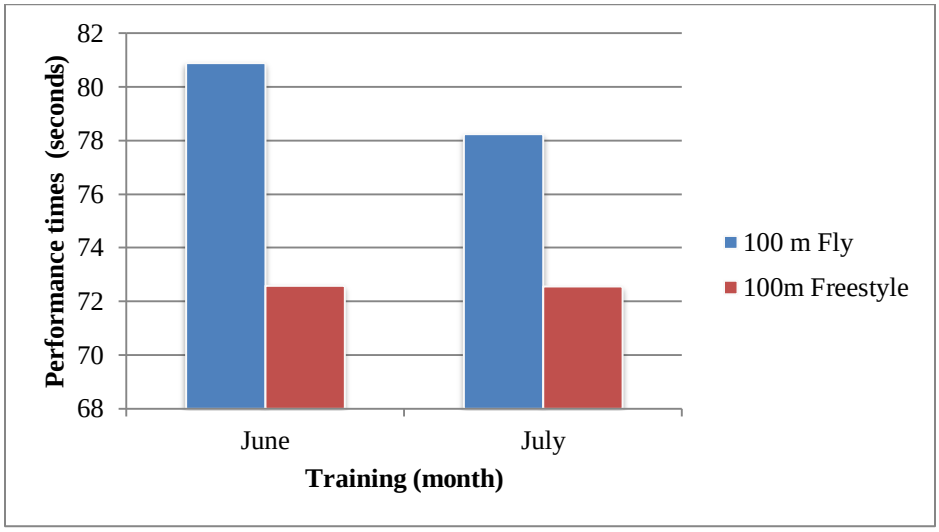


Figure 4.31: Performance times between two months of training of two swimming strokes in one participant (n=1).

iii. Weekly performance times

The performance times of four participants from the start to the end of the study can be found in Table 4.3 and monthly performance times can be seen in Table 4.4. In Table 4.3 it can be observed that each swimmers time improved between 0.88–2.63 seconds from the start to the end of the study. With breast stroke performance times improving by 1.14-2.63 seconds compared to the freestyle stroke time that improved by 0.88-2.54 seconds. Overall performance times of swimmers improved from the start to the end of the study. When comparing the performance times overall from the start to the end of the study no significant difference was found (p=0.90).

Table 4.3: Performance times of four swimmers from the start to the end of the study over four training cycles (n=4).

Participant (number)	Stroke (type)	Distance (metres)	Start of study time (minutes)	End of study time (minutes)	P value (number)
8	Breast	100 m	1.13.5	1.10.87	0.06
13	Breast	100 m	1.20.9	1.19.76	0.05
2	Free	100 m	58.3	55.76	0.06
10	Free	100 m	58.0	57.12	0.05

*$p \leq 0.05$ = significant

Monthly performance times of two participants can be seen in Table 4.4 below. Table 4.4 illustrates the monthly performance tests that were conducted from the start to the end of the study in two participants. It can be observed within both participants that performance times remained the same for the months of June and July, with an improved time seen in August. For participant 3 the performance time improved by 1.25 seconds during the back stroke compared to participant 12's time which decreased by 1.4 seconds in the freestyle stroke. The data was found not to have any significant difference for both participants ($p=0.25$; $p=0.40$).

Table 4.4: Performance times of two participants between May and August (n=2).

Participant (number)	Stroke (type)	Distance (metre)	May time (minutes)	June time (minutes)	July time (minutes)	August time (minutes)	P value (number)
3	Back	100 m	1.14.3	1.14.6	1.14.6	1.13.05	0.25
12	Freestyle	100 m	1.17.8	1.13.4	1.13.4	1.16.4	0.40

*$p \leq 0.05$= significant

Performance readings of resting heart rate for three participants using the Fitbit Inspire HR can be found in Table 4.5 and Figure 4.32. Table 4.5 illustrates the resting heart rate of three participants between week 8 and 15 of data collection with the average RHR being approximately 63.43 beats per minute (bpm). Only one out of the three participants data was significant throughout the study ($p=0.04$).

Table 4.5: Resting heart rate of three swimmers between week 8 and 15 of data collection (n=3).

Participant (number)	Week 8 (bpm)	Week 9 (bpm)	Week 10 (bpm)	Week 11 (bpm)	Week 12 (bpm)	Week 13 (bpm)	Week 14 (bpm)	Week 15 (bpm)	P value (number)
2	69.33	67.71	63.85	65.16	68.42	67.6	65	67	0.45
3	55.5	53.85	55	56.28	54.57	56.28	55.85	55.42	0.28
9	66.71	70.57	71	68.71	68.42	66.71	66.71	66.85	0.04*
Average (bpm)	**63.84**	**64.04**	**63.28**	**63.38**	**63.80**	**63.53**	**62.52**	**63.09**	**0.42**

*$p \leq 0.05$= significant

The average RHR of three participants between week 8 and 15 of data collection can be seen in Figure 4.32. Figure 4.32 shows the average RHR of three participants over the course of an eight week training cycle. The average RHR was 63.43 bpm amongst the participants and fluctuated throughout the duration of the study with week 9 having the highest RHR of 64.04 bpm compared to week 14 of 62.52 bpm. It was found that the RHR decreased as the study progressed, with no significant difference being found (p=0.42).

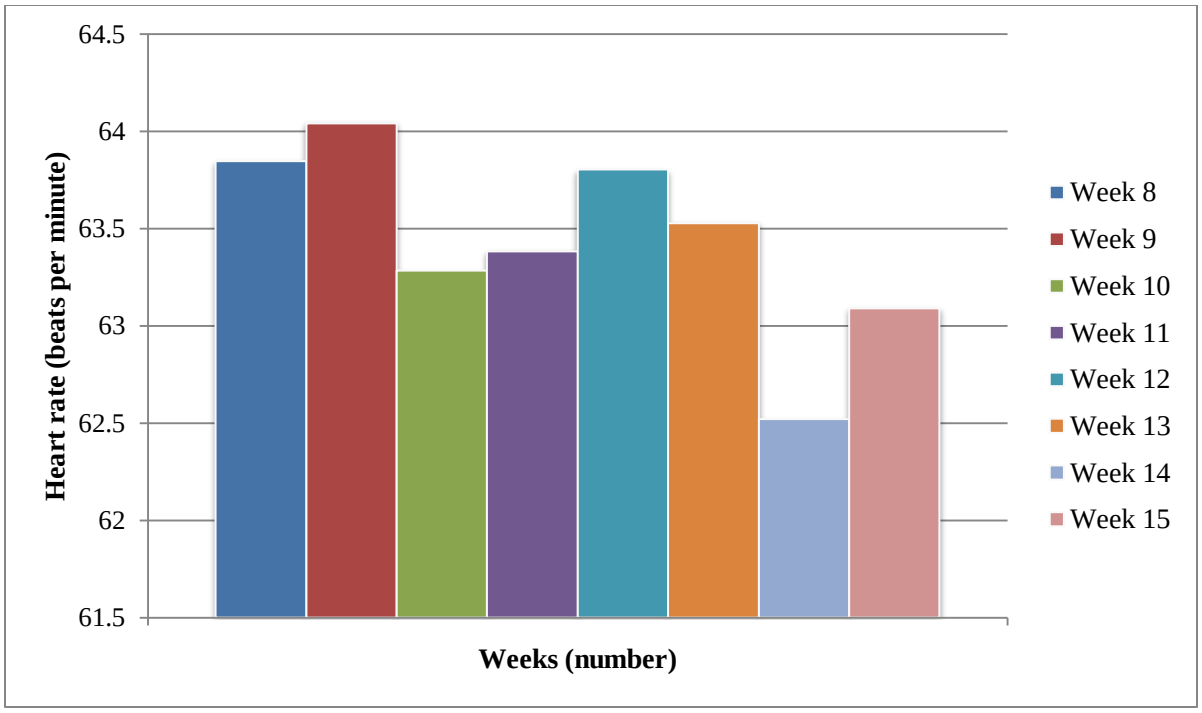


Figure 4.32: Average RHR of swimmers over an eight week training regime (n=3).

Only five swimmers competed in the CGA senior gala and completed the sports emotional questionnaire. A summary of the mood pre, intra and post competition during the CGA senior gala can be found in Figure 4.33. Figure 4.33 shows the pre, intra and post competition moods experienced by five swimmers during the CGA senior gala. It was found that 60% presented with an increased intra competition mood score compared to 40% being below the pre competition score, with no significant difference ($p=0.96$). Post competition mood score decreased by 80% after competitions with only 20% having an elevated post competition mood score, with no mood significant difference ($p=0.60$).

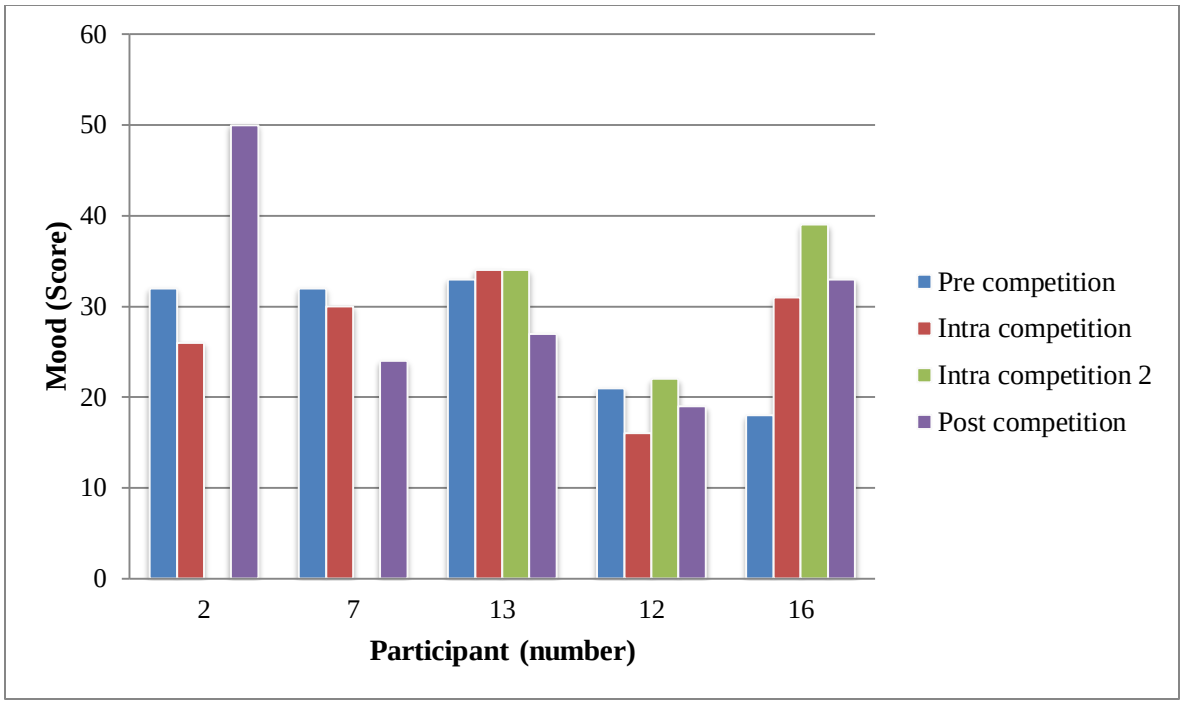


Figure 4.33: The pre, intra and post competition moods experienced during the CGA senior gala (n=5).

3) Objective 3

To determine if a relationship exists between sleep quantity, a swimmer's performance and recovery, using performance testing and sleep questionnaires.

Sleep questionnaires were utilised to compare the different aspects of the TQR and sleep quality to the individual's performance

i. Sleep efficiency

Sleep efficiency according to the sleep diary can be subdivided into three components and observed in Figure 4.34 below. Figure 4.34 shows each component of the sleep efficiency that was recorded by the sleep diary in 12 participants. Sleep efficiency was categorised into three components, refreshed, slightly refreshed and fatigued. A gradual increase in waking up refreshed from cycle 1 to 3 (22% to79%). In comparison to cycle 4, it was found that there was a

20% decrease between cycles 3 to 4 with 60% of individuals waking up feeling slightly refreshed.

When comparing feelings of slightly refreshed and fatigued it was found to correlate (0.13) and with no significant difference (p=0.35). It was also found when doing an unpaired t-test that feeling of refreshed and fatigue was not significant (p=0.51).

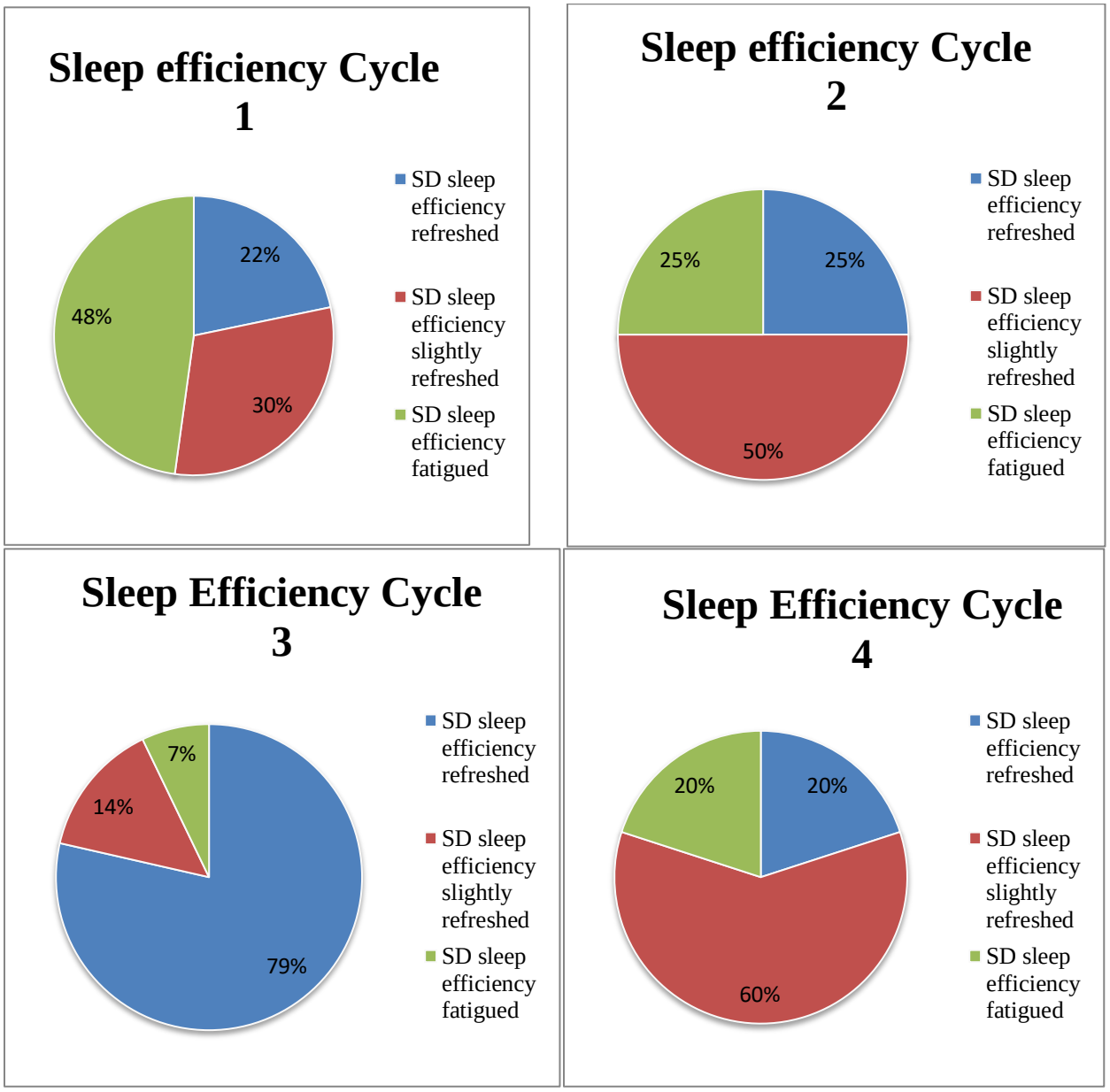


Figure 4.34: Comparison of sleep diary sleep efficiency during each of the four training cycles occurring during the course of 16 weeks (n=12).

ii. PSQI scores

Figure 4.35 illustrates the PSQI scores of 13 individuals over four mesocycles. It was found that throughout the main study the PSQI scores gradually decreased with cycle 1 being the highest with a score of 4.23 and cycle 4 having the lowest total score of 3.30. The PSQI scores from the start to the end of the study was found not to be significant (p=0.42) and had a positive correlation (1.00).

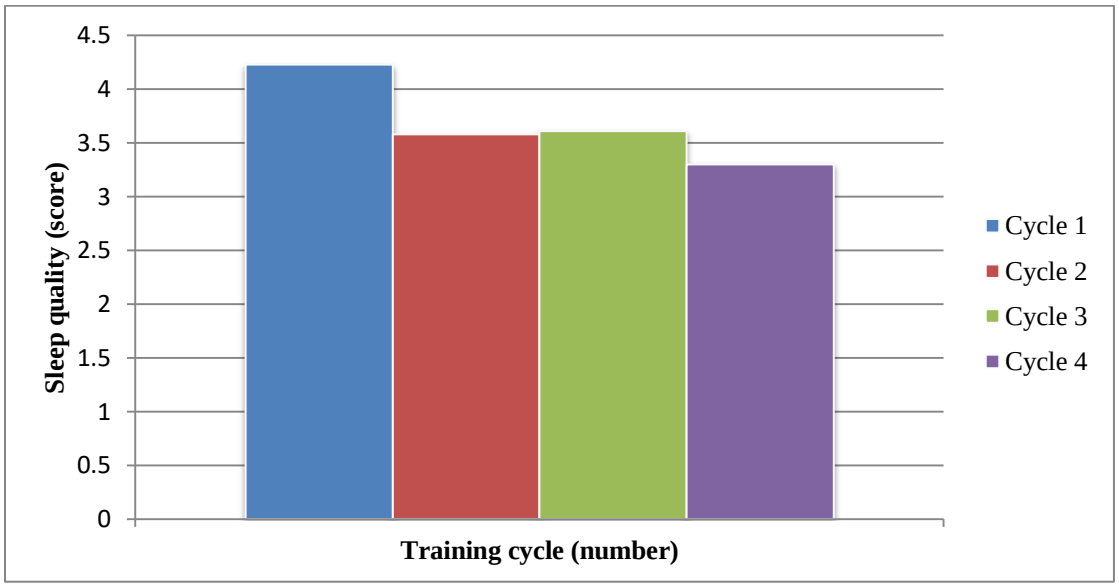


Figure 4.35: PSQI scores in swimmers over a four week training cycle (n=13).

Another aspect of sleep that was observed throughout the study was the sleep hygiene of participants.

iii. Sleep hygiene Index

Figure 4.36 shows the SHI scores of fourteen swimmers throughout the main study. It was found that the SHI scores increased with cycle 2 having the highest score of 20.35 and cycle 4 having the lowest total score of 18. This illustrates that during cycle 4 participants started having better sleep hygiene at the end of the study in comparison to the start of the study. The SHI scores was found not to be significant (p=0.18), however there was a positive Pearson's correlation (1.00) between the four cycles.

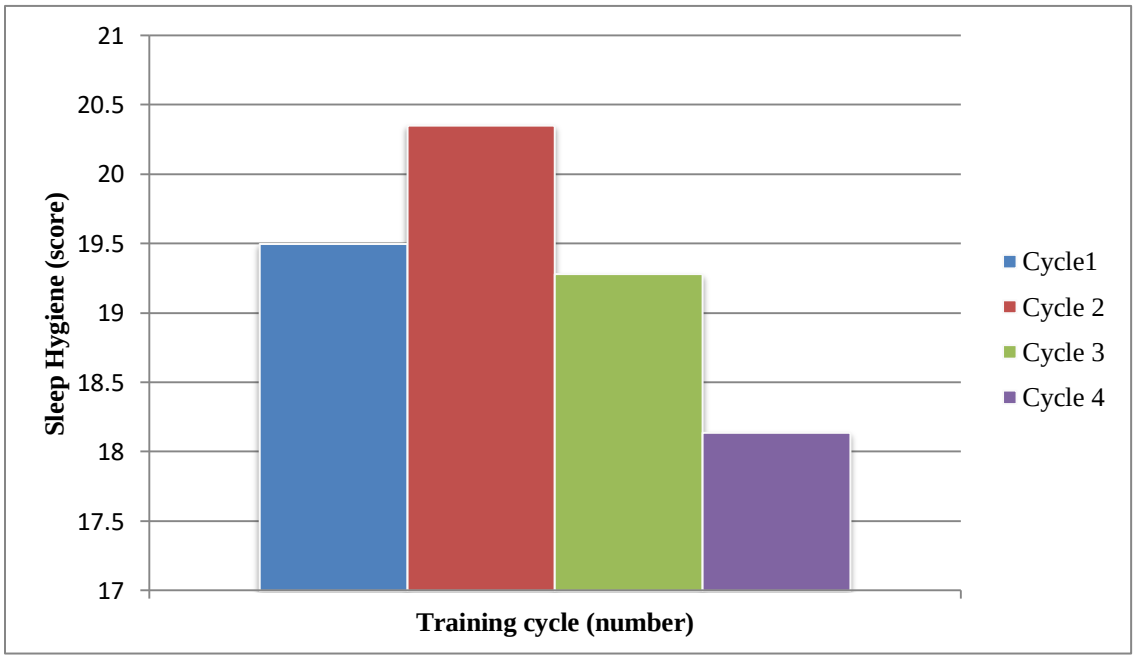


Figure 4.36: Sleep Hygiene Index scores during the course of four training cycles in fourteen swimmers (n=14).

The last aspect of sleep that was studied used the Morningness-Eveningness questionnaire to determine if a participant was a morning or evening person.

iv. Morningness-Eveningness Questionnaire

Figure 4.37 illustrates the MEQ scores of 14 participants throughout a 16 week training regime. It was found that at the start of the study the highest total score was 56.57 and cycle 4 at the end of the study with a lowest total score of 53.21. Showing that at the end of the study participants sleeping pattern changed from individuals being an owl to a lark. The Pearson's correlation test was positive (1.00); however, the data was not significant (p=0.34) for all four mesocycles.

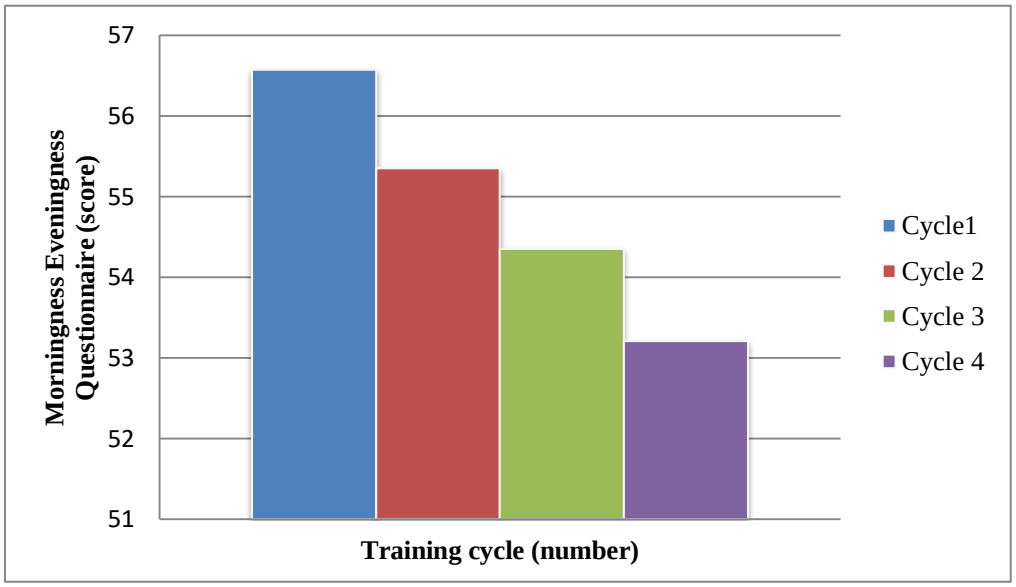


Figure 4.37: MEQ scores during four training cycles in swimmers (n=14).

v. Summary of sleep questionnaire scores

Figure 4.38 shows the combined sleep questionnaire scores of the MEQ (n=14), SHI (n=14) and PSQI (n=13) throughout the duration of the study. It can be observed that the scores for each questionnaire fluctuated throughout the study; however the highest sleep hygiene score was found in cycle 4 with the lowest sleep quality being found in the same cycle. In cycle 4 the lowest sleep quality from the PSQI and lowest MEQ scores were observed possibly showing that individuals during this cycle of the study transitioned to owls.

The PSQI and MEQ were found to be positively correlated using a Pearson's correlation test (0.44). No significance was found between PSQI and SHI (p=1.02) and SHI and MEQ (p=1.42)

and no correlation was found between each with values of -0.34 and -0.56respectively. All correlations and significant differences were calculated between training cycles 1 and 4.

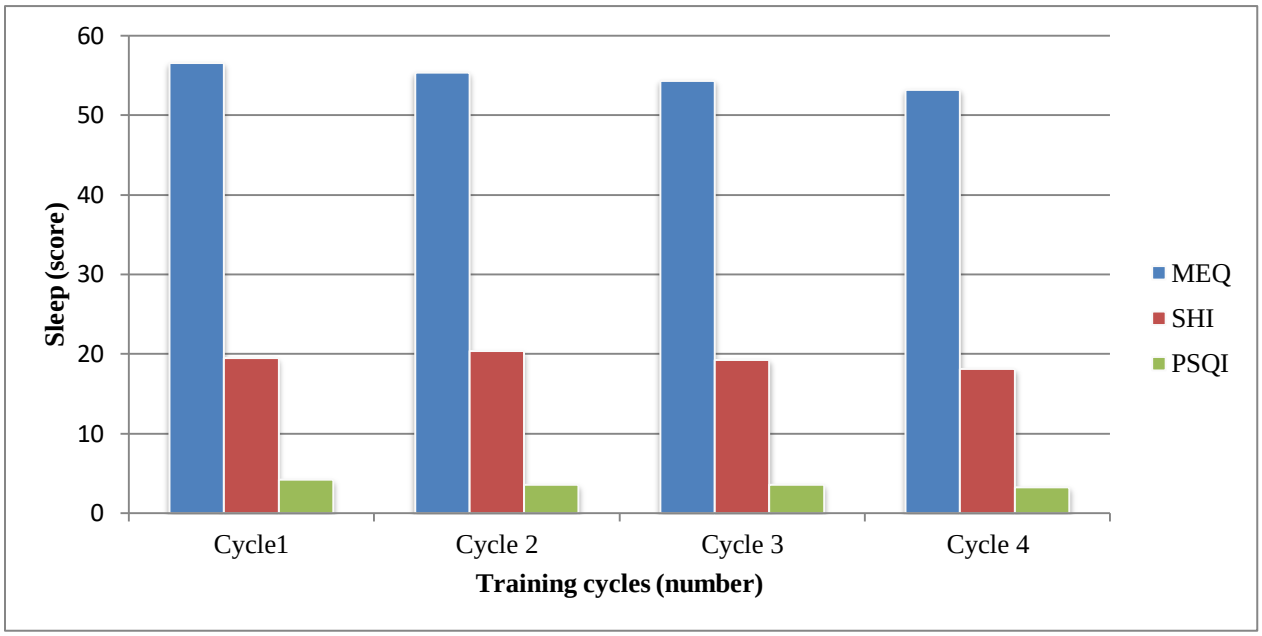


Figure 4.38: Combined sleep questionnaire scores throughout the duration of the study in swimmers (n=14; n=14; n=13).

A general summary of the sleep efficiency and questionnaires can be found in Figure 4.39.Figure 4.39 illustrates the combined average sleep questionnaire scores of the MEQ (n=14), SHI (n=14) and PSQI (n=13) and SD sleep efficiency (n=12) throughout the duration of the study. It can be observed that during cycle 2 the SHI was 20.35 with participants waking up feeling more refreshed. The highest sleep hygiene was found in cycle 4 with the lowest sleep quality being found in the same cycle. Overall the SD sleep efficiency feeling refreshed remained the highest compared to slightly refreshed and fatigued. The highest sleep efficiency was found in cycle 3. Therefore, the second highest sleep quality and sleep efficiency of feeling refreshed was found in cycle 3.

All data between PSQI and sleep efficiency (refreshed, slightly refreshed and fatigued) were significant (p=0.00, p=0.00; p=0.00) between cycles 1 and 4. The only positive correlation found was between the PSQI and fatigue (0.73). Positive Pearson's correlations were found between SHI and slightly refreshed sleep efficiency (0.52) and SHI and fatigue (0.11) between cycles 1

and 4. The last positive Pearson's correlation found was between MEQ and feeling fatigued (0.71) from the start to the end of the study.

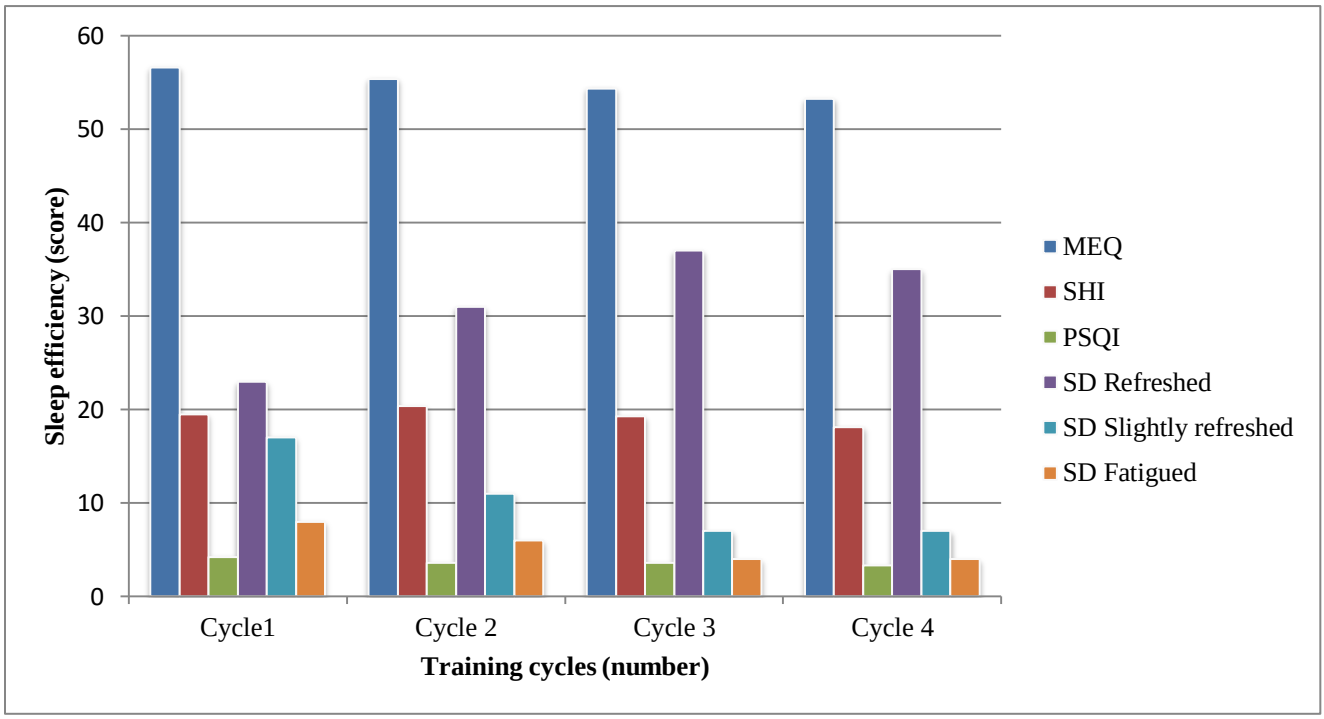


Figure 4.39: Combined swimmers sleep questionnaire scores and sleep diary sleep efficiency throughout the duration of the study (n=14; n=14; n=13; n=12).

CHAPTER 5: DISCUSSION

The topics that will be covered in this chapter include:

5.1 Introduction
5.2 Section A: discussion of baseline data of the pilot and main study
5.3 Section B: discussion per objective for the pilot and main study

5.1 Introduction

The primary purpose of this study was to determine the effect recovery has on a swimmer's overall performance. For this study recovery was defined as the return to the same or improved physical state prior to exercise (Cook and Beaven, 2013). The discussion that follows will address the effect training intensity has on sleep, mood and recovery in an elite swimming population and will be presented in two main sections. Section A will discuss the baseline demographic data and in section B the results per the objectives for the main and pilot study will be discussed. The dropout rates for the pilot and main study will be discussed per objective.

5.2 Section A: Baseline Data

i. Demographic information

In my study the mean chronological age of the participants in the pilot study was 16±2.78 years compared to the main study of 16±1.81 years of age. These ages coincide with international studies by Salguero *et al.* (2003), Toubekis *et al. (*2019) which have observed similar age populations. These findings are similar to a South African study conducted by Bosch (2008) which had participants between the ages of 13-22 years. The mean number of years participants were competing in swimming in the pilot study was 6.5±3.33 years compared to the main study of 6.7±2.71 years. The numbers of year's individuals have been competing was in agreement with studies by Kilen *et al*. (2014) and Toubekis *et al. (*2019). A study by Kilen and colleagues (2014) required swimmer's to have 5 years of swimming experience, and it was similarly found in a South African study by Bosch (2008).

In the pilot study, 62.5% of the participants were female. This is similar to the main study, where female participants comprised of 53.33% of the population size. These findings in both the pilot and main studies are in agreement with studies conducted in the United States of America (Gould *et al.*, 1982), Spain (Salguero *et al.*, 2003), Canada (Fraser-Thomas *et al*,. 2008a) and Greece (Toubekis *et al*., 2019) where the majority of the participants were female. However, this was not found in studies by Salguero *et al.* (2003), Morouço *et al.* (2011) and Sargent *et al.* (2012). Salguero *et al.* (2003) had 40 male and 22 female participants compared to Sargent *et al.* (2012) which had six male swimmer's compared to one female swimmer. Another study by Morouço *et al.* (2011) only had male participants. The South African study conducted by Bosch (2008) does not specify the gender of the participants in their research. Due to the demands of swimming participants and sample size, dropout rate was an important factor in this study.

ii. Dropout

Fraser-Thomas *et al.* (2008a) had a dropout of 10 individuals due to participants having demanding parents, a lack of swimming coaching and swimming peers, and lastly sibling competitiveness. A South African study by Bosch (2008) only had a dropout of 4 individuals with 1 participant being excluded because of irregular swimming attendance and the remaining 3 were excluded due to injuries. In my study similar findings for dropout were reported, with participants being excluded from the study due to demanding parents and irregular swimming attendance. Alternatively other reasons for dropout could be related to the demands from school and individuals not having enough time for academics, extracurricular activities and a research study and lastly, participants may have lost interest in the study.

Although the sample size is relatively small, the total number of participants was 8 and 15, at the end of the pilot and main study respectively; and this was a sample of convenience. The sample size in this study is similar to that in the literature (Bosch, 2008; Fraser-Thomas *et al.,* 2008a; Morouço *et al.,* 2011; Nogueira *et al., 2015*).

The pilot study started with 15 participants and ended with 8 participants. Compliance was poor in the pilot study with an adherence rate of 53.3%. These findings are not reported in the main study, with only 11.7% of individuals dropping out which was due to incomplete questionnaires and Fitbit© data. The dropout and poor compliance to collecting data was observed in the pilot

study, could be related to the demands placed on the individuals from school and participants may not have coped with the stress due to their age. In the pilot study individual's ages ranged between 13-21 years, however, the individuals that dropped out were between the ages of 16-19 years. This theory opposes Heydari *et al.* (2014), which found that younger athletes dropped out due to demands from education and work, instead of being age-related. Studies by Augustini and Trabal (1995), Molinero *et al.* (2009) and Reeves-Turner (2020) reported that one of the main reasons for individuals dropping out could be due to the demands from school. These findings are in agreement with Brown (1985) and Davy (2017) which found that individuals wanted to partake in other activities instead of swimming. Another possible reason for the dropout rate could be the individual's parents or guardians changed their mind on the participant taking part in the study, causing the individual to drop out of the study. This theory is confirmed by Brown (1985) and Baker (2003), due to the physical demands from swimming training and additional stress from the study, individuals could have wanted more free time. Similarly it was found by Salguero *et al.* (2003) and Reeves-Turner (2020) which found that individuals were not enjoying swimming and preferred to be more social.

A possible means to increase compliance would be to identify if individuals are an owl or a lark, identifying if an athlete is a morning or evening person. Within the main study, it was found that individuals had the highest MEQ score at the start of the study with 57.85 classifying them as larks. The pilot study reported a similar MEQ score of 58.25, also identifying the athletes as larks. This finding of athletes being classified as larks could provide an opportunity to improve performance and concurrently possibly improve compliance rates if individuals trained in the morning compared to the evening. These findings are corroborated by Samuels and James (2014) where an increase in morning training sessions and a decrease in the evening training sessions could improve sleep quality and performance. However, these contradict Anderson *et al.* (2018) who reported swimmers to be owls benefiting more from evening training sessions.

Attempts to improve compliance in the pilot study included meeting with interested individuals prior to the start of the study, explaining the requirements, expectations and providing participants with an information pack. This method to maintain participant compliance is similar to methods used by Hellard *et al.* (2001). In addition to this, a social media group was created to remind and follow up on participants to ensure that questionnaires and Fitbit data were recorded

and that the coach was reminding individuals and their parents to complete the questionnaires. The researcher manually captured participant's data once a week, to ensure no Fitbit data was missing. This was an attempt to decrease the pressure that the participants were experiencing with regards to school and training. A study conducted by Hellard *et al*. (2001) maintained participant compliance by arranging meetings and regularly updating participants on their progress.

The main reason for the pilot study was to identify how participant compliance could be improved and apply this to the main study to prevent poor compliance. The main study ended with a total of 15 participants instead of 17, this showed that participant adherence improved by 41.6% between the pilot and main study. Therefore, the improvement in the main study's participant compliance shows that the preventative methods taken in the pilot study were effective when applied to the main study.

5.3 Section B: Discussion per objective

1) To determine how the training regime influences sleep, mood, performance and recovery in swimmers, using the sleep diary, Fitbit, total quality recovery and profile of mood states questionnaires.

i. Calories versus training

In this study, training intensity was defined as energy expenditure in the form of total calories. In the main study, swimming calorie expenditure increased during the recovery week in two cycles. Possible reasons for the increase in swimming calorie expenditure could be a result of participants competing in galas during the recovery week or that individuals were participating in other activities other than swimming. Participants in the main study took part in other sports such as athletics and hockey. This is similar to findings by Brown (1985) and Salguero *et al.* (2003) which found swimmers also played other sports.

In the pilot study, it was found that total calorie expenditure during hard training weeks were lower in comparison to the recovery week. These findings agree with the main study. The increase in total calorie expenditure during the recovery week could be due to individuals participating in other sport. This theory is based on a previous study done by Brown (1985)

which found individuals took part in other activities in conjunction with swimming training. In general, it would be assumed that calorie expenditure would be higher during the hard training weeks compared to the recovery week.

During the recovery week, participants may have practiced other swim strokes to improve technique and time which requires more energy resulting in an increase in swim calorie expenditure. This theory corroborates the findings in two studies Karpovich and Millman (1944) and Barbosa *et al.*(2006) which found that each of the four swim strokes have different energy expenditures, with the freestyle stroke being the most economical followed by the breaststroke. In the pilot study, Ms. X swam three main strokes namely backstroke, fly stroke, and freestyle swimming stroke during training. During training in the main study two participants reported preferring the backstroke and freestyle stroke. The findings in the main study, however, oppose the swim calorie expenditure as it was found that participants swam the two economical swim strokes reported by Karpovich and Millman (1944) and Barbosa *et al.* (2006). However, when comparing Ms. X and Ms. Y competition swimming strokes it was found that Ms. X preferred to swim the back and breast stroke compared to Ms. Y who competed in the backstroke and freestyle swimming strokes. Once again Ms. Y used less calorie expenditure during these swimming strokes, therefore not correlating with the study done by Barbosa *et al.* (2006) regarding calorie expenditure. The second aspect that can be affected by training is sleep.

ii. Sleep versus training

Within the pilot study with an increase in the SD TST occurring between cycle 1 to 4 from 49% to 60% and the FB TST decreased during the study from 51% to 38% between cycles 1 to 4.The same findings were observed in the main study it was found that the manually recorded sleep diary total sleep time (SD TST) gradually increased by 33% from cycle 1 to 4, compared to the Fitbit total sleep time (FB TST) decreased by 33% from cycle 1 to 4. A possible reason for the decrease in the recorded FB TST may relate to participant compliance. At the start of the study participants were eager to complete all the required questionnaires, but as time lapsed individuals became stressed and possibly forgot to wear or charge the Fitbit device therefore sleep was not recorded. This theory is confirmed by studies (Augustini and Trabal, 1995; Molinero *et al.*, 2009; Reeves-Turner, 2020) which found that individuals dropped out due to school stress.

A possible reason for a significant link ($p<0.00$) found between the SHI and PSQI at the start of the study could be the relatively small sample size. When comparing the TST of the FB and SD, the SD TST was greater in both the pilot ($p<0.03$) and the main ($p<0.00$) studies. This increase in FB TST could be due to the FB sensor that records the individual's exact sleep time. However, two studies (de Zambotti et *al*., 2016; Lee *et al*., 2018) oppose this theory as the Fitbit is able to accurately measure TST. The study conducted by Lee *et al*. (2018) compared the effectiveness of different fitness devices to measured sleep in an adult sample and found that the Fitbit Charge HR fell within the mean TST recorded in the sleep diary, which opposes the theory that the Fitbit sensor does not accurately measure TST. While de Zambotti *et al.* (2016) reported the Fitbit Charge HR TST was within 30 minutes of the Polysomnography readings. Another theory is that participants did not complete the SD when they woke up or went to bed, leading to incorrect recording of information which can link to poor compliance. Overall, it is good to observe the difference between the subjective and objective sleep data, which could identify if participants were over-estimating their potential recovery and subsequent performance ability (Kellman, 2002). This is especially important when analysing the TQR sleep.

iii. *TQR sleep and training*

In both the pilot and main study, it was found that each sleep component (TST, 8h, 7-8h, 6-7h, and naps) of the TQR fluctuated during the study. The trends observed in the TQR were the same as the SD and FB TST in both the main and pilot studies. These fluctuations in sleep could possibly be a result of individual's demands from school or other commitments. There is no clear reasoning for the fluctuations in sleep aside from lifestyle. The modern lifestyle of individuals and poor sleep patterns are linked to technology (Calamaro *et al.,* 2009; Shochat *et al.,* 2010). The use of electronics before bed leads to later bedtimes and poor sleep hygiene (Van den Bulck, 2004; Calamaro *et al.,* 2009; Shochat *et al.,* 2010). Adolescent individuals consume caffeine to increase alertness and the caffeine contributes to disturbed sleep (Calamaro *et al.,* 2009). During exams, there is a change in the participants sleep patterns, which relate to the student lifestyle and can create circadian desynchrony (Shochat, 2012). In both the pilot and main studies, it was found that individuals had better sleep hygiene at the end of the study compared to the start of the study and in general individuals woke up feeling more refreshed. This may be due to the participants becoming aware of their sleep habits by completing the questionnaire during the

study. To improve sleep habits a study done by The National Sleep Foundation (2007) reported the use of nightlights in alternative rooms, background noise such as music should be low, and that room temperature was individualized. However, the study also found that colder environments may lead to lack of REM sleep. The National Sleep Foundation (2019) also reported that individuals regarded a quiet room, dark room, cool room temperature; fresh air and having a clean bedroom important elements for good sleep. Therefore, these factors can improve sleep hygiene and concurrently improve sleep quality. Despite an increase in sleep hygiene, a decline in sleep quality was found in both the pilot and main studies, which could relate to an accumulation of fatigue and sleep debt during the studies (Lastella *et al.,* 2014). Sleep can also be affected by an individual's mood.

The relationship between sleep and mood can cause emotional changes (The National Sleep Foundation, 2019). These emotional changes have been found to link to an individual's lifestyle relating to stress, anxiety, and depression, causing an increase in the time taken to fall asleep (No author, 2007). These findings were similar to Dinges and colleagues (1997) which found that individuals who had 4.5 hours of sleep for a week felt stressed, anger, sadness, and mental exhaustion. These studies show that mood and mental state can affect sleep (The National Sleep Foundation, 2019). Anxiety and stress increase body arousal and alertness which may lead to the development of sleep disorders (Nofzinger, 2005; The National Sleep Foundation, 2019). Sleep deprivation disorders such as insomnia and sleep apnea have been reported to cause depression and anxiety (Weissman *et al.,* 1997; Nofzinger, 2005; Necklmann *et al.,* 2007; Harvard Medical School, 2007). These studies show a relationship between lifestyle, sleep, and mood. However, an individual's mood can change according to training and competitions.

iv. Mood versus training

In the main study, no specific emotion increased per cycle, in all six (anger, tension, fatigue, depression, vigor, and confusion) emotions measured by the POMS questionnaire, instead the emotions fluctuated during the study. This however, was not found in the pilot study, where anger gradually increased during the study. Anger could be related to various situations that a participant experienced possibly from frustrations in lifestyle or swimming performance. These findings can relate to a study conducted by Vacher *et al.* (2017) where it was found that swimmers may experience negative emotions during more demanding training periods. Similar

findings were found by Hamilton (2019), except athletes used negative emotions – anxiety, irritability and tension to improve performance. However, studies have found (Lazarus, 2000a; Lazarus, 2000b; Woodman *et al*., 2009) that anger can aid athletic performance if the sport requires a physical aggressive action, but it may also distract the athlete and negatively impact performance (Lazarus, 2000a; Lazarus, 2000b; Woodman *et al.*, 2009). These findings oppose a study conducted by Ruiz and Hanin (2011) which reported in physical contact sport such as karate, anger increased during competitions and facilitated the athlete's performance. These athletes used anger to positively affect performance by using coping skills (Ruiz and Hanin, 2011). For athletes to cope with emotions specifically anger and prevent it from negatively impacting performance, individuals need to implement a pre-performance routine (Baxter, 2017). This routine mainly comprises of positive self-talk enabling individuals to calm the mind, body and emotions to improve focus and re-focusing on what is controllable by drawing attention to elements that can improve performance (Baxter, 2017). In addition to the POMS questionnaire, participants completed the mood aspect of the sleep diary.

The individuals SD mood of the pilot and main study remained pleasant except at the start of the study. This could possibly be from the training regimen the participants were following during the first cycle, which was classified as hard. This theory is supported by Vacher and colleagues (2017) which found that negative moods were associated with intense training. The last factor that could be affected by training is the total TQR recovery score.

v. Recovery (TQR) versus training

In the pilot study a gradual decline in each TQR component namely: hydration, sleep and rest, relaxation and emotional status and active cool-down was observed. This was not found in the main study; instead each TQR component fluctuated during the four training cycles.

The only component that remained relatively steady in the pilot study was water consumption. The TQR questionnaire may have prompted participants to become aware of their hydration status, as individuals were required to record their urine color prior and post-exercise. A study by Burke and Mujika (2014) found that an increase in water consumption had a positive effect on recovery in individuals. In comparison to active cool-down remaining steady during the main study, the steady results could be from forms being incorrectly completed resulting in

components being omitted. However, the consistent active cool-down of participants in the main study could relate to an improved recovery, as active cool-down has been found to increase blood flow to the muscles and skin, (Eyjenth *et al.*, 1985; Bangsbo *et al.,* 1985; Journeay *et al.*, 1985; Mizumura and Taguchi, 2016; Van Hooren and Peake, 2018) and improve an athlete's performance (Ali *et al.,* 2012). Similarly this was reported by Van Hooren and Peake (2018) which found that active recovery improved an athlete's performance the subsequent day and aided in long-term adaptations. Other sport disciples such as runners and soccer players (Takahashi *et al.,* 2006; Rey *et al.,* 2012) have a demanding training program like swimmers. It was found that an active cool-down benefited soccer player's countermovement jump performance a day later after training (Rey *et al.,* 2012) and water-based active cool-down improved performance in downhill long-distance runners (Takahashi *et al.,* 2006) - therefore, these studies coincide with the theory that active recovery is an essential part of a swimmers recovery and should form part of the training programme.

2) To determine how mood can affect a swimmer's performance during competitions, using the profile of mood states and sports emotional questionnaires.

In the pilot case study where Ms. X performance times improved during the cycles and swimming training. There was an improvement by 4.59 seconds in Ms. X's performance time for the freestyle stroke, with a positive correlation (0.99) being found, however this improvement in performance was not significant ($p=0.50$). These findings were consistent with the main study, it was reported that performance times from the start to the end of the study improved between 0.88 to 2.63 seconds in the breast and freestyle swimming strokes among four swimmers. Additionally, during monthly performance tests of two swimmers; the performance times in the first participants backstroke improved by 1.25 seconds, and in the second individual freestyle times decreased by 1.4 seconds. These findings in both the main and pilot studies suggest that the swimmers' training regime of both land and water-based training improved the stroke time amongst all swimmers. This theory corroborates the literature of (Girold *et al*., 2007; Aspenes *et al*., 2009; Garrido *et al.,* 2010) where a combination of water and land-based training improved

swimmers performance in a 50 metre (Girold *et al*., 2007) and 400 metre (Aspenes *et al*., 2009) races and overall freestyle swimming times (Garrido *et al.*, 2010).

During competitions, Ms. X improved in both of the competitive strokes over a 200-metre race. During the individual medley (IM) it was found that her time improved by 9.73 seconds from 2.51.00 to 2.41.27 minutes. The above findings correspond with Ms. Y that competed in two galas during the main study. Pyne *et al.* (2004) had similar results, wherein swimmers improved their performance by 1% during competitions, showing a positive Pearson's correlation. However, this was only observed in the 200 metre freestyle race, with the time improving by 0.04 seconds compared to the 100 metre freestyle which had an increase of 0.2 second, and lastly the 200 metre backstroke, which had a 6 seconds increase from the winter to CGA senior gala. The increase in time for the 100 metre freestyle and 200 metre backstroke could possibly be attributed to the galas having a one week interval, preventing the individual from properly recovering and suffering from fatigue. This is confirmed by Jones (2007) in which overtraining was found to prevent a swimmer from attaining maximum performance. It is suggested by the researcher that resting heart rate (RHR) during training could also be affected.

The average RHR during the main study was 63.43 beats per minute (bpm), with the highest RHR of 64.04 bpm being observed within cycle 2 of the training regime. The higher RHR during cycle 2 can be a result of the hard training regime. These results show that when the training intensity is harder the RHR will be elevated. However, it was also found that the RHR progressively decreased as the study progressed. This could be due to the undulating training regime and participants developing adaptations. The theory can be confirmed by Al-Ani and colleagues (1996b) which found RHR decreased as training intensity decreased. The final factor that was found to influence competitions was mood.

In the main study's case study when comparing mood pre, intra and post-competition, an increase in the pre-competition mood and a decrease in the post-competition mood for both the winter and CGA senior galas could be observed. These results are also confirmed with findings in the pilot case study. A study conducted by Berger *et al.* (1997) explains that mood can affect an athlete's performance during competition.

Within the pilot study, which reported a 50% elevation in intra-competition mood score compared to 37.5% being below the pre-competition score. This is in agreement with the main study, 60% of participants presented with an increased intra-competition mood score compared to 40% being below the pre-competition score. It was observed that post-competition mood score decreased by 80% after competitions. The findings from both the pilot and main study illustrate the individual's intra-competition mood was higher during races. Improvements in performance times for both Ms. Y and Ms. X were observed when participants experienced more stress. A positive relationship was found between mood and performance as seen in studies conducted by Verger *et al.* (1997) and Hamilton (2019). Anxiety in the pilot study could have motivated Ms. X during the competition to swim faster and obtain a record time. However, this theory does not agree with a study done by Swain (2011) which reported that poor performance was directly related to a negative mood in comparison to a positive mood with improved performance times. This finding is opposed by Hamilton (2019) which found that experienced athletes utilise negative emotions to perform at their maximum, forming part of their coping mechanism when it comes to competitions. Therefore in conclusion, athletes of all levels should try to use negative emotions such as anxiety and tension experienced during competitions in a positive manner to improve performance.

3) To determine if a relationship exists between sleep quantity, a swimmer's performance and recovery, using performance testing and sleep questionnaires.

i. Sleep efficiency

The main study findings are that when waking up the participants felt more refreshed between cycles 1 to 3 by 57%, and there was a decrease of 37% in cycle 4. The initial increase in feeling refreshed was similar to findings in the pilot study, except a gradual increase was observed during the study. This could relate to an individual's recovery improving due to participants obtaining more sleep, especially in the pilot study. However, this theory opposes the SD TST, which fluctuated during the pilot study in comparison to FB TST which gradually decreased during the study. If more sleep was obtained it may account for the decrease in the fatigue and increase in individuals waking up feeling refreshed in the pilot study. This theory correlates with

a study done by Halson (2013) which found that individuals require approximately 8 hours of sleep per night. However, the observations in the pilot study do not correspond to the main study, where individuals obtained less sleep during cycles 1 to 2 but woke up feeling refreshed. These findings could possibly be due to swimmers obtaining proper sleep quality in the main study. Samuels and Alexander (2013) reported that if proper sleep quality is attained individuals wake up feeling refreshed, coinciding with this study. Aside from the SD sleep efficiency, total sleep time is another factor that should be considered when analysing sleep.

When comparing the TST for the FB and SD, it was found that the SD TST was greater compared to the FB TST in the main study. The same findings were reported in the pilot study with the SD TST being greater. The possible difference in recording of TST could be due to participants not remembering their bedtimes resulting in human error compared to the FB, which utilises a sensor that is capable of recording the individual's exact total sleep time (Fitbit, 2010). It is important to note the difference between the subjective and objective data as this relates to the accuracy of the subjective TQR score (Kellman, 2002), resulting in the participants, in the pilot study, over-estimating their potential recovery and subsequent performance ability (Kellman, 2002). The National Sleep Foundation (2019) reported that teenage athletes who are aiming to reach peak performance should sleep for a minimum of 10 hours per night compared to young athletes between the ages of 6 to 13 years who require 10 to 12 hours of sleep per night. Sleep quality and sleep hygiene are important aspects in a swimmer's recovery.

The pilot study's SHI scores decreased between cycles 2 and 4 by 3.71 points. Similar findings were found in the main study with a decrease of 2.21 points observed between cycles 2 and 4. This could show that participants improved their sleep hygiene during the study, due to participant's completing the questionnaire they became more aware of their sleep habits. The PSQI score decreased by 78.01% during the main study and 25% of the participants had a score of ≥5, compared to the pilot study where 83.33 % of the participants had a decrease in their PSQI scores (PSQI scores of ≥5) from the start to the end of the study. This suggests an overall decline in the sleep quality of the swimmers in both the pilot and main studies. It is suggested that an accumulation of fatigue and sleep debt, between the start and end of the study as training volume and intensity increased (Lastella *et al.*,2014), could be the reason. It was also found that the total TQR increased during both the pilot and main studies. This increase could also be due to

participant's completing the TQR questionnaire and trying to improve recovery during the pilot and main studies. This shows when the TQR increases the sleep quality decreases. The reduced sleep quality may be due to negative effects from performance which was found in studies conducted by Samuels and James (2014) and Harris *et al.* (2015). It can therefore be concluded that sleep quality and sleep efficiency are important for recovery and performance.

CHAPTER 6: CONCLUSIONS, STRENGTHS AND LIMITATIONS AND RECOMMENDATIONS

The topics that will be covered in this chapter include:

6.1 Conclusion
6.2 Limitations of study
6.3 Strengths of the study
6.4 Recommendations
6.5 Take home message

6.1 Conclusion

Recovery has been shown to directly influence performance (Chalencon *et al.,* 2012). Recovery in this study comprised of the five components of the TQR (Kenttä, and Hassmén, 1998) which were studied separately. Due to the limited amount of research available on sleep quality and sleep quantity in a South African swimming population, this study helped fill the gap in the literature. The current study showed how sleep quantity affected recovery in swimmers' of different ages, where it was found that younger swimmers' who slept longer had a higher TQR recovery score; showing that sleep quantity had a direct effect on a swimmer's recovery. Another aspect of this study that affected recovery was sleep quality, this was studied using the PSQI and SHI questionnaires. These questionnaires encouraged participants to become aware of sleep habits and indirectly improve sleep hygiene practices such as developing a sleep routine and becoming aware of the use of electronics before bedtime. A strong assumption can be made that sleep factors can link to performance through recovery. Recovery and training intensity was found to directly influence each other (Tee, 2009). Sleep quality variables were found to be inversely proportional to recovery (Tee, 2009). In conclusion, this study could effectively correlate aspects of sleep quality and quantity to recovery. The last factor that was studied and found to affect a South African swimmer's performance and recovery indirectly was mood. A positive mood state pre and during training and competitions had a direct influence on the swimmers' performance, improving an individual's times (Lundgvist and Kentta, 2010; Swain, 2011). Therefore, it can be concluded from this study that a swimmer's mood directly influences performance and indirectly affects recovery. Overall younger swimmers require better sleep

quality and more hours of sleep to properly recover from training and to prevent a negative mood state that can affect their performance during training and competitions.

6.2 Limitations of the study

The limitations within the pilot study included:

- A small sample size of 8 participants due to poor compliance and drop out, the training regime of the participants did not have any variation except with an increase in the number of sets or distance swam per week which fluctuated according to a "hard or easy" training week.
- The inability of the FB Flex 2 device to be worn during water-based training resulting in a gap within the swimming data along with the coach not performing weekly performance tests and lastly, the device was unable to record RHR resulting in missing performance data.

These limitations in the pilot study lead to the following changes in the main study:

- A larger sample size of 15 participants trained by the same coach
- The land and water-based training program varied between days and weeks and weekly performance tests were conducted by coach.
- The use of the Fitbit Inspire HR in the main study which measured RHR and enabled the participants to do water-based training wearing Fitbit filling the gap within the data that was not obtained in the pilot study.

However, aside from the above main study changes overall the research study had the following limitations:

- There are two limitations as different aged swimmers may have various galas that span across the year which may not coincide with the mesocycle training at the swimming club and within the South African population, individuals utilise various recovery methods and these methods may not be consistent.
- Due to the reduced sample size one has to be cautious in the interpretation of data and extrapolation to larger groups.

- The participants had some confusion with the relaxation and emotional support category of the TQR. Instead of filling in each row separately, individuals chose to fill in both sub-categories (full relaxation and psychosocial stress) as one subcategory. Participants were however consistent throughout the study allowing the data to still be utilised and compared.
- The current TQR model does not account for multiple training sessions or other sporting activities participated in one day. This is problematic as the swimmers were sometimes completing two training sessions a day.

6.3 Strengths of the study

- The study filled a knowledge gap within a South African swimming population by focusing on recovery in swimming, and sleep quality and quantity and its fundamental role in a swimmers' recovery. The study covers the five aspects of recovery by making use of the TQR and to the knowledge of the researcher; no other study has presented each component of the TQR separately.
- The use of the monthly sleep quality questionnaires encouraged participants to improve sleep hygiene.
- The study also indirectly tested two different Fitbit devices and their ability to record data over the duration of a 16 week period.
- The use of the wellness questionnaire aided the researcher to interpret the weekly POMS scores and gain an understanding of the participant's lifestyle and stress throughout the duration of the study.
- The study was performed at two different sites enabling the researcher to obtain more insight into the different land and water-based training regimes and understand how a coaches training programme can differ and affect an athlete's performance.

6.4 Recommendations

- Future studies should use current validated wearable devices that measure the required outcome parameter.
- Athletes need to be aware of the importance of sleep quality and develop correct sleep hygiene habits to ensure that they obtain good quality sleep. Additional to this, proper

sleep quality and quantity can prevent athletes from experiencing negative emotions such as stress, tension and anger which may hinder their performance during training and competitions.

- Future research could focus on the effect hormonal change could have on the performance and recovery of female swimmers during the menstrual cycle. Hormone changes during the female cycle could possibly directly affect performance times and maybe increase recovery time.

6.5 Take home message

1) Sleep quality and quantity are essential to proper recovery from training.
2) To obtain proper sleep and athletic performance individuals should apply proper sleep hygiene practices such as having a sleep routine, limited use of electronics and no consumption of caffeine before bed, having a comfortable bed and a dark room.
3) Mood has an effect on an individual's performance both within training and competition settings and can be regulated by athletes using coping skills to control emotions such as positive self-talk to calm the mind, body and emotions and re-focus to identify controllable factors in training and competition to improve performance.
4) Younger athletes between the ages of 14-17 years required more sleep to recover from training compared to older swimmers between the ages of 18-24 years.

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Appendix A: Participant/Parental Information Sheet

The University of the Witwatersrand
Faculty of Health Sciences
School of Therapeutic Sciences
7 York Road
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Johannesburg
2193

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

PARTICIPANT/PARENTAL INFORMATION SHEET

Study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers

Principal investigator: Shandré Pretorius

HREC Number: M180279

1. Introduction

Thank you for your interest to take part in this study.

You are invited to take part in this study because you compete at a national swimming level and thus qualify for the classification of elite swimmer. The purpose of the study is to analyse recovery in swimmers and its relation to performance using the Total Quality Recovery questionnaire, Sleep Quality questionnaires and mood state questionnaires.

The Participant Information Sheet will explain everything about the study to you and what the research team would be expecting from you during the course of the study. It outlines all the procedures and also explains the risks involved. Knowing what the study involves will help you to make an informed decision regarding your participation in the study.

Please read all the information outlined below carefully and ask questions about anything that is unclear, that you do not understand or want to know more about.
Participation in this study is entirely voluntary. If you don't wish to take part, you don't have to. If you decide you want to take part in this study, you will be asked to sign the Participant Consent Form. By signing it, you are telling us that you:

- Understand what you have read;
- Consent to take part in the study;

- Consent to participate in the research processes that are described;
- Consent to the use of your personal and health information as described.

You will be given a copy of the Participant Information Sheet and the Participant Consent Form to keep.

2. What is the purpose of this study?

Swimming performance is largely influenced by recovery. There is limited research available on recovery in swimmers. However there is adequate background on the effects of nutrition, hydration, sleep and rest, relaxation, and cooldown, on performance. The TQR in combination with sleep analyses will provide a new angle to analyse recovery at an individual level, and could form a valid basis on which to monitor recovery in elite swimmers in the future.

3. What does participation in this study involve?

Participating in this study involves the filling in of questionnaires for the duration of the study. Additionally performance tests will be conducted weekly. These tests will be integrated into your training routine as prescribed by your coach. This research will not interfere with the training schedule set out by your coach. This study will last the duration of 12 weeks.

Initially an education session will be held to explain and describe the study, and to allow you time to ask questions. Following this you will be given booklets with all the questionnaires you are required to complete. These questionnaires are simple and will take around 5 minutes to complete each. The TQR will need to be filled in daily at the end of the day, and the sleep diary will need to be filled in daily straight after waking up. The remainder of the questionnaires will be completed at the beginning and end of the study.

As part of the TQR questionnaire you will be given a urine colour chart. This is to assess hydration. You will be required to identify the colour of your urine once before and after your training session. For consistency the colour chart will allow you to identify the urine colour as close as possible.

The performance measures to be conducted are the 100 metre test. These measures will be performed prior to the training session on Fridays.

Lastly all participants will wear a Fitbit watch. This is to identify when you are awake and when you are at rest. Heart rate measures can also be taken. The Fitbits will be signed out at the beginning of the study and will need to be signed back in at the end of the study. The watches are to be worn at all times including during swimming, bathing, or showering.

All meetings and performance tests will be held at the Mandeville Dolphins Swimming Club or Waterborne Swimming Club.

4. Exclusion Criteria

- The participant will be excluded if he/she is below the age of 16 years old.
- The participant will be excluded if they are not currently competing at a national level.
- A current musculoskeletal injury like a muscle strain or tendinopathies, which can hinder swimming participation and performance.
- Any known heart related problems and metabolic diseases will exclude the participant from the study.
- Individuals who have colour blindness, this can influence the correct analysis of urine samples for the total quality recovery questionnaire.

.

5. What are the possible risks associated with participating in the study?

There are no significant risks associated with any of the questionnaires. There is a risk of injury to the swimmers with the training programme prescribed by the coach; however this would not be due to the study.

6. What are the possible benefits of this study?

We cannot guarantee or promise that you will receive any benefits from this study. We do, however, believe that this study provides appropriate testing and analysis that will allow the athlete to reflect on their recovery and sleep strategies. We also believe that further research in the field of recovery in swimmers will benefit the scientific and medical communities.

7. Do I have to take part in this study?

Participation in any research project is voluntary. If you do not wish to take part, you do not have to. If you decide to take part and later change your mind, you are free to withdraw from the study at any stage, without penalty or loss of benefits.

8. What if I withdraw from this study?

If you decide to leave the study, the researchers would like to keep the personal and health information about you that has been collected. This is to help them make sure that the results of

the research can be measured properly. If you do not want them to do this, please tell them when you withdraw from the research project.

9. How will I be informed of the results of this study?

If you would like to know the results of this study, please tick the box provided on the consent form and we will be happy to send you a letter explaining our overall findings. We anticipate that the group results of this research will be published in scientific journals and presented at scientific conferences.

10. What will happen to information about me?

Any information obtained for the purpose of this study that can identify you will be treated as confidential and securely stored. All personal information that can identify you will be stored in a locked area by the investigators, and will be kept under safe storage indefinitely after completion of the project. All data and personal information will be stored on password-protected computers at the University of the Witwatersrand, and will only be accessible to members of the research team. Your information will only be disclosed with your permission, except as required by law.

All questionnaires will be labeled with a numerical code and will not contain information that can identify you as a participant. The overall results will have to be reported to the Human Ethics Committee of the University of the Witwatersrand and Medical Research Council of South Africa. It may also be shared among the scientific collaborations of the investigators, and may be published in scientific journals or presented at scientific conferences. In any reporting, publication and/or presentation, information will be provided in such a way that you cannot be identified.

11. Is this study approved?

This study is to be submitted for clearance to the Human Research Ethics Committee of the University of the Witwatersrand.

12. Contact details

If you want any further information regarding this study or if you have any problems, which may be related to your involvement in the study, you can contact the researchers or the Human Research Ethics Committee of the University of the Witwatersrand.

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Appendix B: Biographical questionnaire

The University of the Witwatersrand
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7 York Road
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UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

BIOGRAPHICAL QUESTIONNAIRE

Please take the time to answer these questions thoroughly and honestly

Thank you

Name and Surname: ……

Sex:
- ❒Male
- ❒Female
- ❒Other

Date of birth: ……

Age: ……

Country of birth: ……

Home language: ……

Other spoken languages: ……

Ethnicity:
- ❒ Caucasian
- ❒ African
- ❒ Other
- ❒ Indian
- ❒ Coloured

Marital status:
- ❒ Married
- ❒ Engaged
- ❒ Single
- ❒ In a relationship
- ❒ Separated

Handedness:
- ❒ Left
- ❒ Right
- ❒ Ambidextrous

Would you like a summary of the findings when the research is completed? ❒ Yes
❒ No

1. Employment

What is your current employment status? (Tick as many as appropriate)

❒ Employed full time
❒ Employed part time
❒ Casual employment
❒ Unemployed
❒Home duties
❒ Student
❒ Retired
❒ Disability pension
❒ Multiple
❒ Other

What is your main area of employment?

……..……

Have you ever been diagnosed with a chronic or acute psychiatric disorder? (this includes depression and anxiety)

❒ No (skip this section)
❒ Yes (continue with section)

Please give details of the diagnosis:

……..……

What is the history of the condition? (e.g., when you were first diagnosed, how long you have had/had the problem, etc)

……..……

2. Have you ever had a seizure or been diagnosed with any form of epilepsy? Think back to your childhood/infant years or ask a relative if you cannot remember.

❒ No (skip this section)
❒ Yes (continue with section)

Please describe the seizure or diagnosis:

……..…….

What is the history of the condition? (e.g., when you were first diagnosed, how long you have had/had the problem, etc)

……

3. Do you suffer from high blood pressure?

❒ No (skip this section) ❒ Yes (continue with section)

What is the history of the condition? (e.g., when you were first diagnosed, how long you have had/had the problem, etc)

……

4. Have you ever been diagnosed with an acute or chronic heart condition?

❒ No (skip this section) ❒ Yes (continue with section)

Please describe the diagnosis:

……

What is the history of the condition? (e.g., when you were first diagnosed, how long you have had/had the problem, etc)

……

5. Do you have a family history of heart disease?

❒ No (skip this section) ❒ Yes (continue with section)

Who in your family has/had the condition (e.g. parent/sibling/grandparent etc.)?

……

Please describe their condition and indicate whether or not they died as a result of it.

……

6. Have you ever experienced a stroke?

❒ No (skip this section) ❒ Yes (continue with section)

Please describe when it occurred and the cause, if known:

……..……..……

7. Do you suffer from or have you ever been diagnosed with a sleeping disorder?

❒ No (skip this section) ❒ Yes (continue with section)

Please describe the diagnosis:

……..……..……

8. How many hours of sleep do you get on average per night? ……..

9. Have you ever had or currently have chronic pain?

❒ No (skip this section) ❒ Yes (continue with section)

❒ Current (continue with section) ❒ Past (skip this section)

On a scale of 1–10, 10 being the most extreme, how would you rate this pain in the past week? (please circle one)

1 2 3 4 5 6 7 8 9 10

Please give details of the pain and the cause, if known:

……..……..……

How long does the pain last and is it persistent or does it fluctuate?

……..……..……

10. Do you have any other medical conditions?

❒ No (skip this section) ❒ Yes (continue with section)

Please list these condition/s:

……..……..……

What is the history of these condition/s? (e.g., when you were first diagnosed, how long you have had the problem, etc.)

……..……..……

11. Are you currently undergoing any major or minor medical treatment/s?

❒ No (skip this section) ❒ Yes (continue with section)

Please list this treatment/s:

……..……..……

……..……..……

Please provide a history of the treatment/s (e.g. when did the treatment occur, duration of treatment, reason for treatment etc.)

……..……..……

……..……..……

Do you have a history of being in hospital? What was it for? / When did this occur?

……..……..……

……..……..……

12. Do you currently smoke?

❒ No (skip this section) ❒ Yes (continue with section)

Number of cigarettes a day:

❒ Nil

❒ 1-10 per day

❒ 11-20 per day

❒ 20 +

How long have you been smoking for?

……..……..……

13. Alcohol Consumption

How often do you drink alcohol and how much do you consume?

❒ Don't drink

❒ Drink occasionally (less than once a week)

❒ Drink only on weekends – moderate use

❒ Drink only on weekends – uncontrolled

❒ Drink every day in moderate amounts

❒ Drink every day and sometimes get drunk

❒ Drink to intoxication (excess) every day

❒ Other

When was your last drink? How much did you drink?

……..……..……

14. Head Injury

Have you ever suffered a head injury?

❒ Yes
❒ No
❒ Unsure

If you HAVE had a head injury, did you lose consciousness?

❒ Yes
❒ No
❒ Unsure

If you HAVE had a head injury, were you unconscious for longer than 5 minutes?

❒ Yes
❒ No
❒ Unsure

If you HAVE had a head injury, did you have to go to hospital?

❒ Yes
❒ No
❒ Unsure

15. Are you currently taking any <u>prescribed</u> medication(s)?

❒ No (skip this section) ❒ Yes (continue with section)

Medication name	Medication purpose	Last date taken	Dosage and Frequency	How long have you been taking them?

16. Do you take any <u>non-prescription</u> medication(s) (e.g. over the counter medication, herbal remedies etc.)?

❒ No (skip this section) ❒ Yes (continue with section)

Medication name	Medication purpose	Last date taken	Dosage and Frequency	How long have you been taking them?

17. Do you use any <u>recreational</u> drugs (legal or illegal)?

❒ No (skip this section) ❒ Yes (continue with section)

Substance name	Substance purpose	Last date taken	Dosage and Frequency	How long have you been taking the substance?

Appendix C: Total Quality Recovery

TQR questionnaire

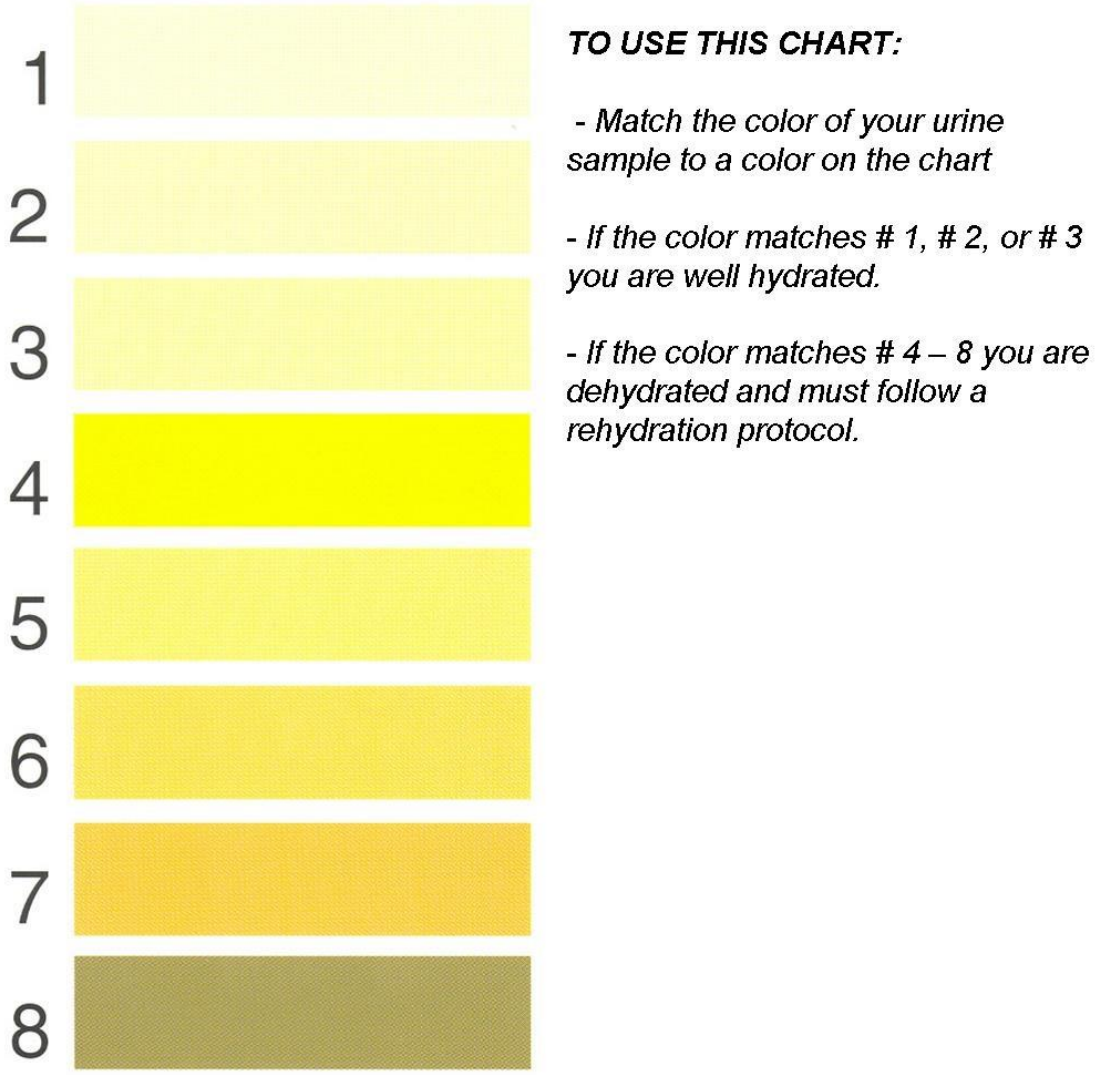
Please tick the applicable column

Adapted from Kentta and Hassmen 1999 train smart: Avoid Overtraining Syndrome, Stockholm: SISU Idrottsbocker

Factors relating to Recovery		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Attended swimming training sessions	Morning							
	Afternoon							
Participated in other physical activity								
Nutrition								
-Breakfast	Full							
	Less than full							
	None							
-Lunch	Full							
	Less than full							
	None							
-Dinner	Full							
	Less than full							
	None							
Pre-workout snack								
Post exercise refuelling within 60 minutes								
Hydration								
Pre-exercise urine:	Clear or light colour							
	Darker colour							
Post-exercise urine	Clear or light colour							
	Darker colour							
Water consumption- how many glasses of water have you consumed?								
Sleep and Rest								
8 hours of restful sleep								
7-<8 hours of restful sleep								
6-<7 hours of restful sleep								
Relaxation and emotional status								
Fully relaxed 60min post exercise 30 min of fear up time post exercise								
No psycho-social stress								
Mild stress								
Marked stress								
Cool down								
Adequate active cooldown								
Partial active cooldown								
10 min of stretching post exercise								

Appendix D: Urine colour chart

Urine colour chart



Ting, T. (2017). *The Hydration Guide*.NUTRITIONALISMO. [Accessed 20 Mar. 2017] Available at: https://nutritionalismo.com/2016/02/10/the-hydration-guide/

Appendix E: Profile of Mood States

Profile of Mood States

Participant name: Participant number:

Directions: Describe HOW YOU FEEL RIGHT NOW by circling the most appropriate number after each of the words listed below:

	Not at all	A little	Moderately	Quite a bit	Extremely
Friendly	0	1	2	3	4
Tense	0	1	2	3	4
Angry	0	1	2	3	4
Worn out	0	1	2	3	4
Unhappy	0	1	2	3	4
Clear-headed	0	1	2	3	4
Lively	0	1	2	3	4
Confused	0	1	2	3	4
Sorry for things done	0	1	2	3	4
Shaky	0	1	2	3	4
Listless	0	1	2	3	4
Peeved	0	1	2	3	4
Considerate	0	1	2	3	4
Sad	0	1	2	3	4
Active	0	1	2	3	4
On edge	0	1	2	3	4
Grouchy	0	1	2	3	4
Blue	0	1	2	3	4
Energetic	0	1	2	3	4
Panicky	0	1	2	3	4

Hopeless	0	1	2	3	4
Relaxed	0	1	2	3	4
Unworthy	0	1	2	3	4
Spiteful	0	1	2	3	4
Sympathetic	0	1	2	3	4
Uneasy	0	1	2	3	4
Restless	0	1	2	3	4
Unable to	0	1	2	3	4
Fatigued	0	1	2	3	4
Helpful	0	1	2	3	4
Annoyed	0	1	2	3	4
Discouraged	0	1	2	3	4
Resentful	0	1	2	3	4
Nervous	0	1	2	3	4
Lonely	0	1	2	3	4
Miserable	0	1	2	3	4
Muddled	0	1	2	3	4
Cheerful	0	1	2	3	4
Bitter	0	1	2	3	4
Exhausted	0	1	2	3	4
Anxious	0	1	2	3	4
Ready to fight	0	1	2	3	4
Good-natured	0	1	2	3	4
Gloomy	0	1	2	3	4
Desperate	0	1	2	3	4
Sluggish	0	1	2	3	4
Rebellious	0	1	2	3	4

Helpless	0	1	2	3	4
Weary	0	1	2	3	4
Bewildered	0	1	2	3	4
Alert	0	1	2	3	4
Deceived	0	1	2	3	4
Furious	0	1	2	3	4
Efficient	0	1	2	3	4
Trusting	0	1	2	3	4
Full of pep	0	1	2	3	4
Bad tempered	0	1	2	3	4
Worthless	0	1	2	3	4
Forgetful	0	1	2	3	4
Carefree	0	1	2	3	4
Terrified	0	1	2	3	4
Guilty	0	1	2	3	4
Vigorous	0	1	2	3	4
Uncertain about things	0	1	2	3	4
Bushed	0	1	2	3	4

Appendix F: Sports Emotional Questionnaire

SPORT EMOTION QUESTIONNAIRE

Below you will find a list of words that describe a range of feelings that sport performers may experience. Please read each one carefully and indicate on the scale next to each item how you feel **right now, at this moment, in relation to the *upcoming* competition**. There is no right or wrong answers. Do not spend too much time on any one item, but choose the answer which best describes your feelings right now in relation to the upcoming competition.

	Not at all	A little	Moderately	Quite a bit	Extremely
Uneasy	0	1	2	3	4
Upset	0	1	2	3	4
Exhilarated	0	1	2	3	4
Irritated	0	1	2	3	4
Pleased	0	1	2	3	4
Tense	0	1	2	3	4
Sad	0	1	2	3	4
Excited	0	1	2	3	4
Furious	0	1	2	3	4
Joyful	0	1	2	3	4
Nervous	0	1	2	3	4
Unhappy	0	1	2	3	4
Enthusiastic	0	1	2	3	4
Annoyed	0	1	2	3	4
Cheerful	0	1	2	3	4
Apprehensive	0	1	2	3	4
Disappointed	0	1	2	3	4
Angry	0	1	2	3	4
Energetic	0	1	2	3	4
Happy	0	1	2	3	4

Anxious	0	1	2	3	4
Dejected	0	1	2	3	4

PITTSBURGH SLEEP QUALITY INDEX (PSQI)

INSTRUCTIONS: The following questions relate to your usual sleep habits during the pas
Your answers should indicate the most accurate reply for the majority o
nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?
   USUAL BED TIME _____

2. During the past month, how long (in minutes) has it usually take you to fall asleep each nig
   NUMBER OF MINUTES _____

3. During the past month, when have you usually gotten up in the morning?
   USUAL GETTING UP TIME _____

4. During the past month, how many hours of actual sleep did you get at night? (This may be
   number of hours you spend in bed.)
   HOURS OF SLEEP PER NIGHT _____

INSTRUCTIONS: For each of the remaining questions, check the one best response.
Please answer all questions.

5. During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week
(a) ...cannot get to sleep within 30 minutes	☐	☐	☐
(b) ...wake up in the middle of the night or early morning	☐	☐	☐
(c) ...have to get up to use the bathroom	☐	☐	☐
(d ...cannot breathe comfortably	☐	☐	☐
(e) ...cough or snore loudly	☐	☐	☐
(f) ...feel too cold	☐	☐	☐
(g) ...feel too hot	☐	☐	☐
(h) ...had bad dreams	☐	☐	☐
(i) ...have pain	☐	☐	☐

(j) Other reason(s), please describe

_____

_____

How often during the past month have you had trouble sleeping because of this?	☐	☐	☐

	Very good	Fairly good	Fairly bad	very bad
6. During the past month, how would you rate your sleep quality overall?	☐	☐	☐	☐

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?	☐	☐	☐	☐
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?	☐	☐	☐	☐

	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

	No bed partner or roommate	Partner/ roommate in other room	Partner in same room, but not same bed	Partner in same bed
10. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	☐	☐	☐	☐

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) ...loud snoring	☐	☐	☐	☐
(b) ...long pauses between breaths while asleep	☐	☐	☐	☐
(c) ...legs twitching or jerking while you sleep	☐	☐	☐	☐
(d) episodes of disorientation or confusion during sleep	☐	☐	☐	☐
(e) Other restlessness while you sleep; please describe	☐	☐	☐	☐

_____

_____

Appendix H: Sleep Hygiene Index

SLEEP HYGIENE INDEX (SHI)

Below you will find a list of statements. Please rate how true each statement is for you by circling a number next to it. Use the scale to make your choice.

0	1	2	3	4
Never	Rarely	sometimes	Frequent	Always

1. I take daytime naps lasting two or more hours.	0 1 2 3 4	_____
2. I go to bed at different times from day to day.	0 1 2 3 4	_____
3. I get out of bed at different times from day to day.	0 1 2 3 4	_____
4. I exercise to the point of sweating within 1 hr of going to bed.	0 1 2 3 4	_____
5. I stay in bed longer than I should two or three times a week.	0 1 2 3 4	_____
6. I use alcohol, tobacco, or caffeine within 4hrs of going to bed or after going to bed.	0 1 2 3 4	_____
7. I do something that may wake me up before bedtime (for example: play video games, use the Internet, or clean).	0 1 2 3 4	_____
8. I go to bed feeling stressed, angry, upset, or nervous.	0 1 2 3 4	_____
9. I use my bed for things other than sleeping or sex (for example: watch television, read, eat, or study).	0 1 2 3 4	_____
10. I sleep on an uncomfortable bed (for example: poor mattress or pillow, too much or not enough blankets).	0 1 2 3 4	_____
11. I sleep in an uncomfortable bedroom (for example: too bright, too stuffy, too hot, too cold, or too noisy).	0 1 2 3 4	_____
12. I do important work before bedtime (for example: pay bills, schedule, or study).	0 1 2 3 4	_____
13. I think, plan, or worry when I am in bed.	0 1 2 3 4	_____
	Total score =	_____

Appendix I: Morningness-Eveningness Questionnaire

MORNINGNESS-EVENINGNESS QUESTIONNAIRE
Self-Assessment Version (MEQ-SA)[1]

Name: _____ Date: _____

For each question, please select the answer that best describes you by circling the point value that best indicates how you have felt in recent weeks.

1. *Approximately* what time would you get up if you were entirely free to plan your day?

   [5] 5:00 AM–6:30 AM *(05:00–06:30 h)*
   [4] 6:30 AM–7:45 AM *(06:30–07:45 h)*
   [3] 7:45 AM–9:45 AM *(07:45–09:45 h)*
   [2] 9:45 AM–11:00 AM *(09:45–11:00 h)*
   [1] 11:00 AM–12 noon *(11:00–12:00 h)*

2. *Approximately* what time would you go to bed if you were entirely free to plan your evening?

   [5] 8:00 PM–9:00 PM *(20:00–21:00 h)*
   [4] 9:00 PM–10:15 PM *(21:00–22:15 h)*
   [3] 10:15 PM–12:30 AM *(22:15–00:30 h)*
   [2] 12:30 AM–1:45 AM *(00:30–01:45 h)*
   [1] 1:45 AM–3:00 AM *(01:45–03:00 h)*

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?

   [4] Not at all
   [3] Slightly
   [2] Somewhat
   [1] Very much

[1]Some stem questions and item choices have been rephrased from the original instrument (Horne and Östberg, 1976) to conform with spoken American English. Discrete item choices have been substituted for continuous graphic scales. Prepared by Terman M, Rifkin JB, Jacobs J, White TM (2001), New York State Psychiatric Institute, 1051 Riverside Drive, Unit 50, New York, NY, 10032. January 2008 version. Supported by NIH Grant MH42931. *See also:* automated version (AutoMEQ) at www.cet.org.

Horne JA and Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International Journal of Chronobiology, 1976: 4, 97-100.

4. How easy do you find it to get up in the morning (when you are not awakened unexpectedly)?

   [1] Very difficult
   [2] Somewhat difficult
   [3] Fairly easy
   [4] Very easy

5. How alert do you feel during the first half hour after you wake up in the morning?

   [1] Not at all alert
   [2] Slightly alert
   [3] Fairly alert
   [4] Very alert

6. How hungry do you feel during the first half hour after you wake up?

   [1] Not at all hungry
   [2] Slightly hungry
   [3] Fairly hungry
   [4] Very hungry

7. During the first half hour after you wake up in the morning, how do you feel?

   [1] Very tired
   [2] Fairly tired
   [3] Fairly refreshed
   [4] Very refreshed

8. If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?

   [4] Seldom or never later
   [3] Less that 1 hour later
   [2] 1-2 hours later
   [1] More than 2 hours later

9. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7-8 AM *(07-08 h)*. Bearing in mind nothing but your own internal "clock," how do you think you would perform?

   [4] Would be in good form
   [3] Would be in reasonable form
   [2] Would find it difficult
   [1] Would find it very difficult

10. At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?

    [5] 8:00 PM–9:00 PM *(20:00–21:00 h)*
    [4] 9:00 PM–10:15 PM *(21:00–22:15 h)*
    [3] 10:15 PM–12:45 AM *(22:15–00:45 h)*
    [2] 12:45 AM–2:00 AM *(00:45–02:00 h)*
    [1] 2:00 AM–3:00 AM *(02:00–03:00 h)*

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirely free to plan your day. Considering only your "internal clock," which one of the four testing times would you choose?

    [6] 8 AM–10 AM *(08–10 h)*
    [4] 11 AM–1 PM *(11–13 h)*
    [2] 3 PM–5 PM *(15–17 h)*
    [0] 7 PM–9 PM *(19–21 h)*

12. If you got into bed at 11 PM *(23 h)*, how tired would you be?

    [0] Not at all tired
    [2] A little tired
    [3] Fairly tired
    [5] Very tired

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?

    [4] Will wake up at usual time, but will not fall back asleep
    [3] Will wake up at usual time and will doze thereafter
    [2] Will wake up at usual time, but will fall asleep again
    [1] Will not wake up until later than usual

14. One night you have to remain awake between 4-6 AM *(04-06 h)* in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?

    [1] Would not go to bed until the watch is over
    [2] Would take a nap before and sleep after
    [3] Would take a good sleep before and nap after
    [4] Would sleep only before the watch

15. You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal "clock," which of the following times would you choose?

    [4] 8 AM–10 AM *(08–10 h)*
    [3] 11 AM–1 PM *(11–13 h)*
    [2] 3 PM–5 PM *(15–17 h)*
    [1] 7 PM–9 PM *(19–21 h)*

16. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week. The best time for her is between 10-11 PM *(22-23 h)*. Bearing in mind only your internal "clock," how well do you think you would perform?

    [1] Would be in good form
    [2] Would be in reasonable form
    [3] Would find it difficult
    [4] Would find it very difficult

17. Suppose you can choose your own work hours. Assume that you work a five-hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?

[5] 5 hours starting between 4–8 AM *(05–08 h)*
[4] 5 hours starting between 8–9 AM *(08–09 h)*
[3] 5 hours starting between 9 AM–2 PM *(09–14 h)*
[2] 5 hours starting between 2–5 PM *(14–17 h)*
[1] 5 hours starting between 5 PM–4 AM *(17–04 h)*

18. At *approximately* what time of day do you usually feel your best?

[5] 5–8 AM *(05–08 h)*
[4] 8–10 AM *(08–10 h)*
[3] 10 AM–5 PM *(10–17 h)*
[2] 5–10 PM *(17–22 h)*
[1] 10 PM–5 AM *(22–05 h)*

19. One hears about "morning types" and "evening types." Which one of these types do you consider yourself to be?

[6] Definitely a morning type
[4] Rather more a morning type than an evening type
[2] Rather more an evening type than a morning type
[1] Definitely an evening type

____ Total points for all 19 questions

Appendix J: Sleep Diary

Sleep Diary: Morning

National Sleep Foundation

Complete in Morning							
Start date: __/__/__	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day of week:	____	____	____	____	____	____	____
I went to bed last night at:	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM
I got out of bed this morning at:	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM
Last night I fell asleep:							
Easily	☐	☐	☐	☐	☐	☐	☐
After some time	☐	☐	☐	☐	☐	☐	☐
With difficulty	☐	☐	☐	☐	☐	☐	☐
I woke up during the night:							
# of times							
# of minutes							
Last night I slept a total of:	Hours	Hours	Hours	Hours	Hours	Hours	Hours
My sleep was disturbed by: List mental or physical factors including noise, lights, pets, allergies, temperature, discomfort, stress, etc.							
When I woke up for the day, I felt:							
Refreshed	☐	☐	☐	☐	☐	☐	☐
Somewhat refreshed	☐	☐	☐	☐	☐	☐	☐
Fatigued	☐	☐	☐	☐	☐	☐	☐
Notes: Record any other factors that may affect your sleep (i.e. hours of work shift, or monthly cycle for women).							

Sleep Diary: End of Day

Complete at the End of Day							
Day of week:	Day 1 ____	Day 2 ____	Day 3 ____	Day 4 ____	Day 5 ____	Day 6 ____	Day 7 ____
I consumed caffeinated drinks in the: (M)orning, (A)fternoon, (E)vening, (N/A)							
M / A / E / NA How many?	____	____	____	____	____	____	____
I exercised at least 20 minutes in the: (M)orning, (A)fternoon, (E)vening, (N/A)							
Medications I took today:							
Took a nap? (circle one)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
If Yes, for how long?							
During the day, how likely was I to doze off while performing daily activities: No chance, Slight chance, Moderate chance, High chance							
Throughout the day, my mood was… Very pleasant, Pleasant, Unpleasant, Very unpleasant							
Approximately 2-3 hours before going to bed, I consumed:							
Alcohol	☐	☐	☐	☐	☐	☐	☐
A heavy meal	☐	☐	☐	☐	☐	☐	☐
Caffeine	☐	☐	☐	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐	☐	☐	☐
In the hour before going to sleep, my bedtime routine included: List activities including reading a book, using electronics, taking a bath, doing relaxation exercises, etc.							

Appendix K: Wellness questionnaire

DATE:

Wellness questionnaire

In the following questionnaire please tick the applicable column and specify if necessary. The questions in table A and B are to be completed on a weekly basis.

Table A

In the last week:

	YES	NO	COMMENTS
Have you taken any medication (this includes prescription, non-prescription, over-the-counter, or anti-inflammatory medications). If so please specify			
Have you been sick or had an infection?			
Do you use a multivitamin?			
Do you use any other form of recovery techniques? If so, please specify.			
Do you use any form of supplement? (this includes pre and post workout) if so please specify in each case			
Have you had a smoke (this includes cigarettes, vape, and hubbly)			
Have you consumed any fast food?			
Have you had adequate family and friend support?			

Table B

In the last week have you:

	MOSTLY (75% of the time)	MODERATELY (50% of the time)	LITTLE (25% of the time)	NONE (0% of the time)
1) Been under physical stress?				
2) Encountered any circumstances that caused you to feel under emotional stress?				
3) Had a higher level of mental stress than normal?				
4) At any time felt overwhelmed?				
5) Been able to cope and manage your stress				

effectively?				
6) Felt more tired than normal?				
7) Taken longer to fall asleep?				
8) Participated in an enjoyable hobby? (which excludes watching TV, movies or series)				
9) Felt better about your self-confidence after training?				

TABLE C

Please rate your average pain over the past week with a score between 0 – 10. With 0 being no pain and 10 being severe.

Please provide an explanation (possible options include training, injury, hormonal and other options you can specify)

Pain Score (0,1,2,3,4,5,6,7,8,9,10)	**Comment:**

Appendix L: Participant booklet

Participant swimmers booklet

Participant's information

Participant number:

Age:

Gender:

Years competing:

Daily Forms

TQR questionnaire

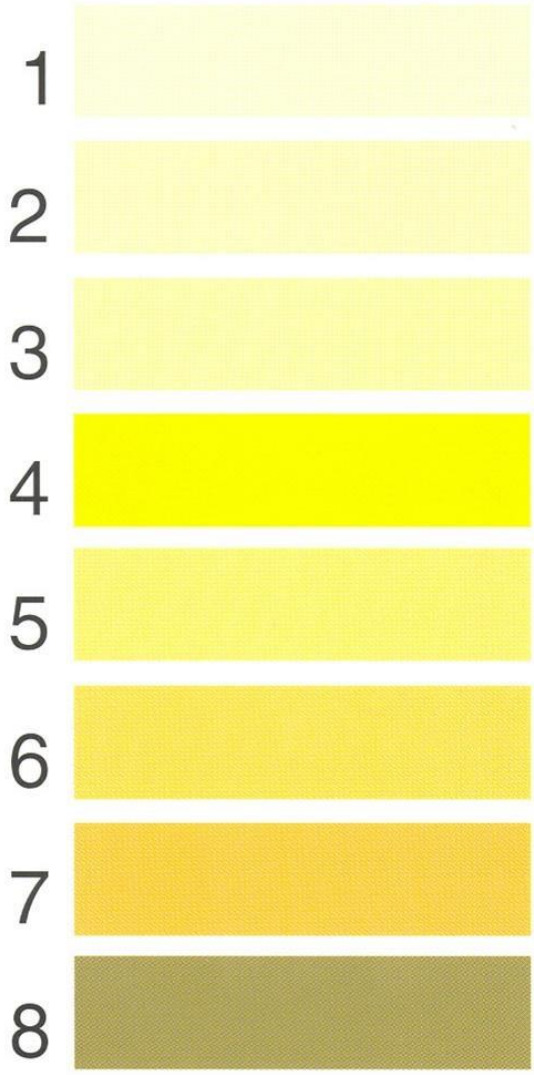
Please tick the applicable column

Factors relating to Recovery		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Attended swimming training sessions	Morning							
	Afternoon							
Participated in other physical activity								
Nutrition								
-Breakfast	Full							
	Less than full							
	none							
-Lunch	Full							
	Less than full							
	None							
-Dinner	Full							
	Less than full							
	None							
Pre-workout snack								
Post exercise refuelling within 60 minutes								
Hydration								
Pre-exercise urine:	Clear or light colour							
	Darker colour							
Post-exercise urine:	clear or light colour							
	Darker colour							
Sleep and Rest								
8 hours of restful sleep								
7- < 8 hours of restful sleep								
6 - <7 hours of restful sleep								
Relaxation and emotional status								
Fully relaxed 60 min post exercise/ 30 min of feet up time post exercise								
No psycho-social stress								
Mild stress								
Marked stress								
Cooldown								
Adequate active cooldown								
Partial active cooldown								
10 minutes of stretching post exercise								

Adapted from Kentta and Hassmen; 1999. Train smart: Avoid Overtraining Syndrome, Stockholm: SISU Idrottsbocker

DATE:

Urine colour chart



TO USE THIS CHART:

- Match the color of your urine sample to a color on

DATE:

- If the color matches # 1, # 2, or # 3 you are well hydrated.

- If the color matches # 4 – 8 you are dehydrated and must follow a rehydration protocol.

Ting, T. (2017). *The Hydration Guide*. NUTRITIONALISMO. [Accessed 20 Mar. 2017] Available at: https://nutritionalismo.com/2016/02/10/the-hydration-guide/

Sleep Diary: Morning

NATIONAL SLEEP FOUNDATION

Complete in Morning	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Start date: __/__/__							
Day of week:	____	____	____	____	____	____	____
I went to bed last night at:	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM	PM / AM
I got out of bed this morning at:	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM	AM / PM
Last night I fell asleep:							
Easily	☐	☐	☐	☐	☐	☐	☐
After some time	☐	☐	☐	☐	☐	☐	☐
With difficulty	☐	☐	☐	☐	☐	☐	☐
I woke up during the night:							
# of times							
# of minutes							
Last night I slept a total of:	Hours	Hours	Hours	Hours	Hours	Hours	Hours
My sleep was disturbed by: List mental or physical factors including noise, lights, pets, allergies, temperature, discomfort, stress, etc.							
When I woke up for the day, I felt:							
Refreshed	☐	☐	☐	☐	☐	☐	☐
Somewhat refreshed	☐	☐	☐	☐	☐	☐	☐
Fatigued	☐	☐	☐	☐	☐	☐	☐
Notes: Record any other factors that may affect your sleep (i.e. hours of work shift, or monthly cycle for women).							

Sleep Diary: End of Day

Complete at the End of Day	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Day of week:	____	____	____	____	____	____	____
I consumed caffeinated drinks in the: (M)orning, (A)fternoon, (E)vening, (N/A)							
M / A / E / N/A How many?	____	____	____	____	____	____	____
I exercised at least 20 minutes in the: (M)orning, (A)fternoon, (E)vening, (N/A)							
Medications I took today:							
Took a nap? (circle one)	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No	Yes / No
If Yes, for how long?							
During the day, how likely was I to doze off while performing daily activities: No chance, Slight chance, Moderate chance, High chance							
Throughout the day, my mood was… Very pleasant, Pleasant, Unpleasant, Very unpleasant							
Approximately 2-3 hours before going to bed, I consumed:							
Alcohol	☐	☐	☐	☐	☐	☐	☐
A heavy meal	☐	☐	☐	☐	☐	☐	☐
Caffeine	☐	☐	☐	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐	☐	☐	☐
In the hour before going to sleep, my bedtime routine included: List activities including reading a book, using electronics, taking a bath, doing relaxation exercises, etc.							

Weekly Forms

DATE:

Wellness questionnaire

In the following questionnaire please tick the applicable column and specify if necessary. The questions in table A and B are to be completed on a weekly basis.

Table A

In the last week:

	YES	NO	COMMENTS
Have you taken any medication (this includes prescription, non-prescription, over-the-counter, or anti-inflammatory medications). If so please specify			
Have you been sick or had an infection?			
Do you use a multivitamin?			
Do you use any other form of recovery techniques? If so, please specify.			
Do you use any form of supplement? (this includes pre and post workout) if so please specify in each case			
Have you had a smoke (this includes cigarettes, vape, and hubbly)			
Have you consumed any fast food?			
Have you had adequate family and friend support?			

Table B

In the last week have you:

	MOSTLY (75% of the time)	MODERATELY (50% of the time)	LITTLE (25% of the time)	NONE (0% of the time)
10) Been under physical stress?				
11) Encountered any circumstances that caused you to feel under emotional stress?				
12) Had a higher level of mental stress than normal?				
13) At any time felt overwhelmed?				
14) Been able to cope and manage your stress effectively?				
15) Felt more tired than normal?				

16) Taken longer to fall asleep?				
17) Participated in an enjoyable hobby? (which excludes watching TV, movies or series)				
18) Felt better about your self-confidence after training?				

TABLE C

Please rate your average pain over the past week with a score between 0 – 10. With 0 being no pain and 10 being severe.

Please provide an explanation (possible options include training, injury, hormonal and other options you can specify)

Pain Score (0,1,2,3,4,5,6,7,8,9,10)	**Comment:**

Profile of Mood States

Participant name: Participant number:

Directions: Describe HOW YOU FEEL RIGHT NOW by circling the most appropriate number after each of the words listed below:

	Not at all	A little	Moderately	Quite a bit	Extremely
Friendly	0	1	2	3	4
Tense	0	1	2	3	4
Angry	0	1	2	3	4
Worn out	0	1	2	3	4
Unhappy	0	1	2	3	4
Clear-headed	0	1	2	3	4
Lively	0	1	2	3	4
Confused	0	1	2	3	4
Sorry for things done	0	1	2	3	4
Shaky	0	1	2	3	4
Listless	0	1	2	3	4
Peeved	0	1	2	3	4
Considerate	0	1	2	3	4
Sad	0	1	2	3	4
Active	0	1	2	3	4
On edge	0	1	2	3	4
Grouchy	0	1	2	3	4
Blue	0	1	2	3	4
Energetic	0	1	2	3	4
Panicky	0	1	2	3	4
Hopeless	0	1	2	3	4

Relaxed	0	1	2	3	4
Unworthy	0	1	2	3	4
Spiteful	0	1	2	3	4
Sympathetic	0	1	2	3	4
Uneasy	0	1	2	3	4
Restless	0	1	2	3	4
Unable to	0	1	2	3	4
Fatigued	0	1	2	3	4
Helpful	0	1	2	3	4
Annoyed	0	1	2	3	4
Discouraged	0	1	2	3	4
Resentful	0	1	2	3	4
Nervous	0	1	2	3	4
Lonely	0	1	2	3	4
Miserable	0	1	2	3	4
Muddled	0	1	2	3	4
Cheerful	0	1	2	3	4
Bitter	0	1	2	3	4
Exhausted	0	1	2	3	4
Anxious	0	1	2	3	4
Ready to fight	0	1	2	3	4
Good-natured	0	1	2	3	4
Gloomy	0	1	2	3	4
Desperate	0	1	2	3	4
Sluggish	0	1	2	3	4
Rebellious	0	1	2	3	4
Helpless	0	1	2	3	4

Weary	0	1	2	3	4
Bewildered	0	1	2	3	4
Alert	0	1	2	3	4
Deceived	0	1	2	3	4
Furious	0	1	2	3	4
Effacious	0	1	2	3	4
Trusting	0	1	2	3	4
Full of pep	0	1	2	3	4
Bad tempered	0	1	2	3	4
Worthless	0	1	2	3	4
Forgetful	0	1	2	3	4
Careful	0	1	2	3	4
Terrified	0	1	2	3	4
Guilty	0	1	2	3	4
Vigorous	0	1	2	3	4
Uncertain about things	0	1	2	3	4
Bushed	0	1	2	3	4

Competition Form

DATE:

SPORT EMOTION QUESTIONNAIRE

Participant name:

Below you will find a list of words that describe a range of feelings that sport performers may experience. Please read each one carefully and indicate on the scale next to each item how you feel **right now, at this moment, in relation to the *upcoming* competition**. There are no right or wrong answers. Do not spend too much time on any one item, but choose the answer which best describes your feelings right now in relation to the upcoming competition.

	Not at all	A little	Moderately	Quite a bit	Extremely
Uneasy	0	1	2	3	4
Upset	0	1	2	3	4
Exhilarated	0	1	2	3	4
Irritated	0	1	2	3	4
Pleased	0	1	2	3	4
Tense	0	1	2	3	4
Sad	0	1	2	3	4
Excited	0	1	2	3	4
Furious	0	1	2	3	4
Joyful	0	1	2	3	4
Nervous	0	1	2	3	4
Unhappy	0	1	2	3	4
Enthusiastic	0	1	2	3	4
Annoyed	0	1	2	3	4
Cheerful	0	1	2	3	4
Apprehensive	0	1	2	3	4
Disappointed	0	1	2	3	4
Angry	0	1	2	3	4
Energetic	0	1	2	3	4

Happy	0	1	2	3	4
Anxious	0	1	2	3	4
Dejected	0	1	2	3	4

Appendix M: Ethical clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research & Post Graduate Affairs)

TO: Ms S Pretorius
School of Therapeutic Sciences
Centre for Exercise and Sport Medicine
Medical School
University

E-mail: slpretorius26@gmail.com

CC: Supervisor: Prof D Constantinou and Ms N Neophytou
<Demitri.Constantinou@wits.ac.za>
and <HREC-Medical.ResearchOffice@wits.ac.za>

FROM: Iain Burns
Human Research Ethics Committee (Medical)
Tel: 011 717 1252

E-mail: Iain.Burns@wits.ac.za

DATE: 15/05/2018

REF: *R14/49*

PROTOCOL NO: **M180279** *(This is your ethics application study reference number. Please quote this reference number in all correspondence relating to this study)*

PROJECT TITLE: *The effect swimming training intensity has on sleep, mood and recovery in elite swimmers*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to the Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

Appendix N: Permission letter from Mr. Dean Price

MANDEVILLE DOLPHINS SWIMMING CLUB

To whom it may concern

I, Dean Price, the coach of Mandeville Dolphins swimming club and Swimming South Africa, residing in 7th Ave, Johannesburg, 2094, hereby give consent for the collaboration between Mandeville Dolphins Swimming Club and the University of Witwatersrand Health Science department. Mandeville Dolphins Swimming Club will recommend subjects for participation in the following study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers. If you have any questions regarding this matter please contact me using the information provided below.

Full Name: Dean Price
Contact number: 084 689 9502
Email: info@mandevilledolphins.co.za

Sincerely
Dean Price



Signature

Cnr 7th & 10th Avenues, Bezuidenhout Valley, Johannesburg
Contact: Dean Price Cell: 084 689 9502

Appendix O: Additional site ethical clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Ms S Pretorius
School of Therapeutic Sciences
Centre for Exercise and Sport Medicine
Medical School
University

24/05/2019

Sent by e-mail to: slpretorius26@gmail.com

Dear Ms Pretorius

Re: **Protocol Ref No: M180279**
Protocol Title: *The effect swimming training intensity has on sleep, mood and recovery in elite swimmers*
Principal Investigator: Ms S Pretorius

Thank you for your e-mail of 21/05/2019.

I confirm that your request to add an additional site at Waterborn Swimming Club to your study has been noted and approved.

Thank you for keeping us informed.

Yours Sincerely

I Burns

Mr I Burns
For the Human Research Ethics Committee (Medical)

Works2000/Iain0007/Acknowledge.docx

Appendix P: Additional device ethical clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

24/05/2019

Ms S Pretorius
School of Therapeutic Sciences
Centre for Exercise and Sport Medicine
Medical School
University

Sent by e-mail to: slpretorius26@gmail.com

Dear Ms Pretorius

Re: **Protocol Ref No: M180279**
Protocol Title: *The effect swimming training intensity has on sleep, mood and recovery in elite swimmers*
Principal Investigator: Ms S Pretorius

Thank you for your e-mail of 22/05/2019.

I confirm that your request to add an additional *Fitbit* device to your study has been noted and approved.

Thank you for keeping us informed.

Yours Sincerely

.....

Mr I Burns
For the Human Research Ethics Committee (Medical)

Works2000/Iain0007/Acknowledge.docx

Appendix Q: Permission letter from Mr. Paul Fryer

To whom it may concern

I, Paul Fryer, the coach at Waterborn Swimming Club, residing in Puttick Ave, Sundowner, Randburg, 2161, hereby give consent for the collaboration between Waterborn Swimming Club and the University of Witwatersrand Health Science department. Waterborn Swimming Club will recommend subjects for participation in the following study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers. If you have any questions regarding this matter please contact me using the information provided below.

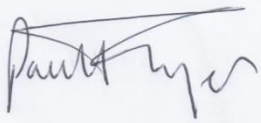
Full Name: Paul Fryer

Contact number: 083 702 9483

Email:

Sincerely

Paul Fryer

Signature 

Puttick Ave, Sundowner, Randburg, 2161, Johannesburg

Contact: Paul Fryer Cell: 083 702 9483

Appendix R: Participant consent form

The University of the Witwatersrand
Faculty of Health Sciences
School of Therapeutic sciences
7 York Road
Parktown
Johannesburg
2193

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

PARTICIPANT CONSENT FORM

Title of the study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers

HREC Number: M180279

Principal Investigator: Shandré Pretorius

PARTICIPANT:

1. I hereby confirm that I have read and understood the participant information sheet about the nature, conduct, benefits and risks of the study.
2. I understand that I may not participate in this study if I have the exclusion criteria stated.
3. I am aware that the results of the study will be anonymously processed into a report.
4. I understand that the study has been approved by the Human Research Ethics Committee, University of the Witwatersrand, Johannesburg.
5. I am aware that I may, at any stage withdraw my consent and participation in the study without prejudice.
6. I have been given the opportunity to ask questions and declare myself willing to participate in the study.

_____ _____

Printed Name and Surname Date and Time

☐ **Please tick if you wish to receive a summary of the findings when this research project is completed.**

INVESTIGATOR:

I have described all procedures and have explained their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered these questions to the best of my ability.

_____ _____

Printed Name and Surname Date and Time

Contact Details:

Shandré Pretorius
School of Therapeutic Sciences
Faculty of Health Science
University of the Witwatersrand
082 688 7946
Slpretorius26@gmail.com

Ms Natalia Neophytou
Centre for Exercise Science and Sports Medicine
School of Therapeutic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 717 3368
natalia.neophytou@wits.ac.za

Professor Demitri Constantinou
Centre for Exercise Science and Sports Medicine
School of Therapeutic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 7173372
Demitri.Constantinou@wits.ac.za

Appendix S: Participant assent form

The University of the Witwatersrand
Faculty of Health Sciences
School of Therapeutic sciences
7 York Road
Parktown
Johannesburg
2193

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

PARTICIPANT ASSENT FORM

(For participants under the age of 18)

Title of the study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers

HREC Number: M180279

Principal Investigator: Shandré Pretorius

PARTICIPANT:

1. I have read and understood the participant information sheet about the content, benefits and risks of the study.
2. I understand that I may not participate in this study if I have the exclusion criteria.
3. I understand that the results of the study will be anonymously processed into a report.
4. I understand that the study has been approved by the Human Research Ethics Committee, University of the Witwatersrand, Johannesburg.
5. I am aware that I may, at any stage withdraw my consent and participation in the study without discrimination.
6. I have been given the opportunity to ask questions and I am willing to participate in the study voluntarily.

_____ _____

Printed Name and Surname Date and Time

☐ **Please tick if you wish to receive a summary of the findings when this research project is completed.**

INVESTIGATOR:

I have described all procedures and have explained their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered these questions to the best of my ability.

_____ _____

Printed Name and Surname Date and Time

Contact Details:

Shandré Pretorius
School of Therapeutic Sciences
Faculty of Health Science
University of the Witwatersrand
082 688 7946
Slpretorius26@gmail.com

Ms Natalia Neophytou
Centre for Exercise Science and Sports Medicine
School of Therapeutic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 717 3368
natalia.neophytou@wits.ac.za

Professor Demitri Constantinou
Centre for Exercise Science and Sports Medicine
School of Therapuetic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 7173372
Demitri.Constantinou@wits.ac.za

Appendix T: Parental consent form

The University of the Witwatersrand
Faculty of Health Sciences
School of Therapeutic sciences
7 York Road
Parktown
Johannesburg
2193



PARENTAL CONSENT FORM

Title of the study: The effect swimming training intensity has on sleep, mood and recovery in elite swimmers

HREC Number: M180279

Principal Investigators: Shandré Pretorius

PARENT/GAURDIAN:

1. I hereby confirm that I have read and understood, the participant information sheet about the nature, conduct, benefits and risks of the study that my child/ward will participate in.
2. I understand that my child/ward may not participate in this study if they have the exclusion criteria stated.
3. I am aware that the results of the study will be anonymously processed into a report.
4. I understand that the study has been approved by the Human Research Ethics Committee, University of the Witwatersrand, Johannesburg.
5. I am aware that I may, at any stage withdraw my child's/wards' consent and participation in the study without prejudice to the course for which I am registered.
6. My child/ward has been given the opportunity to ask questions and declare himself/herself willing to participate in the study.

_____ _____

Printed Name and Surname Date and Time

☐**Please tick if you wish to receive a summary of the findings when this research project is completed.**

INVESTIGATOR:

I have described all procedures and have explained their purpose. I have asked whether or not any questions have arisen regarding the procedures and have answered these questions to the best of my ability.

_____ _____

Printed Name and Surname Date and Time

Contact Details:

Shandré Pretorius
School of Therapeutic Sciences
Faculty of Health Science
University of the Witwatersrand
082 688 7946
Slpretorius26@gmail.com

Ms Natalia Neophytou
Centre for Exercise Science and Sports Medicine
School of Therapeutic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 717 3368
natalia.neophytou@wits.ac.za

Professor Demitri Constantinou
Centre for Exercise Science and Sports Medicine
School of Therapeutic Sciences
Faculty of Health Sciences
University of the Witwatersrand
011 7173372
Demitri.Constantinou@wits.ac.za

Appendix U: Case Study 1

Case study 1: Female participant 14 years of age that has been competing for 2 years, during the course of the study she participated in five different competitions between the period of September and October. Ms. X remained consistent within her training and completed the relevant questionnaires. The information pertaining to her performance and mood can be found below in Table 4.3 and Figures 4.8-4.11.

Table 4.3: Information recorded over training and competition periods from July till October for one of the female participants.

Date	Stroke (type)	Distance (metre)	Time (seconds)	Training (type)
12/09	Free	50m	34.00	Training
15/09	Free	50m	31.37	Gala
15/09	Fly	50m	33.52	
15/09	Breast	50m	40.22	
15/09	Back	50m	36.23	
15/09	Fly	50m	36.00	
19/09	Fly	50m	36.00	Training
19/09	Back	50m	37.00	
19/09	Free	50m	33.50	
21/09	Back	200m	2:47	Gala
21/09	Free	100m	1:06	
21/09	IM	200m	2:51	
4/10	Back	100m	1:13.05	Training
4/10	Fly	100m	1.18.04	
4/10	Free	50m	29.75	
4/10	Free	400m	4.53	

5/10	Free	200m	2.19.12	Gala
5/10	IM	200m	2.41.27	
5/10	Breast	50m	38.33	
5/10	Back	100m	1.11.90	
6/10	Back	200m	2.38.53	Gala
6/10	Free	100m	1.03.51	
6/10	Free	100m	1.04.19	
6/10	Free	800m	10.09.93	
6/10	Breast	100m	1.25.98	
7/10	Breast	200m	3.08.30	Gala
7/10	Back	50m	34.30	

Appendix V: Case Study 2

Case study 2: Female participant 17 years of age that has been competing for 10 years, during the course of the study she participated in two different competitions in the month of July. Ms. Y remained consistent within her training and completed the relevant questionnaires. The information pertaining to her performance and mood can be found below in Table 4.4 and Figures 4.31-4.32.

Table 4.4: Performance times of Ms. Y during the course of the study between the months of May till August.

Date	Stroke (type)	Distance (metre)	Time (minutes)	Training (type)
17/5	**Back**	**100 m**	**1.20.3**	**Performance**
31/5	**Freestyle**	**50 m**	**31.2**	**Performance**
7/6	**Freestyle**	**50 m**	**33.4**	**Performance**
14/6	**Freestyle**	**50 m**	**33.2**	**Performance**
21/6	**Fly**	**100 m**	**1.20.9**	**Performance**
5/7	**Back**	**50 m**	**37.6**	**Performance**
14/7	**Freestyle**	**100 m**	**1.08.1**	**Winter gala**
14/7	**Freestyle**	**200 m**	**2.32.6**	
14/7	**Back**	**100 m**	**1.17.2**	
14/7	**Back**	**200 m**	**2.41.6**	
14/7	**Fly**	**50 m**	**0.48.0**	
19/7	**Freestyle**	**100 m**	**1.12.6**	**Performance**
26/7	**Freestyle**	**100 m**	**1.10.1**	**CGA senior gala**
26/7	**Freestyle**	**200 m**	**2.32.2**	
26/7	**Back**	**200 m**	**2.47.6**	
2/8	**Freestyle**	**100 m**	**1.13.0**	**Performance**
8/8	**Freestyle**	**100 m**	**1.12.56**	**Performance**
16/8	**Fly**	**100 m**	**1.18.25**	**Performance**

Appendix W: Turnitin report

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by Demitri Constantinou

Submission date: 20-Dec-2019 09:20AM (UTC+0200)
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ABSTRACT

BACKGROUND: Swimming is dynamic in nature and utilises both anaerobic and aerobic energy systems, and is a sport in which elite athletes often reach their peak physiological performance. Recovery has been found to encompass several factors; sleep, nutrition, hydration, psychological and emotional state, and active cooldown. Sleep forms one of the main components and if an athlete has poor sleep quality and quantity it may have a negative cascading effect on the physiology involved in the recovery process. Sleep quality and the components of the Total Quality Recovery (TQR) score are all interlinked and dependent on each other in the cycle of recovery. When an individual is in a positive mood during training and competitions the swimmers performance improves. The swimmers' performance can also be linked to the sleep quantity; studies have found that individuals who sleep less than 8 hours a night will have a decrease in performance and affect individual recovery. Although recovery measures have been studied in elite swimmers, quantifying each factor at an individual level by using the TQR, mood and sleep measures will add to the knowledge of optimising swimmers performance.

OBJECTIVE: To determine the effect swimming training intensity has on elite swimmers by assessing sleep, mood, performance and recovery.

METHODS: A prospective mixed-methods analytical study was conducted to assess the effect that swimming training intensity has on sleep, mood, performance and recovery in 15 elite swimmers between the ages of 13-21 years with a mean age of 16 ± 2.09 years. Individuals were required to wear a Fitbit™ device on their non-dominant wrist for the duration of the 14 week study to measure daily calories expenditure, steps, active minutes, distance walked, total sleep time (TST), restless minutes, rapid eye movement (REM), none rapid eye movement (NREM), light and deep sleep ,exercise and resting heart rate (RHR). In addition they completed the following questionnaires daily- Total Quality recovery (TQR) and Sleep Diary (SD), and weekly the Wellness Questionnaire and the Profile of Mood States (POMS). The Pittsburg Sleep Quality Index (PSQI), Sleep Hygiene Index (SHI) and Morningness-Eveningness Questionnaire (MEQ) were completed every 4 weeks and lastly the Sports Emotional Questionnaire (SEQ) was only completed when the athlete swam in an event. Participants completed self-reported questionnaires

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