Monitoring training load and training intensity distribution of amateur Cape Epic mountain bike cyclists

by Karin Winterbach

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Abstract

The aim of this cross-sectional descriptive study was to compare different training load (TL) methods and identify the distribution of the training load during the preparation phase and the Cape Epic MTB race. Secondary, the study aimed to determine how TL distribution influence the performance (race time). Nine amateur male MTB cyclists (mean ± SD: age 40.0 ± 8 y, height 179.4 ± 8.4 cm, body mass 79.1 ± 10.2 kg) and two women (age 41 and 58 y, height 158.6 and 166 cm, body mass 60 and 58.3 kg) volunteered to participate in a 13-week (December – March) preparation period before taking part in the 2017 Cape Epic MTB race.

Before the preparation phase, participants completed a maximal aerobic cycling test in the laboratory to determine three work intensity zones based on heart rate (HR) and corresponding to blood lactate thresholds. Internal training load was calculated using Banister's training impulse (bTRIMP), individualized TRIMP (iTRIMP) and session Rate of Perceived exertion (sRPE). Riders were tracked and monitored throughout the training period using an online training diary (TrainingPeaks®, Boulder, United States). No training prescription was provided to the participants - they followed their own training plan, or a plan provided by their coach.

Strong correlations were observed between the different TL measuring tools for the preparation phase (iTRIMP vs bTRIMP: $r = 0.72$, $P = 0.02$; iTRIMP vs sRPE: $r = 0.86$, $P < 0.01$ and bTRIMP vs sRPE: $r = 0.72$, $p < 0.01$). TL measures for the Cape Epic race yielded even stronger correlations (iTRIMP vs bTRIMP: $r = 0.90$, $P < 0.01$, iTRIMP vs sRPE: $r = 0.79$, $P < 0.01$ and bTRIMP vs sRPE: $r = 0.94$, $P < 0.01$). Moderate correlations were found between the HR-based methods and total race time iTRIMP ($r = -0.56$, $P = 0.85$ and bTRIMP: $r = -0.53$, $P = 0.09$) and a weak correlation for sRPE and total race time ($r = -0.41$, $P = 0.20$). A statistically significant correlation was found between race time and iTRIMP scores during the race ($r = -0.78$, $P < 0.01$), compared to a moderate correlation for bTRIMP during the race and total race time ($r = -0.58$, $P = 0.08$) and a weak correlation for sRPE during the race and race time ($r = -0.36$, $P = 0.31$). With the time-in-zone method, the TID for the preparation phase in Zone 1, 2 and 3 were 58%, 27% and 15%, and for the Cape Epic race it was 42%, 41% and 17% in zone 1, 2 and 3, respectively.

In conclusion, the iTRIMP method is a useful indicator of internal training load in MTB cyclists, and correlates well with previously used internal measures such as sRPE and Banister's

TRIMP. In future, studies should investigate the use of power meters, in cycling especially, because of its instantaneous results and accuracy. Amateur MTB cyclists follows a pyramidal training pattern during the training phase that is in line with higher competitive level cyclists, and result in adequate preparation for the successful completion of the race.

Keywords: Training impulse; Training intensity distribution; Polarised training; Pyramidal training.

Opsomming

Die doel van hierdie dwarssnit beskrywende studie was om die verskillende metingsmetodes van interne oefenlading te vergelyk en die oefenlading-verspreiding tydens die voorbereidingsfase en die Cape Epic bergfietswedren te beskryf. Tweedens was die studie daarop gemik om te bepaal hoe die oefenlading-verspreiding prestasie beïnvloed. Nege amateur bergfietsryers (gemiddelde ± standaard afwyking: ouderdom 40.0 ± 8 jaar, lengte 179.4 ± 8.4 cm, liggaamsmassa 79.1 ± 10.2 kg) en twee vroue (41 en 58 jaar oud, lengte 158.6 en 166 cm, liggaamsmassa 60.0 en 58.3 kg) het vrywillig aan die studie deelgeneem was 'n voorbereidingsperiode van 13 weke (Desember tot Maart)en die 2017 Cape Epic bergfietswedren ingesluit het.

Voor die voorbereidingsfase het die deelnemers 'n maksimale aërobiese oefentoets in die laboratorium voltooi om drie intensiteit-sones te bepaal wat gebaseer is op die harttempo (HT) by verskillende laktaatdraaipunte. Interne oefenlading is bereken deur Banister se TRIMP (TRIMP en bTRIMP), geïndividualiseerde TRIMP (iTRIMP) en sessie meting van waargenome inspanningsvlak (sRPE). Die deelnemers se oefenprogram gedurende die voorbereidingstyd is met behulp van 'n aanlyn-oefenkalender (TrainingPeaks, Boulder, Verenigde State van Amerika) gemonitor. Geen oefenvoorskrifte is aan die deelnemers voorsien nie; hulle het hul eie oefenplan gevolg, of 'n plan wat deur hul afrigter verskaf is.

Sterk korrelasies tussen die verskillende oefenladingmetodes vir die voorbereidingsfase is waargeneem (iTRIMP vs bTRIMP: $r = 0.72$, $P = 0.02$; iTRIMP vs sRPE: $r = 0.86$, $P < 0.01$ en bTRIMP vs sRPE: $r = 0.90$, $P < 0.01$). Die verwantskappe tussen die verskillende oefenladingsmetodes was selfs sterker tydens die Cape Epic wedren (iTRIMP vs bTRIMP: $r = 0.90$, $P < 0.01$; iTRIMP vs sRPE: $r = 0,79$, $P < 0.01$ en bTRIMP vs sRPE: $r = 0,94$, $P < 0,01$). Matige korrelasies is gevind tussen die harttempo-gebaseerde metodes en die totale wedrentyd (iTRIMP: $r = -0.56$, $P = 0.85$, bTRIMP: $r = -0.53$, $P = 0.09$) en ʼn swak korrelasie vir sRPE en totale wedrentyd ($r = -0.41$, $P = 0.20$). Statisties betekenisvolle korrelasies is gevind tussen wedrentyd en iTRIMP tellings gedurende die wedren ($r = -0.78$, $P < 0.01$), in vergelyking met ʼn matige korrelasie vir bTRIMP gedurende die wedren en totale wedrentyd ($r = -0.58$, $P = 0.08$) en ʼn swak korrelasie vir sRPE tydens die wedren en wedrentyd ($r = -0.36$, $P = 0.31$). Met die tyd-in-sone metode was die verspreiding van oefenintensiteit vir die voorbereidingsfase in sone 1, 2 en 3 onderskeidelik 58%, 27% en 15% en vir die Cape Epic wedren onderskeidelik 42%, 41% en 17% in sone 1,2 en 3.

Ten slotte, die iTRIMP is 'n nuttige aanwyser vir die interne oefenlading van MTB- fietsryers en korreleer goed met voorheen gebruikte interne metingsmodelle, soos sRPE en Banister's TRIMP. In die toekoms behoort studies die gebruik van 'n kraguitsetmeters, veral in fietsry, te ondersoek, weens die onmiddellike resultate en akkuraatheid van hierdie instrumente. Amateur MTB-fietsryers volg 'n piramidale oefenpatroon tydens die voorbereidingsfase, wat in lyn is met hoër vlak kompeterende fietsryers, en wat voldoende is om die suksesvolle voltooiing van die resies te verseker.

Sleutelwoorde: Oefenimpuls; Oefenlading verspreiding; Gepolariseerde inoefening; Piramidale inoefening.

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Table of Contents

List of figures

List of tables

List of Abbreviations and Acronyms

°C	:	Degrees Celsius
Δ	:	Delta (change in)
e	:	*Naperian logarithms (2.71)*
#	:	Number
%	:	Percentage
µl	:	Micro litre
[La]	:	Lactate Concentration
ANOVA	:	Analysis of Variance
AT	:	Anaerobic Threshold
AU	:	Arbitrary Units
BMI	:	Body Mass Index
bpm	:	beats per minute
bTRIMP	:	Banister's Training Impulse
CI	:	Confidence Interval
cm	:	Centimetre
CO_2	:	Carbon dioxide
ECG	:	Electrocardiogram
GC	:	General Classification
HIT	:	High Intensity Training
HR	:	Heart Rate
HR_{max}	:	Maximum Heart Rate
HR_{EX}	:	Exercise Heart Rate
HR_{AVE}	:	Average Heart Rate
HR_{PEAK}	:	Maximum Heart Rate
$HR_{RESERVE}$	:	Heart Rate Reserve
HR_{rest}	:	Resting Heart Rate
Int	:	International
ICC	:	Intra class Reliability
iTRIMP	:	Individualised training impulse
Km	:	Kilometre
Kg	:	Kilogram
$Kg.m^{-2}$	:	Kilogram square metre

L		Litre
LIT	:	Low intensity Training
LT	:	Lactate Threshold
LT_1	:	First Lactate Threshold
LT_2	:	Second Lactate Threshold
MTB	:	Mountain Bike
MTBs	:	Mountain Bikes
MTBing	:	Mountain Biking
m	:	Metre
mm	:	Milimetre
min	:	Minutes
min:sec	:	minutes and seconds
ml	:	Millilitres
$mmol.L^{-1}$	:	Millimol per Litre
$ml.min^{-1}$	:	Millilitres per Minute
$ml.min^{-1}.kg^{-1}$	:	Millilitres per Minute per Kilogram
MLSS	:	Maximal Lactate Steady State
N_2	:	Nitrogen
NAT	:	National
NORBA	:	National Off-Road Bicycling Association
Nr	:	Number
n	:	Sample Size
O_2	:	Oxygen
PPO	:	Peak Power Output
PO	:	Power Output
POLT	:	Power Output at Lactate Threshold
PPO: W	:	Peak Power Output to Body Mass ratio
POLT: W	:	Power Output at Lactate Threshold to Body Mass
P	:	Probability
RPE	:	Rating of Perceived Exertion
rpm	:	Revolutions per Minute
r	:	Correlation coefficient
RER	:	Respiratory Quotient

R^2	:	Correlation coefficient squared
RCT	:	Respiratory Compensation Threshold
RPE	:	Rating of Perceived Exertion
s	:	Seconds
SD	:	Standard Deviation
SEE	:	Standard Error of Estimate SRM
	:	Schoberer Rad Messtechnik
sRPE	:	session Rate of Preceived Exertion
THR	:	Threshold Training Model
TID	:	Training intensity distribution
TL	:	Training Load
TRIMP	:	Training Impulse
TSS	:	Training Stress Scores
UCI	:	Union Cyliste Internationale
VO2max	:	Maximal Aerobic Capacity
VO2	:	Oxygen Consumption
VT	:	Ventilatory Threshold
VT1	:	First Ventilatory Threshold
VT2	:	Second Ventilatory Threshold
W	:	Watt
y	:	Years
y_i	:	Individual weighing factor
y	:	Multiplying Factor

CHAPTER 1

INTRODUCTION

Ultra-endurance mountain bike events have become very popular in the last decade with more athletes participating and multiple races across the globe to choose from. One such event in South Africa is the Cape Epic mountain bike (MTB) race which was first held in 2004 and which has received *Union Cycliste Internationale* (UCI) status in 2005 (Greeff, 2014). The race covers 700-800 km over 8-days with a total racing time of between 30-55 hours, making it a true ultra-endurance event.

Challenging events like this demand longer and more detailed preparation. Successful ultra-endurance performance is foremost characterised by the ability to sustain a higher absolute speed for a given distance (Zaryski *et al*., 2005). To achieve this, careful manipulation of intensity, duration and frequency of training over days, weeks and months is needed (Seiler, 2010). To be competitive at the highest level, many athletes and coaches resort to a more scientific approach to both designing and monitoring their training programs.

Monitoring training and competition load is critical for coaches and athletes to determine whether the athlete is adapting to training, to minimise the risk of overreaching and injury, as well as for the periodization of training dose. Traditionally, training programs have been described based on measures of external load (distance, intensity and duration), which is a measure of training load (TL) independent of individual internal characteristics (Wallace *et al*., 2014). For example, in a mountain bike (MTB) cycling program, a coach may prescribe a training session as a desired distance or training time (e.g., 40 km or 2 hrs). While external load is important, the internal load or physiological stress imposed on the athlete should also be accounted for. If two athletes perform a session of similar external load, one athlete might perceive the training session harder than the other. It is therefore important to monitor both the internal and external loads so that training programs can be designed to cater for the individual athlete. While it is easy to monitor the external load, the monitoring of internal load is more challenging (Borresen & Lambert, 2009).

The most common external load monitoring tools used in cycling is power output devices and time motion devices, while internal monitoring tools include heart rate (HR), blood lactate, rate of perceived exertion (RPE), session RPE, questionnaires, diaries and training impulse (TRIMP). High- performance athletes may also use heart rate recovery, neuromuscular function, biochemical/hormonal assessments and sleep quantity and quality to obtain a comprehensive view of their physiological state (Halson, 2014).

The monitoring approach is influenced by factors such as the sport (team or individual) and training modes. However, the importance of individualization of load monitoring is a universal factor for all (Akubat *et al*. 2012). So far, no consensus on a gold-standard for measuring TL in endurance sports has been reported in the literature. A reason for this is that the correlation between training and the corresponding physical and physiological responses is highly individual (Roos *et al*., 2013). Responses depend on many factors, such as psychological parameters, initial training status, recovery potential, non-training stress factors and genetic background (Borresen and Lambert, 2009). In order to avoid under- and overtraining, and to achieve optimal performance at specific time-points, it is important for athletes and coaches to know the physical and perceptual exertion demand of training and be able to monitor individual TL, so training programs can be tailored to the temporary and cumulative individual responses to training (Seiler 2010, Rønnestad *et al*., 2012).

Several methods for quantifying TL in endurance sport have been suggested in the literature. These methods include subjective approaches such as session rating of perceived exertion (sRPE) (Foster *et al*., 2001), and objective approaches based on HR such as Banister's training impulse (bTRIMP) (Banister 1991) and the individualized training impulse (iTRIMP) (Manzi *et al*., 2009). These quantification methods, together with advanced training analysis software (e.g. TrainingPeaks®), has made access to monitoring data easily accessible for athletes and coaches. However, while access to data is now easier than ever, there is still considerable uncertainty around the validity of this data for quantifying load (Sanders *et al*., 2016).

Besides determining the training load of endurance athletes, the distribution of the training load also needs careful manipulation when designing training programs. In a recent review by Seiler it was concluded that the desired training intensity and duration distribution of Olympic endurance athletes in sport disciplines which include cycling, cross-country skiing, rowing and long-distance running is an 80-20 distribution, meaning 80% of training takes place at low intensities, while the other 20% takes place at lactate threshold and high intensities. This polarised training model, with high levels of low-intensity training and very little training at or above lactate threshold, seems to be superior to the threshold training model in world-class Olympic endurance athletes (Seiler &

Kjerland, 2006). However, in untrained subjects - training for 2-3 months, 4-5 days per week – training at intensities within the lactate accommodation zone, has caused significant improvements in VO2max, lactate threshold, and endurance performance (Seiler & Kjerland, 2006).

The Cape Epic mountain bike race is unique in that it attracts world champions, Olympic champions, and other top professional riders, as well as a large field of international amateur participants. Statistics of the 2017 race revealed that 75.5% of the 1332 participants completed the race as a pair, with another 114 individual finishers (*https://www.cape-epic.com)*. This indicates that nearly 25% of the participants did not complete the race.

Appropriate load monitoring can aid in determining whether an athlete is adapting to a training program and in minimizing the risk of overreaching or injury. To gain an understanding of the training load and its effects on the athlete, several potential methods are available. However, no consensus on a gold-standard of measuring training load in endurance sports has been reported in the available literature so far. Determining the TL and the distribution of the TL of Cape Epic riders will assist coaches in determining the day to day load and distribution which will allow them to adjust the program before injury or over-and under-reaching occur. No previous studies have investigated the TL or TL distribution of multi-stage mountain bike races, and this study will assist mountain bike riders to prepare optimally for this prestigious race.

CHAPTER 2

LITERATURE REVIEW

A. INTRODUCTION

Current trends in endurance participation and events have changed drastically in the last two decades. While some, like the Comrades Marathon and Ironman triathlons, have stood the test of time, a growing number of new events have been created to appeal to those athletes who still seek more gruelling pastimes (Zaryski *et al*., 2005). Ultra-endurance events are those lasting longer than 6 hours, however, training for these events is no different than preparing for other endurance events; it involves careful manipulation of intensity, duration and frequency of training over days, weeks and months (Seiler, 2010). Mountain biking is one of the sports that have morphed into many different racing forms and specifically multi-day stage racing has become a major attraction for ultra-endurance athletes. For example, the Cape Epic mountain bike race is an 8-day stage race covering between 700 and 800 km, making it a true ultra- endurance event. The first Cape Epic mountain bike race was held in 2004 and the race has since gained UCI status (Greeff, 2014).

Coaches and trainers generally agree that the outcome of the training process depends on the type and amount of the stimulus, and understanding this cause-and-effect relationship between training dose and response is crucial to prescribing exercise training accordingly (Lambert & Borressen, 2010). It is simply not possible to identify the effects of training without a precise quantification of the training load (TL). Monitoring athletes' TL is essential for determining whether they are adapting to their training program, understanding responses to training, assessing fatigue and the associated need for recovery, and minimising the risk of nonfunctional overreaching, injury and illness (Bourdon *et al*., 2017). Training monitoring is also about keeping track of what athletes accomplish in training and for improving the interaction between the coach and athlete (Foster *et al*., 2017). A primary goal of load monitoring should be to assist and inform athletes of their training status and progress in a simplified manner on a regular basis (Bourdon *et al*., 2017).

Many studies (Borresen & Lambert, 2009; Halson, 2014; Foster *et al*., 2017, Mujika, 2017) described and reviewed methods aimed at quantifying the TL, as well as make recommendations for their practical use (Mujika, 2017). Both internal and external loads contribute to the quantification of an athlete's TL, and a combination of both may be the key for proper training monitoring (Halson, 2014). At present, there is no single, definitive marker that accurately measures the fitness and fatigue responses to exercise training. One of the main reasons for this is the highly individualised responses of athletes to training (Roos *et al.,* 2013). Key features of monitoring systems should include practical design, accurate result reporting, ability to be used remotely, translatability of data into simple outcomes, flexibility and adaptability for different sports, ability to simply and efficiently identify meaningful change, an assessment of cognitive function, and capability of providing both individual and group responses (Mujika, 2017).

Recent studies have shown that methods to quantify TL that integrate individual physiological characteristics, such as the individualised TRIMP (iTRIMP) and the training stress scores (TSS) showed a high dose-response validity in runners and cyclists (Manzi *et al*., 2009; Sanders *et al.*, 2017). The iTRIMP integrates the individual's HR-blood lactate relationship into exponentially weighted exercise intensities, while TSS integrate the individual's functional threshold power. However, an active debate on finding the "optimal" method to quantify training load in endurance athletes is ongoing.

Data relating to training load and athletes' responses can also motivate an athlete by highlighting their awareness of time and effort investment and promoting a goal-orientated approach (Halson, 2014). In a recent study on training manipulation, Mujika (2017) emphasised the importance of information about training load and a precise description of the training contents in terms of volume, intensity and frequency, before and during intervention or competition. He suggested that sport scientists and coaches should be more precise when recording data. Continuous mapping and tracking of training data across training seasons will assist in making it useful for future studies.

Timing peak fitness and performance is a priority for endurance coaches and athletes. Endurance athletes adjust to a high-volume training approach with the sensible application of high-intensity training incorporated throughout the training cycle (Seiler, 2010). The effect of different combinations of intensity distribution and duration of endurance training have been studied for many years, however, the application and outcomes of these different combinations to the long-term training of endurance athletes are not clear. Finding a standardised intensity scale is required to describe and compare training intensities for different endurance sports. The standardised scale can lead to improved communication between coaches and athletes, as well as across sports disciplines by improving the match between the intensity prescription from a coach and the athlete's interpretation of that prescription (Seiler, 2010).

Researchers have retrospectively analysed endurance athletes' training intensity distribution (TID) in a variety of sports to determine the optimal volume and intensity for maximal adaptation (Stöggl & Sperlich, 2015). Many studies (Robinson *et al.*, 1991; Mujika *et al.,* 1995; Steinacker *et al.*, 1998; Steinacker *et al.,*2000; Lucia *et* al., 2000; Billat *et al.*, 2001; Schumacher & Mueller, 2002; Billat *et al.,* 2003; Fiskerstrand & Seiler, 2004; Esteve-Lanao *et al*., 2005; Seiler & Kjereland, 2006; Zapico *et al.,* 2007; Sandbakk *et al.,* 2011; Plews *et al.,* 2014; Tønnessen *et al.,* 2014) demonstrated that, even though all competitive endurance events are performed at or above the lactate threshold, the majority of the training performed is below lactate threshold intensities. Manzi *et al*. (2015) found that long-distance recreational runners followed a similar TID 76.3% / 17.3% / 6.4% for time spent in zone 1, 2 and 3 respectively, compared to the national runners 71% / 21% / 8% (Esteve-Lanao *et al*., 2005) and elite cross-country skiers 91% / 6.4% / 2.6% (Seiler &Kjerland, 2006). Reasons given for the high volume of zone 1 training are that these intensities are most effective in stimulating mitochondrial biogenesis, enhancing oxidative processes and increasing mobilization of energy reserves (Esteve-Lanao *et al*., 2005).

Monitoring of the amount of high-intensity training in endurance athletes is important, as increases above certain levels do not improve performance further and can induce symptoms of overreaching (Halson *et al.,* 2014). Studies have demonstrated superior responses to performance variables in endurance athletes when applying a polarised TID in well-trained and recreational individuals when compared with a TID that emphasizes threshold training (Stöggl & Sperlich, 2015). No optimum TID pattern among the different endurance disciplines has been identified. Factors that cause these differences include the duration of monitoring, the period during which the data are recorded, the TID methodology, as well as the endurance discipline.

Mountain bike, multi-day endurance races, are relatively new events, and limited literature is available on training load and intensity distribution of these athletes during their preparation phases.

B. DETERMINE TRAINING LOAD

1. Training load in endurance sport

Endurance sports events, including mountain biking, does not only require a solid endurance capacity, it also requires that athletes accelerate and complete long climbs, amongst others. Anaerobic capacity, power and speed will contribute to endurance performance and competition outcomes (Mujika, 2017). Both high-intensity and low-intensity training are important for the endurance athlete to optimise adaptive physiological and biochemical signalling and technical mastery at an acceptable level of stress (Stöggl & Sperlich, 2014). It is therefore important that training load quantification methods cover the entire range of training intensities, in addition to other training variables, such as volume and frequency.

Table 2.1 Methods to determine training load

External training load	**Internal training load**	
	Subjective methods	**Objective methods**
Power meter	RPE	Heart rate
Time-motion analysis	sRPE	Blood lactate concentrations
GPS (for distance, time, speed, elevation)		Oxygen consumption
		TRIMP

1.1 External training load

For coaches to adjust training variables appropriately, it is important to monitor the training load (TL) for each cyclist. TL consists of an external and internal component. In the past, external monitoring has been the main variable measured by most monitoring systems. The external load is defined as the work completed by the athlete, measured independently of his or her personal characteristics (Wallace *et al*., 2009). External load in MTBing would be the average speed sustained for a given duration of time (i.e. 18 km.h^{-1} for 60 min).

The external load is fundamental in the understanding of the training completed and to evaluate the capacities (aerobic and anaerobic) of the athlete. Methods for monitoring external load in cycling include power meters, which measures the continuous work rate (power output), as well as heart rate monitors and global positioning systems (GPS) for the measurement of time, speed, acceleration and distances covered. Although very useful, the external load does not account for the individual response of the athlete, and therefore a combination of both external and internal training load is important for training monitoring.

1.2. Internal training load

Internal TL has been defined by Foster as "*the exertional demand placed upon or experienced by an athlete during a training session or accumulated over time"* (Foster *et al*., 2001). Banister *et al.* (1975) defined internal TL as "*a dose of work that stresses psychophysiological systems and induces adaptive responses leading to performance enhancement*". Physiological adaptation characteristics are highly individual and depend on many factors, including psychological parameters, initial training status, recovery potential, non-training stress factors and genetic background (Borresen and Lambert, 2009). These factors can lead the athletes to train below or above the intensity as planned by the external load. Athletes and coaches must rather monitor individual TL so training programs can be tailored to individual responses (Seiler, 2010, Rønnestad *et al*., 2012).

Several methods for quantifying internal TL have been suggested in the literature. These methods include subjective approaches, such as session rating of perceived exertion (sRPE) (Foster *et al.*, 2001) and objective approaches based on heart rate (HR), such as Banister's training impulse (bTRIMP) (Banister, 1991) and the individualized training impulse (iTRIMP) (Manzi *et al*., 2009). Multiple studies have "validated" the internal-related TL methods by correlating them with each other. A few studies have also used change in fitness and/or performance to validate the internal TL methods in endurance sport. Manzi *et al*. (2009) monitored responses to internal TL in long-distance runners using iTRIMP and bTRIMP and compared it to performance (5- and 10- km races), as well as changes in submaximal aerobic fitness (running speed at blood lactate concentrations of 2 and 4 $mmol.L^{-1}$. iTRIMP was significantly related to 5000 m (r = -0.74, P = 0.04) and 10 000 m performance (r = - 0.82, P = 0.01). They concluded that iTRIMP is a valid tool to predict performance in long-distance runners.

1.2.1 Perception of effort

The rating of perceived exertion (RPE) has been used extensively to measure internal load subjectively. The athlete can monitor his or her physiological stress during training by means of a Borg scale (6-20) to identify the load experienced during training. RPE responses are gender-independent and knowledge about the athlete's fitness level is not required when describing the load (Wallace *et al.,* 2014). Literature reported that RPE is a valid means of assessing the effort during steady-state exercise and high-intensity interval cycling training, but not so much during short-duration high-intensity soccer drills (Lambert & Borresen, 2010).

Chen *et al.* (2002) carried out a meta-analysis to determine the relationship between RPE scores and gender of participants, fitness, type of RPE scale used, type of exercise, exercise protocol, RPE mode and study quality. The weighted mean validity coefficients between RPE and physiological variables were 0.62 for heart rate, 0.57 for blood lactate, 0.64 for % VO2max 0.63 for VO_2, 0.61 for ventilation and 0.72 for respiration rate. The highest correlations were found in the following conditions: when male participants (whose VO_2 or ventilation was measured) were required to maximally exert themselves (measuring % VO2max or ventilation); when the exercise task was unusual (e.g. when participants were swimming, which is less common than walking or running), or when the 15-point RPE scale (measuring blood lactate concentration) was used. The study concluded by acknowledging the use of the RPE-scale to identify training intensity, but noted that its validity is not consequent in different conditions.

1.2.2 Session rating of perceived exertion

The session rating of perceived exertion (sRPE) was developed by Foster *et al*. (1996) as a modification of the original RPE method. The session RPE is a rating of the overall difficulty of the training session obtained 30 minutes after the completion of the session. The sRPE method multiplies the athlete's RPE (on a 1 – 10 scale) by the duration of the session (in minutes) to quantify training load. The main advantage of this method is that it is simple and does not need expensive equipment.

The validity and reliability of the sRPE have been shown during steady-state cycling exercise in well-trained cyclists and college basketball players in a two-part study, with individual correlations between sRPE and summated heart rate zone scores ranging between r = 0.75 and r = 0.90 ($P < 0.05$) (Foster *et al.,* 2001). Impellizzeri *et al*. (2004) found that individual correlations between sRPE and Banister's TRIMP ranged between r = 0.50 and r = 0.77 ($P < 0.01$) and individual correlations between the sRPE and the summated heart rate zone method ranged from r = 0.54 to r = 0.78 ($P < 0.001$) in young soccer players during training and matches, respectively. Borresen & Lambert (2008) reported correlations of r = 0.76 between TRIMP and sRPE and r = 0.84 between the summated heart rate zone method and the session RPE in recreational endurance athletes.

Herman *et al*. (2006) designed a study to evaluate both the validity and reliability of the sRPE method in comparison with objective measures including the percentage of maximum heart rate (%HR_{peak}), the percentage of heart rate reserve (%$HR_{reserve}$), and percentage of maximal ventilatory threshold (%VO_{2peak}). Healthy volunteers performed six random 30-minute constant-load exercise bouts at three different intensities. HR and VO_2 were measured throughout each exercise bout. Thirty minutes after the exercise, participants rated the global intensity of the exercise using the modified Borg scale (0-10). The rating was compared to the mean value of the objectively measured exercise intensity across the duration of the exercise. The day-to-day reliability for sRPE (R^2 = 0.78), %VO_{2peak} (R^2 = 0.96), %HR_{peak} (R^2 = 0.93) and %$HR_{reserve}$ (R^2 = 0.93) were all statistically significant ($P < 0.05$). The sRPE method was also compared with %VO_{2peak}, %HR_{peak} and %$HR_{reserve}$ to determine the degree to which the various methods of exercise intensity were measuring the same thing. The coefficients of determination (R^2) between the sRPE and %VO_{2peak} (R^2 = 0.76), %HR_{peak} (R^2 = 0.74), and %$HR_{reserve}$ (R^2 = 0.71) were strong and statistically significant ($P < 0.05$) throughout. They concluded that this subjective method of measuring TL was valid and reliable however less precise than the objective measures of TL (Herman *et al*., 2006). While the sRPE may indicate how an athlete feels, the underlying physiological stress arising from training may not be well represented by this subjective score, and therefore the sRPE is often used in conjunction with objective measures to describe the internal TL.

1.2.3 Heart rate

Monitoring heart rate (HR) is one of the most common means of assessing internal load in athletes (Halson, 2014). Heart rate shows a response to exercise intensity similar to that of oxygen consumption (positive, linear relationship) and can be used in a similar fashion to measure intensity when the workload is maintained at a steady state for several minutes (Hopkins *et al*., 1991). For calculating target heart rate, there are two methods. First, the percentage of the individual's maximum heart rate (%HR_{max}) is calculated as a percentage of peak heart rate or secondly, the heart rate is measured at a specified percentage of maximum $\dot{V}O_2$(Plews *et al.,*2014). Target HR is best determined in the laboratory by means of an incremental test. In this test, the oxygen uptake and the lactate concentration in the blood and corresponding heart rate are measured. From these results, the running/cycling speed and heart rate corresponding to aerobic, partly anaerobic or strongly anaerobic running/cycling can be determined (Karvonen & Vourimaa, 1988).

Several studies have reviewed the validity of HR monitors and practical usability (Burke & Whelan, 1987; Leger & Thivierge, 1988). Leger and Thivierge tested the validity of 13 different HR monitors against results of an ECG and found excellent correlations (r = 0.93 – 0.98). Due to the daily intra-personal variation in HR, in some cases, up to 6.5% for sub-maximal HR, factors such as hydration, environment and medication is important when HR is used to monitor internal TL (Halson, 2014).

In some instances, however, exercise cardiology overrules exercise physiology. The Frank Starling stall and cardiac creep are common examples of these and should be taken into consideration when using HR-monitors to determine work rate (Burke & Whelan 1987). The Frank Starling stall phenomenon occurs during sudden increase in work rate. The expected linear increase in HR is slower than expected due to the heart muscle's fibres ability to stretch further during exercise when filling up with blood and causing an increase in stroke volume, but not stroke frequency. The athlete will perceive higher effort, but the HR-monitor will “stall”.

Cardiac creep will occur during endurance, steady state exercise where the effort or pace is not increased, but the HR gradually increase over time. This is caused due to the blood volume that diminishes during prolonged training with the loss of fluids and the heart have to beat faster to maintain body temperature. The athlete will experience an increased HR that does not reflect exercise effort (Burke & Whelan 1987).

HR monitoring forms the basis for the quantifying of the physiological demands of endurance training (Borressen & Lambert, 2009). A comparison between individual competition HR values with those previously obtained in a laboratory test allows researchers and practitioners to determine the physiological demands of competition participation (Palmer *et al.,* 1994; Lucia *et al.,* 1999; Padilla *et al.,* 1999; Padilla *et al.,* 2001; Lucia *et al.,* 2003; Rodriguez-Marroyo *et al.,* 2003). This method has been used to estimate not only exercise intensity during competition, but also the exercise load during competitive cycling training situations by using the training impulse (TRIMP) as a unit that integrates exercise intensity and duration (Padilla *et al.,* 2008; Sanders e*t al.,* 2017).

1.2.4 Blood lactate concentrations

Blood lactate concentrations are sensitive to changes in exercise intensity and duration and blood lactate is a very useful measurement to determine intensity markers in the laboratory (Borresen & Lambert, 2008). Manzi *et al*. (2009) used the individual HR and blood lactate profiles determined during incremental treadmill tests to establish the individualised TRIMP (iTRIMP) values in long-distance runners. The iTRIMP equation uses a multiplying factor (*y)* to identify the intensity of the exercise bout that is based on the exponential rise in blood lactate levels with the fractional elevation of exercise above the resting heart rate. Thus, each athlete’s TL is calculated from his/her own physiological status at the time.

Seiler & Kjerland (2006) investigated the intensity distribution of junior cross-country skiers during a 32-day training camp. To identify and compare the distribution of training they used HR, sRPE and lactate measurements. The intensity distribution across endurance training sessions (n=318) was similar when based on heart rate analysis

(75 ± 3%, zone 1; 8 ± 3%, zone 2; 17 ± 4%, zone 3) or session RPE (76 ± 4%, zone 1; 6 ± 5%, zone 2; 18 ± 7%, zone 3). Similarly, from measurements of 60 consecutive sessions, 71% were performed at ≤ 2.0 mmol L^{-1} blood [lactate], 7% between 2 and 4 mmol.L^{-1}, and 22% at > 4 mmol L^{-1} (mean = 9.5 ± 2.8 mmol L^{-1}). These findings demonstrate that blood lactate concentrations are accurate measures of exercise intensity and TL.

Potential limitations in the utilization of lactate data for monitoring purposes are inter- and intra- individual differences in lactate accumulation. An individual's blood lactate response to exercise is affected by a number of factors, among other, environmental temperature, hydration status, diet, muscle glycogen content, previous exercise, amount of muscle mass utilised during exercise, as well as blood sampling methods and procedures (Borresen & Lambert, 2010).

1.2.5 Oxygen consumption

Oxygen consumption (VO_2) is the amount of oxygen taken up and utilised by the body per minute and is directly proportional to training intensity (Borresen and Lambert, 2010). This measure is also very useful in the laboratory, but the ability to measure oxygen consumption during training and competition to assess internal TL is extremely limited and impractical.

1.2.6 Training impulse methods

With the development of easy-to-use heart rate monitors, the ability to use HR to calculate internal TL became possible (Borresen and Lambert, 2009). Banister *et al*. (1991) proposed a training load quantification method termed training impulse (TRIMP), which is an integration of training duration (time in minutes), mean heart rate (HR) of the training session and an exponential factor to weigh the intensity of exercise.

TRIMP = duration of training (min) x ΔHR ratio x Y……………………..…………Eq.2.1

where ΔHR ratio = $HR_{ex} – HR_{rest} / HR_{max} – HR_{rest}$

and Y = $0.64e^{1.92x}$ for men, Y = $0.86e^{1.67x}$ for women, e = 2.712 and x = ΔHR ratio.

To quantify and reduce training intensity to a single figure/factor was very appealing to determine internal TL and have been used often in practice. Limitations have been noted, namely being dependent on HR monitors and assuming that HR is a good marker of exercise intensity. Another limitation of this technique is that the equation depends on a weighting factor (Y) that was established from the lactate profiles of trained athletes (five men and five women) that make the equation generic for gender (Akubat *et al.,* 2012). Literature has also found that Banister's TRIMP scores work better with steady-state heart rate measures, limiting the accuracy with exercise of an interval nature (Borresen & Lambert, 2009).

The search of the optimal measuring tool has compelled researchers to adapt by compiling other formulas, Banister's TRIMP, like Edward's TRIMP, which uses accumulated exercise time in five arbitrary HR zones multiplied by a weighting factor (Edwards, 1993); Lucia's TRIMP, which uses three HR zones that are based on individually determined lactate thresholds (Lucia *et al*., 2003) and Stagno's TRIMP that uses a five zone "team" threshold for hockey players (Stagno *et al*., 2007). An individualised TRIMP has been used for runners (Manzi *et al*., 2009) and tested in soccer players (Akubat *et al*., 2012). For this measure (iTRIMP), the individual's own data from the incremental test in the laboratory is used to calculate the relationship between the fractional elevation in HR and blood lactate concentration, with each HR data point measured during training weighted according to this relationship.

iTRIMP (AU) $= D(min) \times \Delta HR_{ratio} \times y_i$……………………………………………..Eq.2.2

Where:

y_i = individual relationship between ΔHR_{ratio} and [La-]b to increasing exercise intensity using an exponential model. This method cancels out the limitations of arbitrary zones and weighting factors as used in Edward's TRIMP, as well as generic weightings used in Banister's and Stagno's TRIMP (Manzi *et al*., 2009).

1.2.7 Comparison between different internal training load methods

Some studies have validated the TL methods by correlating them with each other. Two studies (Impellizzeri *et al.,* 2004; Alexiou & Coutts, 2008) examined relationships between the HR-based methods (Edward's TRIMP, Lucia's TRIMP and Banister's TRIMP) and sRPE in soccer players. Impellizzeri *et al*, (2004) studied the TL of young soccer players during seven weeks of training including one match per week and reported significant relationships ($r = 0.50$ to $r = 0.85$; $P < 0.01$) between sRPE and all heart rate methods. Alexiou & Coutts (2008) studied elite women soccer players for a 16-week period and found statistically significant correlations between sRPE and three HR-based methods ($P < 0.05$). However, in both studies, the different methods were not correlated with changes in fitness or performance (Akubat *et al*., 2012). Determining the relationships between the various TRIMP scores and changes in fitness and performance will assist in developing an appropriate TL measuring tool for different sports disciplines.

A few studies have used changes in fitness or performance to validate the TL methods in runners (Manzi *et al*., 2009), youth soccer players (Akubat *et al*., 2012) and cyclists (Sanders *et al*., 2017). Manzi *et al*. (2009) concluded that in well-trained distance runners the iTRIMP method relates better to changes in aerobic fitness and endurance performance than Banister's TRIMP. Improvements in running speed (%) at 2 mmol L^{-1} ($r = 0.87$; $P = 0.005$) and 4 mmol L^{-1} ($r = 0.74$; $P = 0.04$) concentrations (OBLA) were significantly related to weekly iTRIMP sum. The iTRIMP was also significantly related to 5000 m ($r = -0.77$; $P = 0.02$) and 10,000 m track performances ($r = -0.82$; $P = 0.01$).

Akubat *et al.* (2012) used change in fitness/ performance to validate the TL methods used in youth soccer players. They calculated the average weekly training load by determining sRPE, Banister's TRIMP (bTRIMP), Stagno's TRIMP and individualised TRIMP (iTRIMP) and correlated the methods to each other and to the performance measured as the percentage change in the running velocity, blood lactate concentrations and HR at 2 mmol L^{-1} (LT_1) and 4 mmol L^{-1} (LT_2). bTRIMP was significantly correlated with sRPE ($r = 0.75$; $P = 0.02$) and Stagno's TRIMP ($r = 0.92$; $P < 0.001$). The percentage change in vLT_1 was significantly correlated to mean weekly iTRIMP ($r = 0.67$; $P = 0.04$). These results suggested that iTRIMP related better to changes in vLT_1 in youth soccer players than other methods (Akubat *et al*., 2012).

Sanders *et al*. (2017) investigated relationships between different TL methods and aerobic fitness and performance in competitive road cyclists. Banister's TRIMP, Edward's TRIMP, individualized TRIMP, Lucia's TRIMP (luTRIMP), and sRPE were used to record the internal TL. Performance was measured using an eight-minute time trial before and after a 10-week training period. They found large to very large relationships (r = 0.54 – 0.81) between TL and changes in submaximal fitness variables (i.e. power output at 2 and 4 $mmol.L^{-1}$) for all TL calculation methods. The strongest relationships with changes in aerobic fitness variables were observed for iTRIMP (r = 0.81 [95% CI 0.51–0.93, r = 0.77 [95% CI 0.43–0.92]) and the Training Stress Score™ (TSS). r = 0.75 [95% CI 0.31–0.93], r = 0.79 [95% CI 0.40–0.94]). The strongest dose-response relationships with changes in the eight-minute time trial test were observed for iTRIMP (r = 0.63 [95% CI 0.17–0.86]) and luTRIMP (r = 0.70 [95% CI 0.29–0.89). They concluded that TL methods that incorporate individual physiological weighing factors are best to use in well-trained cyclists.

A study by Wallace *et al.* (2014) that assessed the validity of different methods for quantifying TL, fitness and fatigue in well-trained runners monitored seven endurance runners for 15 weeks. HR, running pace and RPE were used to monitor training sessions. TL was calculated using the sRPE, Banister's TRIMP and the running training stress score (rTSS). Performance was recorded weekly by means of a 1 500-m time trial, fitness was measured using submaximal HR and resting HR and fatigue was measured using the profile of mood states and HR variability. A mathematical model was applied to training data of each runner to provide individual estimates of performance, fitness and fatigue. Relationships between the modelled and actual weekly performance, fitness and fatigue were correlated for each runner. Correlations were r = 0.70 ± 0.11 for the rTSS, r = 0.60 ± 0.10 for sRPE and r = 0.65 ± 0.13 for TRIMP. The within-individual correlations between each of these methods were not significantly different between methods (P = 0.33). They concluded that the TL methods used in this investigation are appropriate for quantifying endurance training dose in well-trained runners.

In a quest to find the gold standard to quantify TL in endurance athletes, Wallace *et al*. (2014) designed an experimental study to determine the validity and reliability of methods used to quantify TL. Ten recreational athletes performed 18 steady state and interval sessions in a controlled environment over a 6-week period. VO_2 and HR were measured throughout all sessions, whereas blood lactate concentrations and RPE measures were taken every six minutes during sessions. sRPE was collected after each session. Banister's TRIMP and Lucia's TRIMP were used to calculate the total TL of the athletes. The mean VO_2 was used as the criterion measure of internal TL. The total work (kilojoules) performed during each training session was calculated and used as a measure of external work load All ten individuals demonstrated correlations between VO_2 and external load (r = 0.88 - 0.97), HR (r = 0.65 – 0.90) and sRPE – based methods (r = 0.55 - 0.89) that were statistically significant ($P < 0.05$). A poor level of test-retest reliability was shown for Banister's TRIMP (5.6% coefficient of variance [CV]), Lucia's TRIMP (10.7% CV) and sRPE (28.1% CV). Good reliability was shown for HR (3.9% CV). They concluded that external work load is the most valid and reliable quantification of TL in endurance athletes.

C. TRAINING INTENSITY DISTRIBUTION

Stöggl & Sperlich (2015) reviewed the training intensity distribution (TID) of well-trained and elite athletes. They reported that most retrospective studies on these athletes showed a 'pyramidal' training intensity distribution (TID), with high volumes of low-intensity training. A 'polarised' training distribution has been used successfully by some elite athletes during certain phases of the season. However, experimental studies lasting 6 weeks to 5 months demonstrated better responses to polarised TID when compared with TID that emphasised lactate threshold training and high volume low-intensity training.

Reasons provided for the better results of polarised training were that the combination of high volumes of low-intensity training, with an adequate amount of high-intensity sessions, improves endurance performance with potentially less autonomic and hormonal stress and boredom (Stöggl & Sperlich, 2015). Other reasons for the variety in TID amongst endurance disciplines might be the use of different methods to determine the intensity zones or the highly individual training responses. No "optimal" TID has been identified and more investigations over extended periods of time in many different disciplines are needed to address this issue.

1. Intensity distribution markers in endurance sport

Even though there is general agreement on the physiological factors contributing to elite endurance performance, there is an ongoing debate on how to structure and organise the combination and distribution of intensity and duration for optimal performance (Seiler, 2010).

Low-intensity training (LIT), lactate threshold training (LT), and high-intensity aerobic training (HIT) are well-known terms to describe different levels of the intensity scale. Both LIT and HIT have positive effects on aerobic endurance, measured as maximal oxygen consumption (VO_2 max) or power output at lactate threshold (Helgerud *et al*., 2001, 2007; Esteve-Lanao *et al*., 2005; Ingham *et al*., 2008). It is also evident that a combination of LIT and HIT is necessary to obtain optimal development of endurance performance (Esteve-Lanao *et al*., 2007; Laursen, 2010; Seiler, 2010).

Describing and comparing training intensity distributions require a common intensity scale (Seiler, 2010), which is typically broken into training zones according to physiological markers obtained during a laboratory exercise test.

1.1 5-Zone scale

Originally, the Norwegian Olympic Federation developed the 5-zone scale. On this scale, zone 1 represents training between 50-59% of VO_2max, zone 2, 60 – 69% VO_2max, zone 3, 70-79% VO_2max, zone 4, 80-89% VO_2max and zone 5, 90-100% VO_2max. Tønnessen *et al*. (2014) studied the TID of elite cross–country skiers and biathletes for a whole year. Norwegian athletes use a 5-zone scale to identify their training intensities which were individually anchored around blood lactate concentrations. Zone 1 and 2 of this 5-zone scale represents blood lactate levels of 0.8-2.5 $mmol.L^{-1}$ which is similar to the 3-zone scale (zone 1 >2 $mmol.L^{-1}$) They combined zone 1 and 2 training and called it low-intensity training (LIT), while zone 3 compared to zone 2 with blood lactate levels between 2.5 and 4 $mmol.L^{-1}$. Zone 4 and 5 was combined as high-intensity training to compare their results with the majority of studies using the 3-zone intensity scale. They reported that over the whole year, the majority of training was done at low intensities (91%), while 9% was high intensity training.

1.2 3-Zone scale (Time–spent-in-zone)

Lucia *et al.* (1999) were the first to use individual-specific zones based on laboratory determined physiological markers to identify the intensity distribution as a "time-spent-in" zone when they analysed the data of eight professional cyclists during the Tour de France. The researchers identified two reference heart rates corresponding to each cyclist's ventilator thresholds (VT_1 and VT_2) to establish three phases, namely phase I <VT_1, phase II (VT_1 –VT_2) and phase III>VT_2. Cyclists wore HR-monitors and the average time spent by each cyclist in each of the three phases was recorded. They noted that the overall contribution of moderate (VT_1 to VT_2) and high-intensity exercise (>VT_2), were 23% and 7%, respectively. These values used are substantially lower than that of light, aerobic exercise (< VT_1) (70%). They also stated that a clear distinction must be made between the different type of stages during the race (i.e. easy, flat routes vs. mountain stages or time trials).

This three-phase method fixes the change from one zone to the next to definite, individual physiological markers and is more accurate when determining the individual load at different intensities (Lucia *et al*., 1999). Since then, this 3-zone "time-spent-in zone" method has become very popular in studies on endurance athletes and have been used in runners (Billat *et al.,* 2001, 2003; Esteve-Lanao *et al.,* 2007), cyclists (Lucia *et al*., 2003), sprint skiers (Sandbakk *et al.,* 2012) and Ironman triathletes (Neal *et al.,* 2013). The refined 3-zone method anchor the zones as follows: Zone 1 refers to low-intensity training below the first ventilation threshold (VT_1) or below LT_1, zone 2 is moderately high intensity between VT_1 (LT_1) and VT_2 (LT_2) and zone 3 denotes high-intensity exercise above VT_2 or LT_2. A limitation of the time-in-zone approach is that it underestimates the time spent working at high intensity due to heart rate lag time during intervals (Seiler, 2010). In other words, an athlete may have already exercised for some time at a high intensity before his/her heart rate actually elevates into zone 3. Limitations of "the-time-spent-in-zone" method lead to the development of the session goal approach by Seiler & Kjerland (2006).

1.3 Session goal method

The session goal approach is a categorical approach that assigns the entire session into a single intensity zone with the assumption that the main section of the session will determine the physiological stress (Sanders *et al*., 2017). A categorical approach likely gives a realistic picture of the total training intensity distribution (TID) over the long term (Sylta *et al.,* 2014). This method has been used in elite cross-country skiers (Seiler & Kjerland, 2006; Sandbakk *et al*., 2011; Tonnessen *et al.,* 2014), well-trained runners (Esteve-Lanao *et al*., 2007) and in well-trained runners, cyclists and cross-country skiers (Stöggl & Sperlich, 2014). The session goal approach provides a true reflection of the time spent at high intensities. However, disadvantages of this approach are that coaches and athletes may not be familiar with this categorical method of analysing training data and the analysis is more complicated and time-consuming (Borressen & Lambert, 2008).

1.4 Session rate of perceived exertion method

Another method that is widely used to quantify the training intensity is the session RPE (sRPE) method. Athletes record their perceived exertion ~30 minutes after the training session on a 10-point scale. Their rating is then used to establish 3 intensity zones. Zone 1:≤4; zone 2: include ratings of 4-7; and zone 3:≥7. These three training intensity zones are different in terms of stress load, motor unit involvement and duration to fatigue (Seiler & Kjerland, 2006). Time spent in these zones is subsequently used to evaluate the training intensity distribution over a training period.

Seiler & Kjerland (2006) compared the sRPE method to the session goal approach and the blood lactate zones and found no statistically significant difference in TID between the three methods. They also determined that the intensity zone determinations based on sRPE and the session–goal HR method was in agreement for 92% of all sessions. In the remaining sessions, the sRPE method identified lower intensity zones than heart rate, probably because of heart rate drift over the course of a longer workout. Thus, the authors concluded that sRPE is a useful method of monitoring daily TL and demonstrated similar results than TL measures using HR and blood lactate measures.

sRPE may be particularly useful when the actual intensity of the exercise is low, but the intensity of the session is increased by its duration or the training status of the athletes. The sRPE method is easy to use and one does not need any technological devices. A limitation of this method is that the sRPE could approach maximal values during a session when the objective exercise intensity remains within a clear submaximal zone (Sylta *et al.,* 2014). This scenario is likely when the athlete approaches, or is already in a state of overtraining.

2. Training intensity distribution models

Patterns of TID have been presented in previous descriptive studies. These include the high-volume, low-intensity training pattern, the threshold training model, the polarised-training model and the pyramidal model (Stöggl & Sperlich, 2015). As it is difficult to involve elite athletes in scientific experiments, most of the studies dealing with TID in well-trained to elite athletes are based on retrospective analysis of their training (Stöggl & Sperlich, 2015). The TID of endurance athletes is also affected by the periodization period during which the data is collected. These periods can vary drastically from one sports discipline to the next and the nature of the competition duration (i.e. one day/ multi-day or a competition phase).

2.1 High-volume low-intensity training model

Figure 2.1 illustrates a typical high-volume, low-intensity model. In this case, most training occurs in zone 1 with very little training in zone 2 and 3. This type of pattern has been recorded by Robinson *et al.* (1991) for long distance runners over a period of eight weeks where races and interval training were excluded from the analysis. Lactate threshold markers were used to establish the intensity zones.

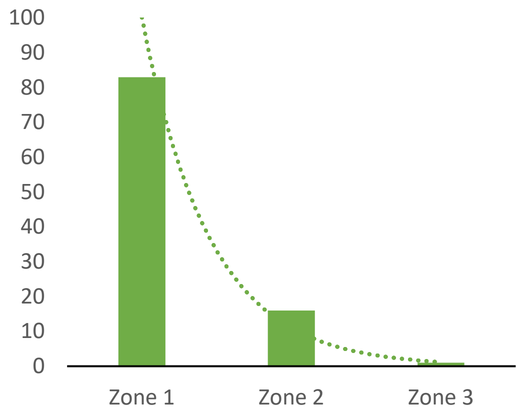

Figure 2.1 High-volume low intensity model (graph constructed from own data)

Seasonal analysis of cross-country skiing (Tønnessen *et al*., 2014) and cycling (Schumacher and Mueller, 2002) also presented a high-volume, low-intensity TID. Tønnessen used the 5-zone scale to analyse the TID of Norwegian cross-country skiers over a year using the session goal approach. They found that 87% of the training occurred in zone 1 and 5% in zone 2 with very little training in zones 3, 4 and 5. Schumacher and Mueller (2002) analysed the TID of the German pursuit team cyclists over the year leading up to the 2000 Olympics. As the TID of the whole year was combined, the 94% time spent in zone 1, with 4% and 2% in zone 2 and 3, confirmed the suggestion that TID should rather be analysed during different phases of the periodization plan to identify different TID models within the periodization cycles (Stöggl & Sperlich, 2015).

2.2 Threshold training model

Fig. 2.2 depicts the threshold training model (THR). In this model, athletes perform most of their training at intensities at or close to their blood lactate threshold (e.g. 4 mmol.L^{-1}), or Zone 2.

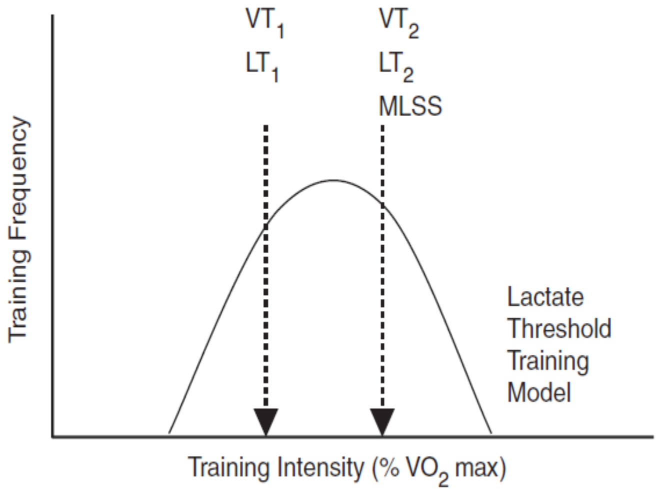

Figure 2.2 Threshold training model

[From**:** Seiler & Kjerland (2006). Quantifying training intensity distribution in elite endurance athletes: is there evidence of an "optimal" distribution? *Scandinavian Journal of Medicine & Science in Sports* 16(1):50.]

The threshold training model has been observed in untrained individuals training at their lactate threshold intensity in various studies (Kindermann *et al*., 1979; Denis *et al*., 1984; Londeree, 1997; Gaskill *et al*., 2001) and has been associated with improvements in exercise performance. A possible reason why less experienced athletes follow this model is that they tend to train harder than prescribed during low-intensity sessions and not hard enough during prescribed high-intensity sessions (Seiler, 2010).

2.3 Polarised training model

Figure 2.3 is an illustration of the polarised-training model. This model suggests that the bulk of the training (~75%) takes place at intensities much lower than lactate threshold (zone 1) and 15-20% clearly above the lactate threshold (zone 3), with very little training taking place at the lactic threshold (zone 2).

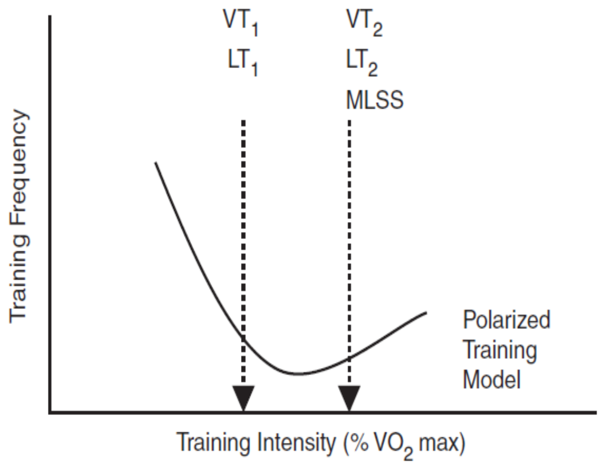

Figure 2.3 Polarised Training model

[From**:** Seiler & Kjerland (2006). Quantifying training intensity distribution in elite endurance athletes: is there evidence of an "optimal" distribution? *Scandinavian Journal of Medicine & Science in Sports* 16(1):50.]

This model is used by well-trained athletes (Billat *et al*., 2001; Seiler and Kjerland, 2006; Esteve-Lanao *et al*., 2007; Tønnessen *et al*., 2014) and was associated with improved exercise performance.

A possible reason for following this approach may be that large volumes of moderately to hard intensity training on most days may increase the risk of overtraining and fatigue (Seiler & Kjerland, 2006). Changing the TID from a threshold training pattern to a polarised TID lead to improvements in physiological capability and performance of speed skaters, cyclist and runners (Yu *et al*., 2012; Neal *et al*., 2013; Munoz *et al*., 2014). Improved performances were recorded by Yu *et al.* (2012) in national, World Cup and Olympic competitions for all skaters in their study, as well as a decrease in blood lactate levels after competitions.

Neal *et al*. (2013) assessed 12 male cyclists who completed two 6-wk training periods: *1)* a polarised model; 80%/0%/20% TID and *2*) a threshold model; 57%/43%/0% TID. The training intensity zones were identified for each individual at LT_1 and LT_2, and the time-in-zone- method was used to record the TID. Endurance performance (40-km time trial), peak power output (PPO), lactate threshold (LT) as well as high-intensity exercise capacity (95% maximal work rate to exhaustion) increased significantly over both training periods. However, improvements were greater following the polarised training model than the threshold training model for PPO [mean (±SE) change of 8 ± 2%

vs. 3 ± 1%, $P < 0.05$], LT [9 ± 3% vs. 2 ± 4%, $P < 0.05$] and high-intensity exercise capacity [85 ± 14% vs. 37 ± 14%, $P < 0.05$].

Munoz *et al.* (2014) investigated the effect of a polarised training model versus a threshold model in 30 recreational runners. They used the 3-zone intensity distribution method and anchored the zones according to VT_1 and VT_2. The time-in-zone-method was used to determine the TID and a 10-km race on the same course was used to test performance before and after the training intervention. Both groups significantly improved their 10-km time (39 min 18 s ± 4 min 54 s vs. 37 min 19 s ± 4 min 42 s; $P < 0.01$ for the group following the polarised training distribution; 39 min 24 s ± 3 min 54 s vs. 38 min 0 s ± 4 min 24 s; $P < .001$ for the threshold model group. The improvements of 5.0% and 3.6%, respectively translates to ~ 41 s difference after the training intervention.

Seiler & Kjerland (2006) described the TID of Norwegian junior level cross-country skiers over a 32-day period prior to their competition phase as "polarised", with the distribution of their training in zone 1: ~75%; zone 2: 5-10%; and zone 3: 15-20%. In a longitudinal retrospective investigation (1970 -2001) by Fiskerstrand and Seiler (2004) international rowers were asked to describe their TID across their competitive years in ratios of low intensity vs. high-intensity training. Although high-intensity training decreased from ~ 50% in the 1970's to ~31% in the 1990's, it still demonstrated a polarised TID.

Billat *et al*. (2001) analysed the training of elite French and Portuguese marathon runners. Training intensity was identified according to specific velocities: > marathon velocity; = marathon velocity and < marathon velocity and runners kept training logs for the duration of 8 weeks before the competition. TID for this period was a distribution in zones 1, 2 and 3 of 78%/4%/18%, thus also demonstrating a polarised distribution.

2.4 Pyramidal training model

Figure 2.4 depicts the pyramidal training model. Here, the distribution presents high volumes of training in zone 1, substantial amounts of zone 2 training and less training in zone 3. The majority of descriptive studies in endurance sport demonstrated this "pyramidal" distribution (Sylta *et al*., 2014). Elite athletes in rowing (Hartmann *et al*., 1990; Plews *et al*., 2014), running (Billat *et al*., 2003; Esteve- Lanao *et al*., 2005, 2007; Manzi *et al*., 2015), cycling (Lucia *et al.,* 2000; Schumacher & Mueller, 2002, Zapico *et al*., 2007;

Sanders et al., 2017), swimming (Mujika *et al*., 1995) and cross-country skiing (Tønnessen *et al*., 2014) followed pyramidal TID in different training periods during their periodization plan.

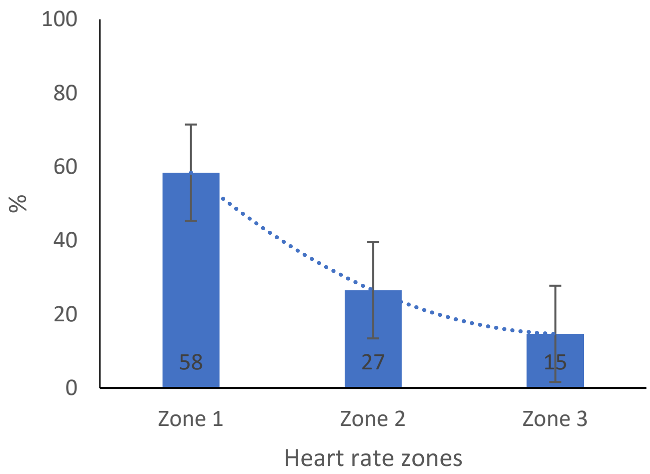

Figure 2.4 Pyramidal model (graph constructed from own data)

Relevant to the current study, research on cycling, as well as studies taking place during the pre-competition preparation phase, will be discussed.

In a 7-month study on professional cyclists preparing for the Olympic Games, Lucia *et al*. (2000) studied the TID for the active rest, pre-competition and competition phases. The TID was quantified using the HR time-in-zone method. The distributions for the rest phase for zone 1, 2 and 3 were (88%/11%/2%), pre- competition phase (78%/17%/5%) and competition phase (77%/15%/8%) were all "pyramidal", with very high volumes of zone 1 training in the active rest phase and an increase in zone 3 training closer to the competition. During the different phases, the total training volume increased from 267 km to 713 km to 810 km per week, respectively.

Similar findings as above were reported by Zapico *et al*. (2007). They analysed the TID of elite U23 cyclists over one season. The period was split into winter and spring training and the HR time-in-zone method was used to determine the intensity zones. The winter TID for zone 1, 2 and 3 was 78%/20%/2% and the spring 70%/22%/8%, showing similar pyramidal distributions to Lucia *et al.* (2000).

Schumacher and Mueller (2002) analysed the TID of the German pursuit team over the year leading up to the 2000 Olympics. The combined TID of the whole year showed that 94% of time spent in zone 1, and 4% and 2% in zone 2 and 3, respectively. During the pre-competition phase, regional- and national runners, like the cyclists, demonstrated a pyramidal TID in zone 1,2 and 3 71%/21%/8% over a 6-month training period (Esteve-Lanao *et al*., 2005). These results confirmed the suggestion that TID should rather be analysed during different phases of the periodization plan (Stöggl & Sperlich, 2015).

Esteve-Lanao *et al.* (2007) also conducted an experimental study on sub-elite runners over a 5-month period. Twelve runners were randomly assigned to two separate groups performing equal amounts of zone 3 training (8.4%). The groups varied in the amount of zone 1 training performed (81% vs. 67%) and zone 2 training (12% vs. 25%). The training loads (TRIMP scores) were the same for both groups. The magnitude of improvements in running performance was significantly greater (P = 0.03) in the group that completed higher volumes of their training in zone 1, compared with the group that completed high volumes of training in zone 2 (Esteve-Lanao *et al*., 2007). These results provided evidence that it is better to have a TID with high volumes of zone 1 training, provided that sufficient amount of zone 3 training is included for the pending competition phase, described as a pyramidal model.

As mentioned before, Neal *et al.* (2013) reported similar results than Esteve-Lanao *et al.* (2007), but with well-trained cyclists. As described in the polarised distribution section above, Munoz *et al*. (2014) found improvements in 10-km running speeds of recreational runners following a polarised and threshold model, with more improvements recorded for the runners following the polarised model.

A study by Manzi and colleagues (2015) investigated the hypothesis that well-trained athletes follow a polarised training model, whereas non-elite athletes follow a lactate threshold model for TID. They studied the intensity distribution of seven long distance recreational runners who were preparing for a marathon, over a period of five months. They used the three-zone intensity model to determine the TID. The TID recorded was 76%/17%/6%, demonstrating that non-elite endurance athletes followed a pyramidal TID preparing for a marathon.

The studies described above analysed the TID during preparation or competition phases. Limited studies are available on the TID of multi-stage races. Knowing the intensity distribution of the race may inform the choice of distribution during the preparation.

3. Training intensity during competition

Wirtnitzer & Kornexl (2008) examined the exercise intensity of seven amateur cyclists during the Transalps mountain bike (MTB) challenge over 8 days. Laboratory tests were done to establish four intensity zones. These HR-related zones were established for each cyclist at specific lactate concentrations. Zone 1: >2 $mmol.L^{-1}$, zone 2: between 2 $mmol.L^{-1}$ and 4 $mmol.L^{-1}$; zone 3: between 4 $mmol.L^{-1}$ and 6 $mmol.L^{-1}$ zone 4 above 6 $mmol.L^{-1}$. The rating of perceived exertion (RPE) was also recorded after each stage (RPE Borg scale 6-20). They found that cyclists spent 79-85% of total race time in zones 1 and 2 and 27-36% in zones 3 and 4, with a mean RPE of 16.1 over the 8 days. Possible limitations of the study are that only 7 athletes completed the race with 8 recorded HR stages each.

In a study by Lucia *et al.* (2003) to determine which of the Tour de France or the Vuelta an Espanã was the hardest, the intensity distribution of both races demonstrated a pyramidal pattern, with a distribution of 75%/21%/ 4% in the Tour and 71%/24%/5% for the Vuelta an Espanã across the 21 stages.

D. CONCLUSION

The ABSA Cape Epic is a gruelling 8-day MTB race that requires extended planning with regards to training. Of the 700 paired teams that start the race, approximately 25% do not complete the race. Reasons may include technical problems, personal circumstances or an accident during the race; however, through personal communication with Cape Epic finishers many stated that their preparation for the race was inadequate. Preparation for a race like this requires a well-structured individualised plan, monitoring of the plan and structural feedback. Although many of these amateur riders do follow an individualised plan, many still rely on the media and generic training plans that might lead to inadequate preparation and poor performance.

Monitoring an athlete’s training load is essential for determining whether they are adapting to their training program, understanding individual responses to training, assessing fatigue and the associated need for recovery, as well as minimising the risk of nonfunctional overreaching, injury or illness (Bourdon *et al.,* 2017). Evident from the literature discussed in this chapter is that there are various methodologies to determine the TL of endurance athletes and that some have been used with marginal success in certain sports disciplines.

The majority of researchers concur that an integrated approach to training load quantification is important and therefore a combination of both internal and external training load should be used to provide greater insight into the training stress of individual athletes. The methods used in endurance sport include internal measures such as RPE, training impulse (TRIMP), HR and its derivates, blood lactate concentrations and oxygen consumption, as well as external measures such as speed, power output, training time and distance. Even though there is no single, definitive marker that can accurately measure an individual's response to training, the development and validation of equipment and methods to quantify endurance training and competition loads have been a focus in recent years. Thus, efficient result reporting and translation of data into simple outcomes on a daily basis and for each individual athlete, is now possible.

In a training plan, the TL will be manipulated by adjusting the distribution of the training intensity throughout the training plan. There is an ongoing debate on how to structure and organize the combination and distribution of intensity and duration to achieve optimal performance. Evidence from the literature discussed shows that there is still a non-uniform training intensity distribution among endurance disciplines and that an optimal TID among elite athletes is yet to be identified. However, various studies demonstrated that depending on the periodization phase of the analysis, the polarised distribution was effective for some elite athletes and superior for programs lasting 6 weeks to 5 months before the competition. Most retrospective studies reported a pyramidal distribution with high volumes of low-intensity training.

With regards to the variety in training load distribution in endurance athletes and the lack of literature on multi-day mountain biking, it will be of great interest to investigate the training load distribution of individuals in preparation for the Cape Epic race, as well as determine if the choice of TID influenced their race performance.

CHAPTER 3

PROBLEM STATEMENT

A. SUMMARY OF THE LITERATURE

The Cape Epic is one of the most prestigious and toughest multi-day mountain bike (MTB) races in the world with world champions competing for UCI points, while amateur and recreational cyclists take on the challenge too. For a challenging event like this, substantial amounts of training are required, and cyclists often consult coaches and sports scientists for advice. However, the lack of literature available on multi-day endurance event preparation and consensus on what is best practice for day to day training for endurance athletes makes it problematic for sports scientists and coaches to adequately advise these MTB cyclists.

The training prescribed by the coach can be manipulated by the frequency, duration and intensity of sessions and is dependent on the cyclist's initial fitness level, experience, time available for training and the period until the targeted event. Training load (TL) has two components, namely external and internal load. The external load is the "dose" of training, while the internal load is the physiological and psychological stressors imposed on the cyclist during training or competitions. Quantifying both external and internal workload is important because it allows the coach to evaluate the "dose-response" balance and adjust the individual training program accordingly. Multiple methods to determine training load have been suggested, including physiological markers such as oxygen uptake and blood lactate concentrations, speed and power output measurements, training impulse (TRIMP), session RPE and the use of global positioning systems (GPS) (Lambert & Borresen, 2010; Mujika, 2017). For a training load measure to be valid and have practical application, the method used must be related to an outcome of importance. In most sport, these outcomes are fitness, fatigue or performance.

The first study to investigate the use of a mathematical model to measure internal training load was introduced by Banister in 1975 (Banister *et al*., 1976). In this original model, different levels of swimming training were assigned to different intensity factors that were used to calculate TL in arbitrary units (AU). This mathematical model was complicated and difficult to use. In 1991 Banister developed the training impulse (TRIMP) method. Banister's TRIMP (bTRIMP) was an integration of time, intensity and relative weighting of the intensity of exercise to describe the exercise "dose" as a single number. Since then the TRIMP method has been redefined, including two summated-zone TRIMP methods proposed by Edwards (Edwards, 1993) and Lucia (Lucia *et al*., 2003), where the time spent in pre-defined HR zones are weighted using linear weighting factors and secondly, the individualized TRIMP (iTRIMP) method proposed by Manzi *et al*. (2009) where the individual's HR–blood lactate relationship is used to calculate the exponential factor for weighting exercise intensity.

However, the application of HR as a measure of intensity has several limitations. HR response may be a relatively poor method for evaluating intensity during very high-intensity exercise such as interval training, due to cardiovascular drift (caused by dehydration), environmental temperature and humidity or muscle glycogen depletion (Padilla *et al.,* 2008). Systemic dehydration and plasma volume shifts during competitive events, resulting in a decline in plasma volume, have been defined as confounding factors in the HR response during actual events (Bescós *et al.,* 2011). Another limitation is the need for expensive equipment that is not suitable for all sports (Wallace *et al*., 2014). Foster and Florhaug (2001) developed the easy-to-use session rate of perceived exertion (sRPE) method that excludes heart rate (HR) measurements. The sRPE method has been used successfully to measure the internal training load of athletes at steady state exercise and compared favourably with more complicated methods of quantifying internal TL in endurance athletes. The most common methods used in cycling are HR-based TRIMP methods, sRPE and power output ("Training Stress Score™") (Sanders *et al*., 2017).

Sanders *et al*. (2017) recently recorded the TL of well-trained cyclists using bTRIMP, Lucia's TRIMP, Edwards's TRIMP, iTRIMP and sRPE. The power output at 2 mmol.L^{-1} and 4 mmol L^{-1} blood lactate concentrations before and after a ten-week intervention period were recorded for all the TL methods. The iTRIMP method had the strongest relationships with changes in aerobic fitness variables (r = 0.81 [95% CI: 0.51 - 0.93], r = 0.77 [95% CI 0.43 - 0.92]), demonstrating the superiority when calculating the TL using individualized weighting factors. Moderate relationships were also found between sRPE and power output at 2 mmol.L^{-1} and 4 mmol.L^{-1} (r = 0.52 and 0.51, respectively) and bTRIMP and power output at 2 mmol.L^{-1} (r = 0.52). These results suggest that bTRIMP and sRPE are also valid methods to determine TL in cyclists.

In an attempt to establish the criterion validity and test-retest reliability of bTRIMP, Lucia's TRIMP and sRPE, Wallace *et al.* (2014) studied ten recreational athletes and compared their oxygen consumption (VO_2) with external work (measured in kilojoules), HR and sRPE. They found statistically significant correlations between VO_2 and external work (r = 0.88 - 0.97), HR (r = 0.65 - 0.90) and sRPE (r = 0.55 - 0.89), demonstrating that all these factors can be used to measure training load. A poor level of test-retest reliability was shown for bTRIMP (coefficient of variance [CV] 15.6%]), Lucia's TRIMP (CV = 10.7%) and sRPE (CV = 28.1%). Therefore, it is concluded that the lack of a single physiological marker to measure internal training load (TL), and no scientific consensus or "gold standard" to measure it, makes the validation of the TL-methods challenging.

Training intensity and its distribution over time is one essential variable for prescribing the training load. The training intensity for cyclists is typically divided into 3 zones using parameters such as heart rate, blood lactate levels, gas exchange, power output or velocity and/or perceived exertion. Zone 1 refers to low-intensity training below the first ventilation threshold (VT_1) or below the first lactate threshold (LT_1), zone 2 is moderately high intensity between VT_1 (LT_1) and the second ventilation or lactate threshold (VT_2, LT_2) and zone 3 depicts high-intensity exercise above VT_2 or LT_2.

In these 3-zone models, it is assumed that the ventilation and lactate thresholds (one and two) take place at the same work intensity. Although LT and VT do not represent the same physiological events, they often occur nearly simultaneously. Kindermann *et al*. (1979) first described the ''aerobic- anaerobic transition'' beginning with the aerobic threshold, marking the first increase in blood lactate and ending with the anaerobic threshold, corresponding to the maximal lactate steady state. Studies using breath-by-breath gas exchange measurements (Lucia *et al*., 1999) have identified two specific ventilatory changes that correspond to the aerobic (LT_1) and anaerobic (LT_2) thresholds introduced by Kindermann and colleagues. These reproducible ventilatory changes are associated with simultaneous changes in blood lactate, electro cardiogram (ECG) amplitude, and catecholamine concentration (Chwalbinska-Moneta *et al.,* 1998). While questions remain regarding the cause–effect relationship among ventilatory and lactate thresholds, both appear to provide useful laboratory markers for the identification of three training intensity zones that are distinguished by meaningful differences in sympathetic stress load, motor unit involvement and duration to fatigue.

Training intensity distribution (TID) according to the three intensity zones has been described by Seiler and Kjerland (2006) as either a threshold model or a polarised model. The threshold model suggests that most training takes place in zone 2, whereas the polarised model proposes that most training takes place in zone 1 and almost 20% of the training takes place in zone 3. Recently, Stöggl and Sperlich (2015) reviewed studies on the training intensity distribution of well-trained to elite athletes. Subsequently, they added two additional models, namely the "high volume, low-intensity" distribution pattern and the "pyramidal" pattern to describe the training intensity distribution of athletes. The high volume, low-intensity model demonstrates high volumes of zone 1 training with very little training in zones 2 and 3, while the pyramidal model depicts most training in zone 1, less in zone 2 and the least training in zone 3.

Different methods to quantify the TID of endurance athletes have been used successfully. These include the percentage time-in zone method, the session goal method and the sRPE method. The choice of method used might influence the distribution curve. Sylta *et al*. (2014) quantified the TID of elite cross country skiers according to the time-in-zone method, a mixed time-in-zone and session goal method, as well as the session goal method. Distribution according to the time-in-zone method was 96.1% in zone 1, 2.9% in zone 2 and 1.1% in zone 3. For the mixed method it was 95.5%, 2.4% and 0.8%, respectively, while the distribution for the session goal method in zone 1, 2 and 3 was 86.6%, 11.1% and 2.4% respectively. They suggested conversion factors from the time-in-zone method and the mixed method to session goal method (and vice versa) of 0.9/1.1, respectively in zone 1 and 3.0/0.33 for zone 2 and 3. These results can give coaches a practical way to analyse data that used different quantification methods.

To date, the TID of elite nationally ranked and world class athletes during their preparation, pre-competition and competition phases have been reported. These athletes competed in rowing (Hartmann *et al*., 1990; Steinacker *et al*., 2000; Guellich *et al*., 2010), running (Robinson *et al*., 1991; Billat *et al*., 2001), cycling (Lucia *et al*., 2000) and cross-country skiing (Seiler and Kjerland, 2006; Sandbakk *et al*., 2011; Tonnessen *et al*., 2014). Findings indicate that the majority of elite endurance athletes followed a polarised model. Training intensity based on seasonal analysis was also recorded in marathon runners. High volumes of zone 1 training were recorded (70 %-91%) with variations in the amount of threshold training (4%-22 %) (Esteve-Lanao *et al*., 2005).

Numerous studies also manipulated the TID in athletes and then studied the changes in performance. In the majority of these studies, recreational athletes or sub-elite athletes were investigated. All these studies reported an improved endurance performance, however, in most of the studies, the polarised model resulted in the greatest changes in various endurance performance variables (Esteve-Lanao *et al*., 2007; Ingham *et al*., 2008; Neal *et al*., 2013; Munoz *et al*., 2014; Stöggl & Sperlich, 2014). A more recent study by Manzi and colleagues (Manzi *et al.*, 2015) investigated the hypothesis that the TID of elite athletes follows a polarised training model, whereas sub-elite athletes follows a lactate threshold model. They studied the intensity distribution of recreational long-distance runners preparing for a marathon over a period of five months. In reality, the runners followed a "pyramidal" distribution with 76.3% of their training in zone 1, 17.4% in zone 2 and only 6.3% in zone 3, and not a "threshold" distribution as hypothesised.

Using the individualized training impulse (iTRIMP) method to determine the TL of athletes excludes the problems encountered with previous TRIMP calculations where arbitrary zones and generic weighting factors were used to determine TL. TL is often manipulated by the intensity of training and the distribution thereof. Studies in different sport disciplines have reported non-uniform intensity distribution patterns in various phases of their periodization plans, with the polarised and pyramidal patterns most prominent in endurance athletes (Stöggl & Sperlich, 2014). Knowledge of which model is best to use during a specific training phase and how to analyse the TID will assist coaches in their training prescriptions.

B. MOTIVATION

Founded in 2004, the Cape Epic is the only eight-day mountain bike (MTB) stage race classed as "hors catégorie" (beyond categorisation) by the Union Cycliste Internationale (UCI), meaning it has more climbs than the existing categories 1 - 4, where category 1 refers to races with the steepest climbs. The race is unique in that it attracts world champions, Olympic champions, other top professional riders, as well as a large field of international amateur and recreational participants. This eight-day event includes a prologue and seven stages and covers approximately 700 km, which usually includes about 15000 m of altitude gain. Over the years, the Cape Epic has grown into the most televised mountain bike stage race in the world. Statistics of the race has demonstrated that 20 - 25% of the 1200 - 1300 participants do not complete the race. Various reasons exist for not being successful; however, implementing an appropriate TL on a daily basis and correctly balancing high and low intensity training will surely reduce the risk of becoming part of this statistic.

Many athletes and coaches are taking an increasingly scientific approach to both designing and monitoring training programs. Appropriate load monitoring can aid in determining whether an athlete is adapting to a training program and in minimizing the risk of overreaching or injury. To gain an understanding of the training load and its effects on the athlete, several potential methods are available. However, no consensus on a gold standard of measuring training load (TL) in endurance sport has been reported in the literature so far. The reason for this is that the correlation between training and the corresponding physiological responses is highly individual. Recent studies on soccer players and world class cyclists showed positive correlations between training dose and the individual training impulse, but no data exists for multi-stage mountain bikers (Akubat *et al*., 2012, Sanders *et al.*, 2016).

The information gained in this study will inform coaches and riders on the usefulness of measuring daily individual TL to assist in the periodization of their cycling programs. It will help coaches to write individual programs that use the individual data and incorporate valid and reliable values of TL to prevent injury and overtraining. It will also show the most successful TID curve for multi-day events. This may lead to a higher success rate for riders in this race (success meaning completing the race), as well as guiding potential riders in what the optimum TL is for completing a Cape Epic successfully.

Many mountain bikers train on their own. It could be of great importance for them and their coaches to have a reliable and practical analyses tool to track the physical and perceptual exertion demand of training and be able to monitor individual TL, as well as accurately controlling the intensities at which they train. Training programs can then be tailored acording to individual needs and responses before injury or illness due to inappropriate training dose occur.

To date, no study has described the TL of mountain bikers and how they distribute the TL in the weeks leading up to the race. This will be the first study that will investigate how mountain bikers train for a multi-stage endurance event and will provide cyclists and coaches with essential information to prepare for this event.

C. AIM

To investigate methods of training load monitoring and to describe the training load and load distribution of amateur MTB riders in preparation for the Cape Epic.

D. OPJECTIVES

1. To compare Banister's TRIMP (bTRIMP), the Individualized Trimp (iTRIMP) and session RPE (sRPE) methods to quantify TL in Cape Epic MTB riders.
2. To determine TID of Cape Epic mountain bike riders.
3. To determine the relationship between TID during the preparation phase and the race, and the cyclists' performance (race time) in the Cape Epic MTB race.

E. HYPOTHESES

1. The iTRIMP method is an appropriate tool to quantify the TL in MTB cyclists.

The dose-response relationships between different training load measures and changes in fitness and performance have only once been described for well-trained cyclists. In this study by Sanders *et al. (*2017), the strongest dose-response relationship between training load and changes in submaximal aerobic fitness variables was observed for iTRIMP and TSS (56% to 65% of the variance explained). The dose-response relationships with performance changes measured during an 8-minute time trial, showed iTRIMP to have the strongest relationships compared to the other training load measures used. These results showed that the iTRIMP method has the strongest dose-response relationships (Sanders *et al.,* 2017).

2. Cyclists will spend similar amounts of time in zone 1 training during the preparation phase and during the race.

The competitive level of the cyclists in this study was catogorised as amateur. Untrained athletes have demonstrated significant improvements in physiological parameters when training at their lactate threshold intensity (Kindermann *et al*., 1979; Denis *et al*., 1984; Londeree, 1997; Gaskill *et al*., 2001). However, elite athletes have demonstrated superior improvements when following a polarised TID (Seiler & Kjerland, 2006). The findings of an unpublished thesis on the 2014 Cape Epic race found a THR distribution of 50.8%, 41.95% and 7.25% in zones 1, 2 and 3 respectively (Greeff, 2014).

3. There will be a statistically significant inverse relationship between training time in zone 1 and the cyclists' performance in the Cape Epic MTB race.

When the volume of high intensity training was kept constant, and the only difference between the training programs of recreational runners was the distribution of training intensity between zone 1 and zone 2, the athletes spending more time in zone 1 performed better (Esteve-Lanao *et al.,* 2007; Munoz *et al.,* 2014).

CHAPTER 4

METHODOLOGY

A. STUDY DESIGN

This study followed a cross-sectional descriptive design to describe the internal training load((TL) and distribution of TL for the 13 weeks before, and including, a multi-day mountain bike (MTB) event. Fourteen weeks prior to the event the participants performed a laboratory exercise test. During each training session and stage of the event, they wore heart rate monitors compatible with the online training diary (TrainingPeaks®, Boulder, United States). There was no control group in this study and no training prescription was provided to the participants. They followed their own training plan, or a plan provided by their respective coaches.

B. PARTICIPANTS

Fifteen men and women volunteered to participate in the study. Participants were recruited through advertisements that were placed on various cycling related websites.

For inclusion, participants had to be healthy and older than 18 years, had to have proof of a 2017 Absa Cape Epic entry and own a downloadable heart rate (HR) monitor set compatible to the online training diary (TrainingPeaks®, Boulder, United States). They had to complete the pre-event performance test (maximal aerobic capacity, VO2max) and questionnaires (Appendix A, C, D, E, F). They were excluded from the study if they didn't complete the full 13-week preparation phase or all the stages of the Cape Epic. Participants were also excluded if they used medication that could affect their blood lactate and HR responses during the exercise test.

1. Assumptions

It was assumed that participants gave all-out efforts during the laboratory exercise test. It was also assumed that participants were honest in downloading all their daily training sessions and that they reported the use of caffeine, tobacco and other medication in the event questionnaire (Appendix G).

2. Delimitations

The participants included in the study were from the same geographic location (Cape Town, Stellenbosch, Strand, Paarl and Somerset-West) and the sample was further limited to those with a valid 2017 Absa Cape Epic entry at the time of recruitment and a compatible HR monitor.

C. EXPERIMENTAL DESIGN

1. Laboratory tests

The study protocol and aims of the study were explained to the volunteers. Time was given for questions, where after the participants signed the consent form. The participant's body composition was measured using a BodyMetrix BX2000 device, followed by an incremental exercise test to fatigue on the cycle ergometer. The cyclist's capillary blood lactate concentrations were measured after each workload increment.

All laboratory tests were completed in the Sport Physiology Laboratory at the Department of Sport Science at Stellenbosch University. All tests were done at temperatures between 18 and 20°C.

2. Ethical aspects

The study protocol was approved by the Ethics Committee for Human Research (Humanities) at Stellenbosch University (Reference number: SU-HSD-003957) (Appendix B). During the laboratory visit, the study protocol and informed consent (Appendix A) form were explained to each participant. Participants were given the opportunity to read through the form and ask questions. Cyclists were informed that their participation was completely voluntary and that they could withdraw from the study at any time.

D. MEASUREMENTS AND TESTS

All participants completed a body composition screening and a maximal graded exercise test to exhaustion within 14 weeks prior to the event.

1. Anthropometric measurements

Anthropometric measurements included stature, body mass and percentage body fat. Participants were asked to void their bladders and to refrain from exercise and drinking diuretics like caffeine or alcohol for at least four hours before conducting the tests. The participants also refrained from smoking four hours before taking the measurements.

a. Body mass

Participants' mass was determined with a balance beam scale and recorded to the nearest 0.1 kg. Participants were asked to stand in the middle of the scale, distributing weight evenly on both legs. Participants were barefoot and clothed in lightweight cycling attire.

b. Stature

Stature was measured with a sliding stadiometer (Seca, Germany). Measurements were taken to the nearest 0.1 cm. Participants were barefoot and stood with heels together and upper back, buttocks and heels against the stadiometer. The head was placed in the Frankfurt plane. The Frankfurt plane is achieved by positioning the lower edge of the eye socket (Orbitale) in the same horizontal plane as the notch just above the tragus of the ear (Tragion). The measurement was then taken from the inferior aspect of the feet to the vertex of the skull (the highest point on the skull). The standing height and body mass were used to determine body mass index (BMI).

c. BodyMetrix analysis

The participant's lean and fat mass was measured with the BodyMetrix BX2000 (Hosand Technologies Srl, Verbania). Ultrasound technology was used, and body composition was calculated by measuring subcutaneous fat thickness at multiple sites. The BodyMetrix™ System generates an ultrasound signal that travels through tissue and then records the reflected signal. Continuing the echo analogy, ultrasound waves travel in tissue and strong reflections occur at the boundary of different tissue types, for example, fat-muscle and muscle-bone. The BodyMetrix™ transmits and receives pulse echoes to produce a graph on which the percentage body fat is recorded Due to its excellent reliability, coaches and trainers can use this portable and easy to use A-mode ultrasound to assess body composition changes in athletes (Wagner, *et al.,* 2016).

For the men, measurements were taken from the chest (midway between the anterior axillary line and the nipple), the waist (2.5 cm lateral from the umbilicus) and the thigh (midway between the patella and the crease of the hip on the anterior midline of the thigh). For the women, the hip (the supra iliac can be located just above the iliac crest, from the front side tip of the top of the hip bone), the waist (2.5 cm lateral from the umbilicus), and the triceps (midway between the acromion and the elbow) were taken. The measurements took about 3-5 seconds each. During this time, the BodyMetrix ultrasound probe, with ultrasound gel, was slid about 1 cm to either side over a cleaned area of the anatomical point. The whole procedure took less than 10 minutes. BodyViewProFit™ software was used to analyse the results.

2. Maximal aerobic capacity

The results of this test were used to describe the endurance capacity of participants and to determine the exercise intensity zones for the aerobic and anaerobic components of the race.

A progressive incremental exercise test to exhaustion was performed on the Velotron Dynafit Pro (Australia) cycle ergometer to determine maximal aerobic capacity (VO_{2max}). The Cosmed CPET (Italy) metabolic analyser was used for breath by breath analysis of the cardiorespiratory variables throughout the test. The participants performed a 10-min warm up at 80 W and a cadence of their choice. They were allowed to drink water after the warm-up and before the face mask and heart rate monitor was fitted. Men started the test at 120 W and the workload was increased to 150 W in the first 60 s, after that, the workload increased by 30 W every 150 s. Women started at 80 W and increased by 30 W every 150 s. Participants were asked to keep the cadence between 80-100 rpm throughout the test.

A finger stick blood sample was taken before and during the VO_{2max} test. The finger was cleaned with an alcohol swab and then pricked with an Accucheck soft clicks lancet (Roche Diagnostics, Manhein, Germany). The first droplet of blood was wiped away and the second was drawn into the capillary tube of the Lactate Pro 2 meter (ARKRAY, Inc. Kyoto, Japan). Samples were taken 30 sec before the end of each completed workload until the lactate concentration reached 4 $mmol.L^{-1}$. The last sample was taken at the termination of the test. The total volume of blood sampled did not exceed 2 ml.

The exercise test was terminated upon voluntary exhaustion. The test was considered a maximal effort if three of the five criteria were reached according to the testing procedures of the American College of Sports Medicine (ACSM, Thompson et al., 2010). The criteria included: (i) the VO_2 does not increase by more than 150 ml per successive workload, (ii) a respiratory quotient (R) value equal or above 1.15 is reached, (iii) heart rate is more than 90% of the age-predicted maximal heart rate, (iv) the rating of perceived exertion (RPE) is above 19 on the 6–20 Borg scale (Borg, 1970) and (v) the blood lactate concentration is above 8 $mmol.L^{1}$.

Throughout the test breath by breath expired gases were sampled through the turbine flow meter and gas sampling line and analysed by a cardio-pulmonary metabolic system (Cosmed Quark CPET, Rome, Italy). The gas analysers were calibrated with atmospheric gas and known gas concentrations (16 % O_2, 4 % CO_2, balance N2) and the turbine flow meter was calibrated with a 3 L calibration syringe prior to each test. Heart rate was measured through telemetry (COSMED wireless HR monitor, Italy) which was interfaced with the metabolic system.

Two lactate thresholds (LT_1 and LT_2) were determined for each individual by using an Excel spreadsheet that calculates blood lactate endurance markers (Newell *et al*., 2007). LT_1 was defined as the point where the blood [lactate] increased by

1 mmol.L^{-1} from the baseline values, whereas LT_2 was defined as the point where blood lactate concentration was equal to 4 mmol.L^{-1} (Figure 4.1).

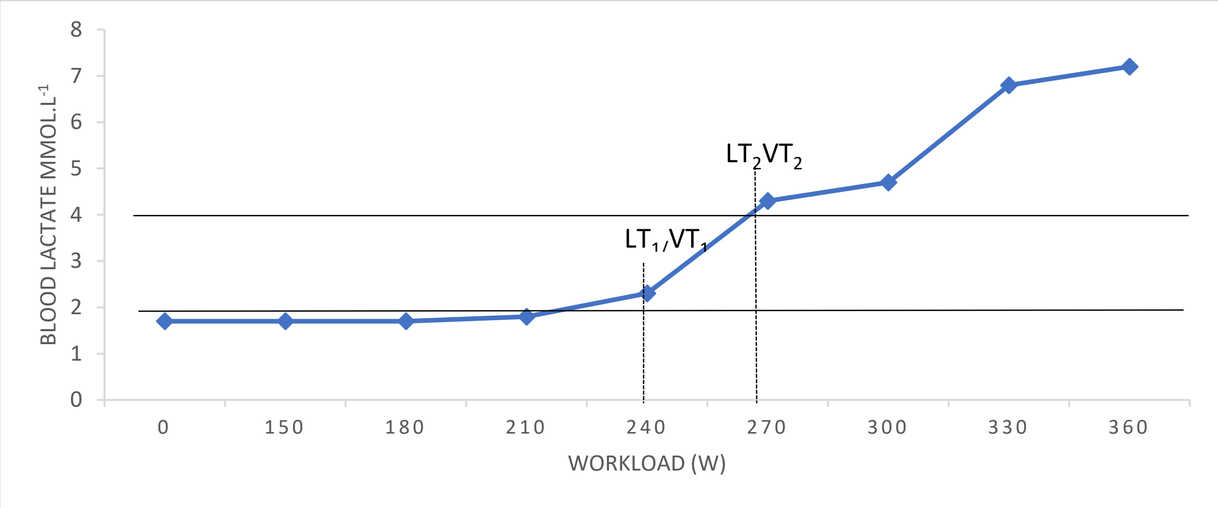

Figure 4.1 Determination of LT_1 and LT_2 for each cyclist during the maximal aerobic capacity test.

3. Data monitoring during training phase and Cape Epic

Participants recorded all endurance training sessions and races lasting > 15 minutes, as well as the event using their own heart rate monitor. The training sessions were downloaded from their watch to a training diary. Each training session reviewed 1) training mode, 2) heart rate data and 3) session rate of perceived exertion (sRPE). Participants were provided with their own online training diary (TrainingPeaks®, Boulder, United States) (Appendix E) with a unique username and password. This online training diary was linked to the researcher's coaching edition TrainingPeaks® software (Appendix F) and all sessions uploaded by the participant could be accessed by the researcher. Weekly training sessions were uploaded for the researcher to analyze. All forms of communication between the researcher and participants took place via personal email.

Training loads for each individual was calculated using the original methods of bTRIMP (Banister, 1991), iTRIMP (Manzi, *et al*., 2009) and sRPE (Impellizzeri, *et al*., 2004) in Excel (Microsoft, Redmond, WA, USA) using a customized spreadsheet. All the training data that were analyzed was endurance related activities lasting longer than 15 minutes. Any additional training sessions, i.e. weight training and others, were noted in the training diary. TL was calculated using different methods based on either heart rate or session rating of perceived exertion (sRPE).

Banister's Training impulse (bTRIMP) (Banister, 1991) was calculated based on training duration, HR, and a weighting factor using the following formula:

Men: bTRIMP = duration training(D) (minutes) x ΔHR x $0.64e^{1.92x}$.......................Eq. 4.1

Women: bTRIMP = duration training(D) (minutes) x ΔHR x $0.86e^{1.672x}$................. Eq. 4.2

where: $\Delta HR = (HR_{ex} - HR_{rest}) / (HR_{max} - HR_{rest})$, e equals the base of the Napierian logarithms, 1.92 and 1.672 equals generic constants for men and women and *x* equals ΔHR.

The Individualized Training impulse (iTRIMP) (Manzi *et al*., 2009) was calculated by weighting exercise intensity according to the individual's own HR-blood lactate relationship and then using this to determine every HR rather than creating zones. An accumulated iTRIMP was then calculated by summating the iTRIMP value for each HR data point. The individual weighting factor (y^i) was calculated for each participant with the best-fitting method using exponential models as per the method of Manzi *et al*. (2009).

iTRIMP (AU) $= D(min) \times \Delta HR_{ratio} \times y_i$.. Eq.4.3

where: y_i = individual relationship between ΔHR_{ratio} and [La-]b to increasing exercise intensity using an exponential model.

As a subjective measure of internal TL, sRPE were calculated using the participants' RPE (CR-10 scale) (Appendix D) and session duration for each training session, as well as each day of the event. The RPE was obtained 30 min after the training session based on the question: "How hard was your workout?" Training load for the session was quantified by multiplying the RPE by the duration of the session (minutes).

E. DATA ANALYSIS

Statistical analysis was performed using Microsoft Office Excel (Windows Office 2010) and Statistica 12.0. Descriptive statistics are reported as means and standard deviations (±SD) unless otherwise specified. Unpaired T-tests were performed to assess for statistically significant differences between groups and Spearman Rank-order correlations were calculated to describe relationships between physiological characteristics obtained in the laboratory and performance parameters from the event. Correlations were classified as follow: 0.90 to 1.00 very high, 0.70 to 0.89 high, 0.50 to 0.69 moderate, 0.30 to 0.49 low and 0 to 0.29 negligible (Mukaka, 2012). The exercise intensity zones were determined based on HR values at lactate parameters (LT_1 and LT_2). Three zones were determined. Zone 1 for intensities below HR corresponding to $LT_{1,}$ zone 2 for intensities between HR corresponding to LT_1 and LT_2 and Zone 3 for intensities above HR corresponding to $LT_{2.}$

CHAPTER 5

RESULTS

A. INTRODUCTION

Fifteen participants were recruited for the study and underwent the laboratory tests. Three participant's data could not be analyzed because their HR-monitors failed to synchronize with the TrainingPeaks® software that was used. One more participant withdrew from the Cape Epic within the first two weeks of the training phase due to injury. Eleven participants completed the 13-week preparation phase and the race and are reported in this study. One female participant experienced difficulty downloading her heart rate data during the race and therefore her TRIMP scores and intensity distribution could not be calculated for the race. During the preparation phase 43 – 76 sessions per participant were recorded and analysed. Together with the data from the eight stages of the race a total of 678 sessions were recorded.

B. DESCRIPTIVE CHARACTERISTICS OF THE PARTICIPANTS

1. Physical characteristics

Complete data sets of eleven (11) participants (9 men and 2 women) were analysed. The physical characteristics of the participants are presented in Table 5.1. Their ages ranged between 30 and 58 years and both the youngest and oldest participants were men.

Table 5.1 Physical characteristics of the cyclists

	Men (n = 11)			Women (n = 2)			
	Mean (± SD)	**Median**	**Range**	**Mean (± SD)**	**Range**	**Median**	**P-value**
Age (years)	40.0 ±8	39	30 - 58	46 ± 7	41-58	-	>0.05
Height (cm)	179.4 ±8.4	179.2	160.6- 188.2	162.2 ± 5.2	158.6-166.0	-	0.014
Body mass (kg)	79.1 ±10.2	76.5	61.7- 96.7	59.2 ± 1.2	58.3-60.0	-	0.013*
BMI ($kg.m^{-2}$)	24.6 ± 2.3	24.3	21.9- 28.9	22.6 ± 1.2	20.7-22.4	-	>0.05
Body fat (%)	13.5 ± 2.6	12.9	11.1- 19.2	21.5 ± 1.2	20.7- 22.4	-	0.001*

2. The maximal exercise capacity of the cyclists

The physiological characteristics of the participants are presented in Table 5.2. The absolute VO_{2max} values for the men ranged from 3.5 – 5.6 $l.min^{-1}$ and for the woman from 2.7 – 3.6 $l.min^{-1}$. The PPO values for the men ranged from 276 – 426 W and for the woman from 212 – 298 W. According to their peak power output, the men were classified as professional (>420 W), top amateur (360 - 420 W), competitive level club (320 – 359 W) and competitive (265 – 319 W). One woman was classified as top amateur (275 - 325 W) and the other as junior club level (190 - 219 W), Whaley *et al.,* 2006).

There were statistically significant differences in the absolute maximal aerobic capacity between the men and women (P = 0.04), as well as the absolute peak power output (P = 0.02) and the power output at lactate threshold (P = 0.02).

Table 5.2 The physiological characteristics of the cyclists

	Men (n = 11)			**Women (n = 2)**			
	Mean (± SD)	**Median**	**Range**	Mean (± SD)	**Range**	**Median**	**P-value**
Absolute VO_2 max ($L.min^{-1}$)	4.2 ± 0.65	4.1	(3.5 – 5.6)	3.2 ± 0.67	-		0.04*
Relative VO_2 max ($ml. min^{-1}.kg^{-1}$)	53.3 ± 6.7	54	(46 – 62)	53.5 ± 10.6	-		>0.05
HR_{max} (bpm)	180 ± 7.8	177	(171 - 195)	173 ± 5	-		>0.05
HR_{LT} (bpm)	160 ± 7.5	158	(152 – 174)	159 ± 0.7	-		>0.05
% HR_{max} (%)	88.9 ± 3.1	89	(82 – 92)	92.5 ± 5	-		>0.05
PPO **(W)**	341 ± 45.6	360	(276 – 426)	255 ± 60.8	-		0.02*
PPO: BW ($W.kg^{-1}$)	4.5 ± 0.6	4.5	(3.2 – 5.1)	3.9 ± 0.1	-		>0.05
PO_{LT} (W)	267.4 ± 37.7	270	(187 – 330)	197.5 ± 53	-		0.02*
% PO_{LT} / PPO%	78.3 ± 5.7	77	(68 – 87)	77 ± 2.8	-		> 0.05

Absolute VO_{2max} $ml.min^{-1}.kg$; maximum aerobic capacity; l. min^{-1}, Liter per minute; ml. $min^{-1}.kg^{-1}$, milliliters per minute per kilogram; HR_{max}, maximal heart rate; bpm, beats per minutes; HR_{LT}, heart rate at lactate threshold; PPO, peak power output; W, Watts; PPO: BW, peak power output to body weight ratio; W. kg^{-1}, watts per kilogram; PO_{LT}; power output at lactate threshold; % PO_{LT} / PPO, power output at lactate threshold as a percentage of peak power output. *statistically significant

3. Total training sessions and distance covered during the 13-week preparation phase

A total of 678 training sessions were recorded during the 13- week preparation phase. All types of endurance sessions lasting longer than 15 minutes, including preparation races, were included. The number of training sessions and total training hours during the 13-week recording period prior to the event are presented in Table 5.3. The women completed significantly more sessions (P = 0.006) prior to the race than the men. There was no statistically significant difference in the total training distance between the men and the woman (P > 0.05). For this reason and because only two women were involved in the study, the results were pooled for further analysis.

Table 5.3 Total training sessions and training distance covered during the 13-week period

	Men (n = 11)			Women (n = 2)			
	Mean (± SD)	**Median**	**Range**	**Mean (± SD)**	**Range**	**Median**	**P-value**
Total training sessions over 13-weeks	52 ± 7.4	47	43 - 65	70 ± 9.2	63 - 76	-	0.006*
Total distance (km) over 13-weeks	2684.8 ± 448	2724.5	1974 - 3229	3485.07 ± 1205	1415-4338	-	>0.05

Figure 5.1 and 5.2 illustrate the total distance covered by each participant and the average distances covered per week during the 13-week preparation phase. S10 was the winner of the woman's category and S11 represents the other female participant. The distances covered for the men ranged from 1974 km for S4 to 3229 km for S8. Peak average mileage for week 3 was 324 ± 118.5 km, while the taper week before the race averaged 61 ± 43.6 km. The cyclist who performed best in the Cape Epic (S10) covered 4338 km during training, while the cyclist with the worst performance (S11) covered 1415 km during training. Overall, a weak correlation was

found between total training distance and total race time (r = -0.31; P > 0.05) (Table 5.7).

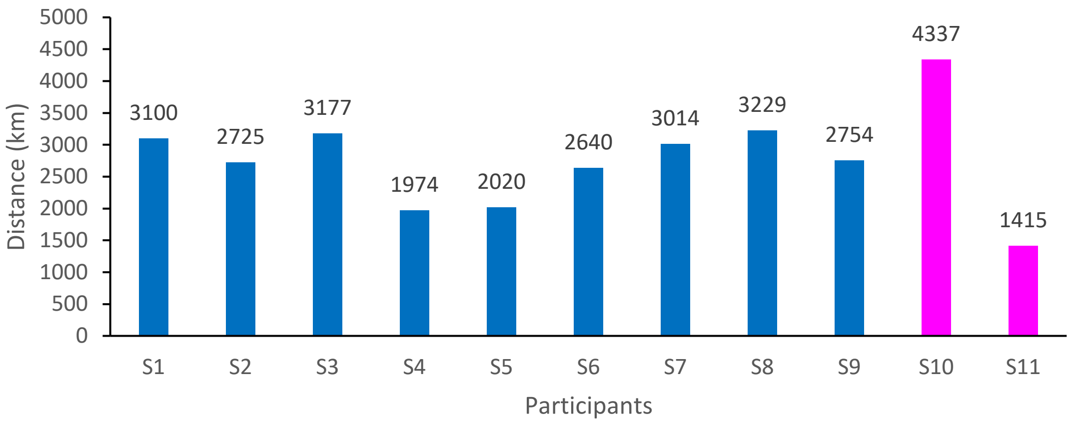

Figure 5.1 Total training distance for each participant during the 13-week preparation phase. S10 and S11 depict the women.

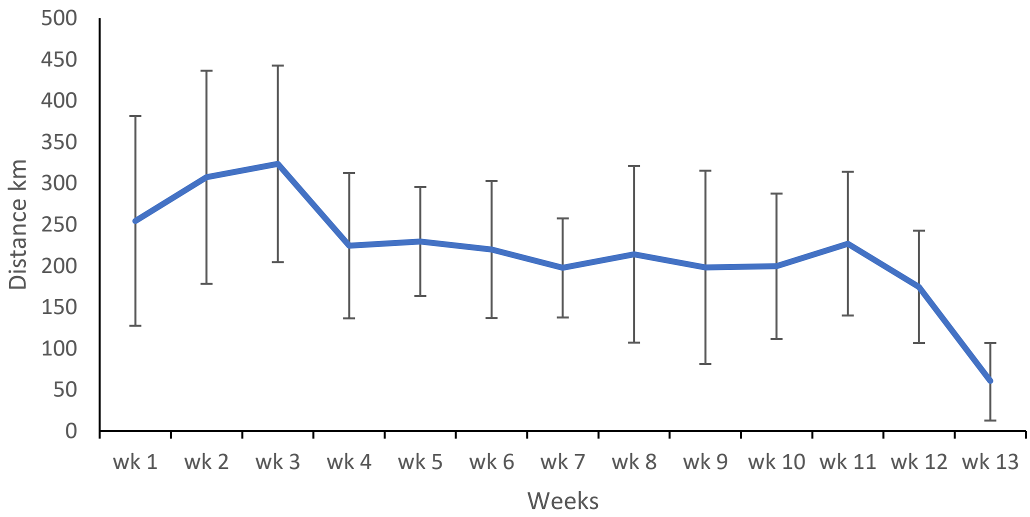

Figure 5.2 Average distance per week covered by all the participants during the 13-week preparation phase.

4. Training load for each participant for the 13-week preparation phase

Figure 5.3 A, B and C illustrates the total training loads for the participants over 13 weeks according to iTRIMP, bTRIMP and sRPE scores, respectively. S10 and S11 are the women cyclists. For the iTRIMP scores, the minimum value recorded was 2188 AU for S3 and the maximum 14730 km for S10. For bTRIMP the scores ranged from 1817 AU to 18 427 AU and for sRPE the scores ranged from 10 385 to 44 621 AU.

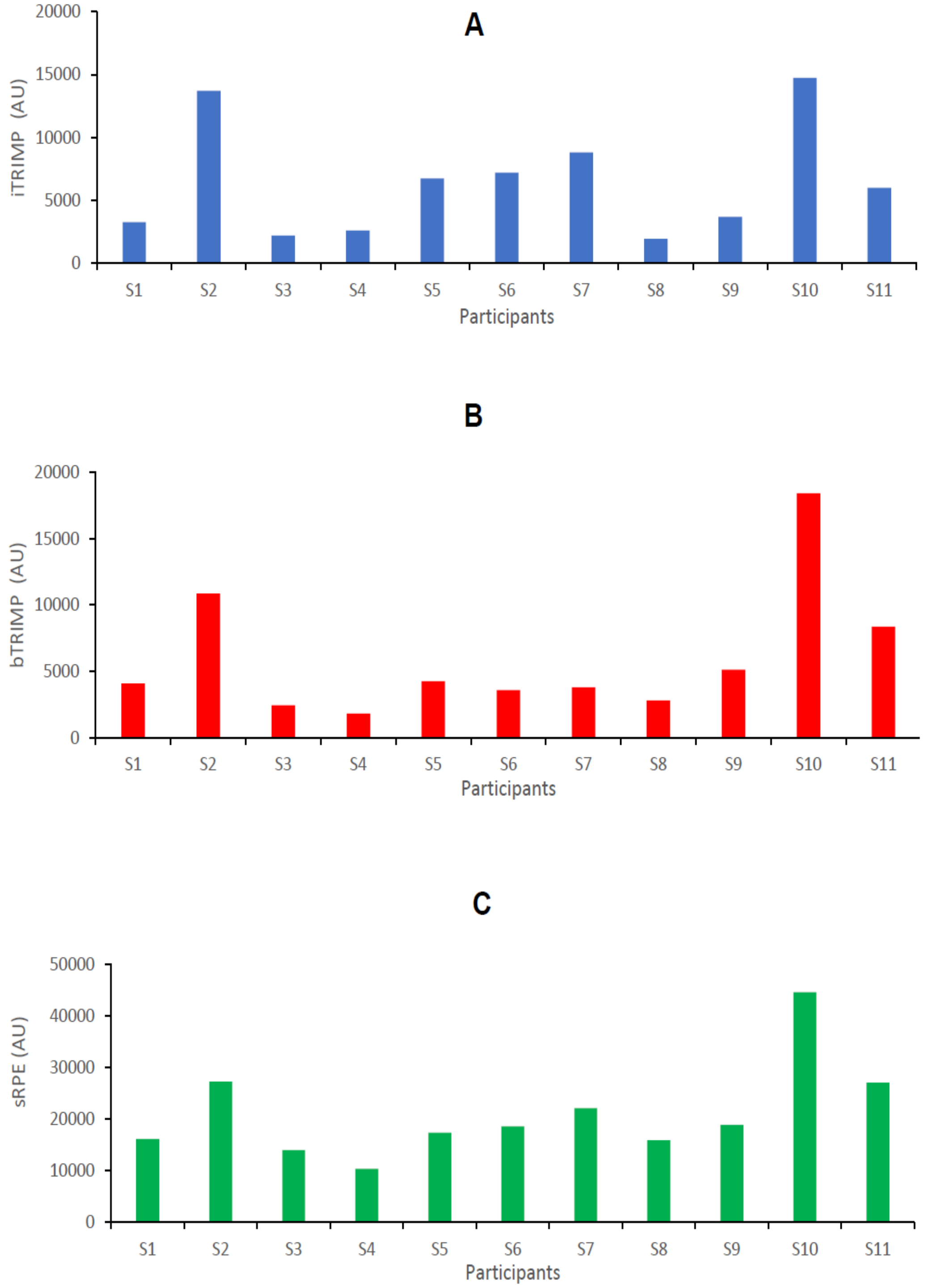

Figure 5.3 Individual training loads during the 13-week preparation phase presented as (A) iTRIMP, (B) bTRIMP and (C) sRPE scores. S10 and S11 depict the women.

5. Average training load for all participants during the 13-week preparation phase

Figure 5.4 A, B and C illustrates the average training load of all participants during the 13-week preparation phase using the iTRIMP, bTRIMP and sRPE scores. High volumes of training were recorded during weeks 3, 5 and 8, due to multi-stage preparation races taking place during these times. High volume weeks were followed by much lower volume recovery weeks. A 2-week tapering phase with reduced load is clearly visible before the race.

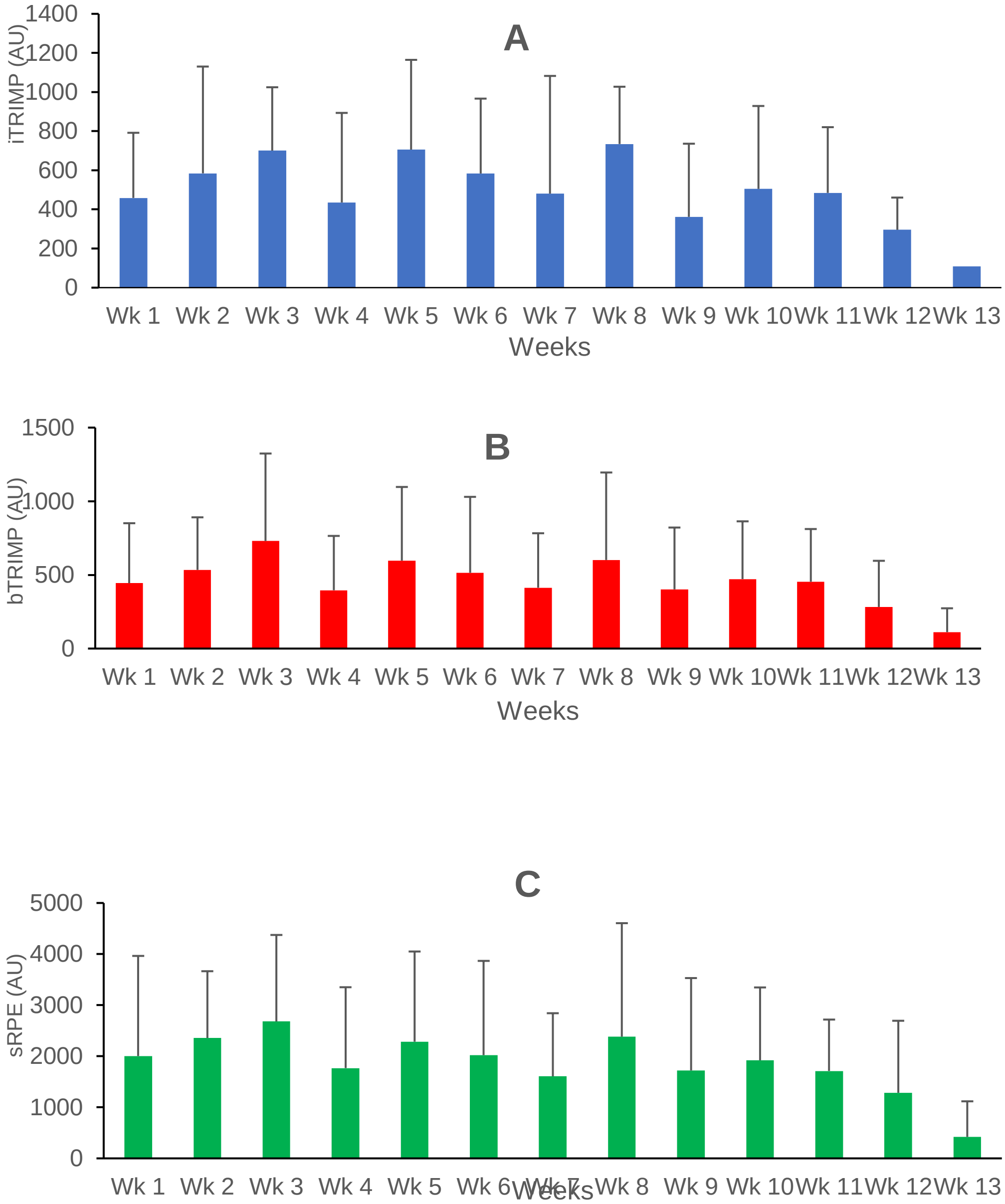

Figure 5.4 Average training load (mean ± SD) for 13-week preparation phase presented as (A) iTRIMP, (B) bTRIMP and (C) sRPE scores.

Figure 5.5 illustrates the combined training load calculated as iTRIMP, bTRIMP and sRPE during the 13-week preparation phase. The cyclist that performed best in the Cape Epic (S10) had the highest scores in iTRIMP (14 730 AU), bTRIMP (16 127 AU) and sRPE (31 921 AU), while the person with the worst performance (S11) had scores of 6006, 8366 and 27 106 AU for the iTRIMP, bTRMIP and sRPE, respectively.

Strong correlations were recorded between the iTRIMP and bTRIMP scores during the preparation phase ($r = 0.72$; $P = 0.02$), as well as between the iTRIMP and sRPE scores (r = 0.86; P < 0.01). A very strong correlation was found between the bTRIMP and the sRPE scores during the preparation phase (r = 0.90; P < 0.01). A summary of all the correlations is found in Table 5.7.

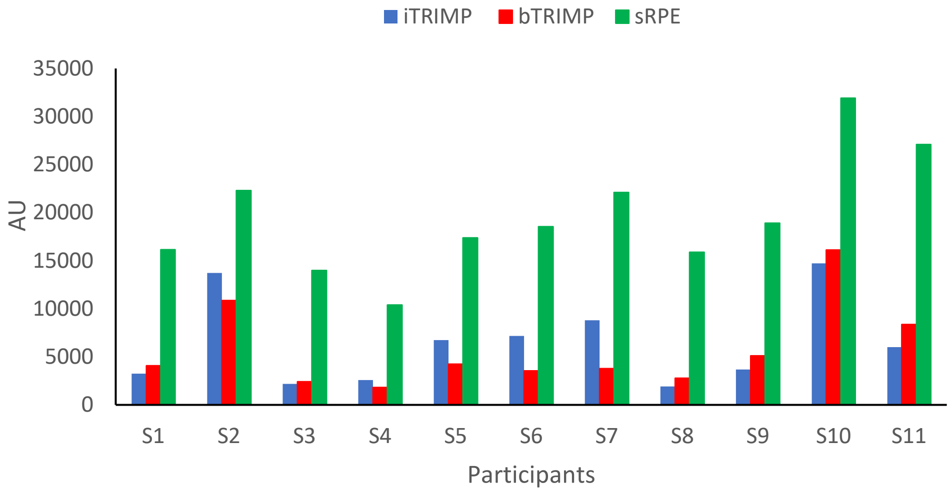

Figure 5.5 Combined iTRIMP, bTRIMP and sRPE scores for each participant during the preparation phase S10 and S11 depict the women.

C. THE DESCRIPTIVE FEATURES OF THE 2017 ABSA CAPE EPIC

1. The course profile

Participants in the 2017 ABSA Cape Epic competed over 649 km, with 15 400 m of climbing over the 8-day stage race (Table 5.4). The distance (km) per day ranged from 26 km (day 1) to 103 km (day 6). The weather conditions are reported for the time the cyclists spent every day in the field from 7 am to 5 pm (Table 5.5). The weather conditions are representative of the closest nearby town and weather station where each stage took place, and are presented as average temperature (±SD) over 8 days, plus the minimum and maximum temperature for each day.

Table 5.4 Characteristics of the course profile of the 2017 Absa Cape Epic

	Prologue	**Stages**							**Mean (±SD)**
		1	**2**	**3**	**4**	**5**	**6**	**7**	
Distance (km)	26	101	63	78	112	86	103	85	82 ± 27
Altitude (m)	750	2300	1500	1650	2150	2100	2750	1350	1819 ± 630

Table 5.5 Weather conditions during the 2017 Absa Cape Epic

	Temperature (°C)	Range (°C)	Rain (mm)
Prologue	23.5 ± 5.4	15 - 32	0.0
1	28.5 ± 5.9	19 - 38	0.0
2	25.5 ± 5.9	16 - 35	0.0
3	24.5 ± 3.6	19 - 30	0.0
4	21.0 ± 3.3	16 - 26	0.0
5	17.5 ± 3.0	13 - 22	0.0
6	19.0 ± 3.9	13 - 25	0.0
7	17.5 ± 4.8	10 - 25	0.0

2. Training load for each participant during the race

Figure 5.6 A, B and C illustrates the race load for each participant presented as iTRIMP, bTRIMP nd sRPE scores. Only 10 participants completed the race and S10 represents the only woman. Table 5.7 summarizes the correlation statistics for all the comparisons between training load methods. A very strong correlation was found between iTRIMP during the preparation phase and iTRIMP scores during the race ($r = 0.85$; $P < 0.01$). A strong correlation was found between bTRIMP scores during the preparation phase and the race ($r = 0.78$; $P = 0.01$), as well as for sRPE scores during preparation and the race ($r = 0.71$; $P = 0.03$).

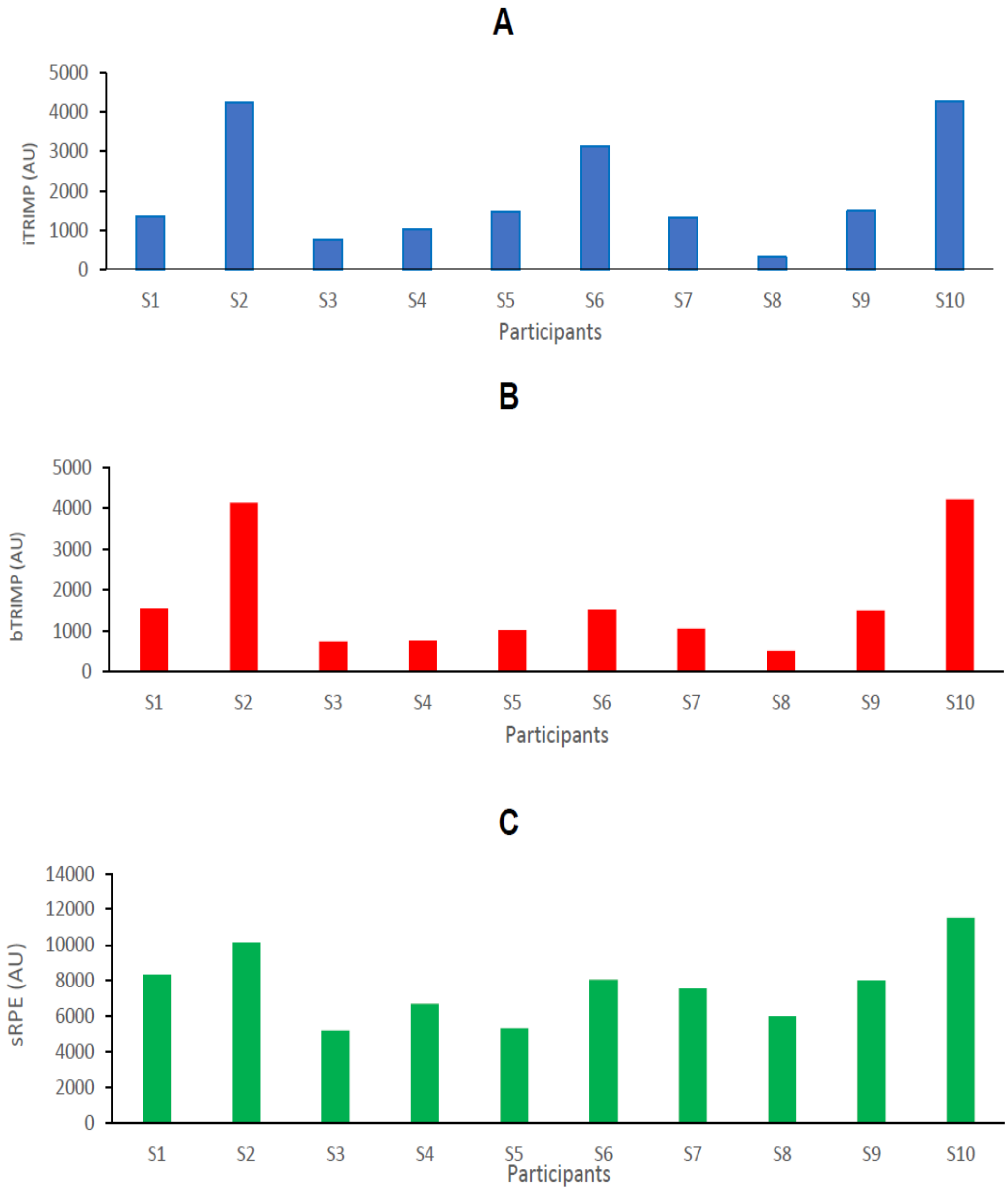

Figure 5.6 Race load calculated as scores for each (A) iTRIMP, (B) bTRIMP and (C) sRPE. S10 and S11 depict the women.

Figure 5.7 compares the individual iTRIMP, bTRIMP and sRPE scores for the race. Very strong correlations were found between iTRIMP and bTRIMP ($r = 0.90$; $P < 0.01$) and between bTRIMP and sRPE ($r = 0.94$; $P < 0.01$), while a strong correlation was found between iTRIMP and sRPE scores during the race ($r = 0.79$; $P < 0.01$).

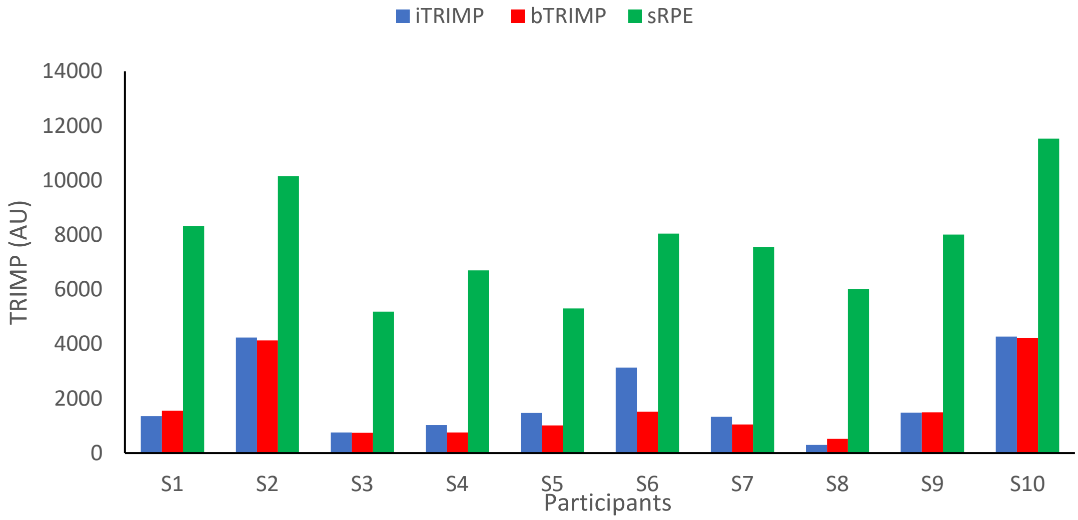

Figure 5.7 Race load calculated as iTRIMP, bTRIMP, and sRPE during the race.

Figure 5.8 A, B and C shows the iTRIMP, bTRIMP and sRPE scores of all the participants over the 8-day race. The orange line represents the only lady (and winner) of the race. The black line indicates the average scores and ranged between 206 and 837 AU. All participants experienced the highest load during stage 1 due to high mileage (101 km) and extreme outdoor temperatures (19 - 38°C). The winner of the woman's race recorded much higher load volumes than the majority of the participants throughout the race.

The correlation between the iTRIMP scores during the race and total race time was statistically significant ($r = -0.78$; $P < 0.01$). Correlations for the bTRIMP ($r = -0.58$; $P = 0.08$) and sRPE ($r = -0.36$; $P = 0.31$) scores during the race and the total race time were not statistically significant (Table 5.7).

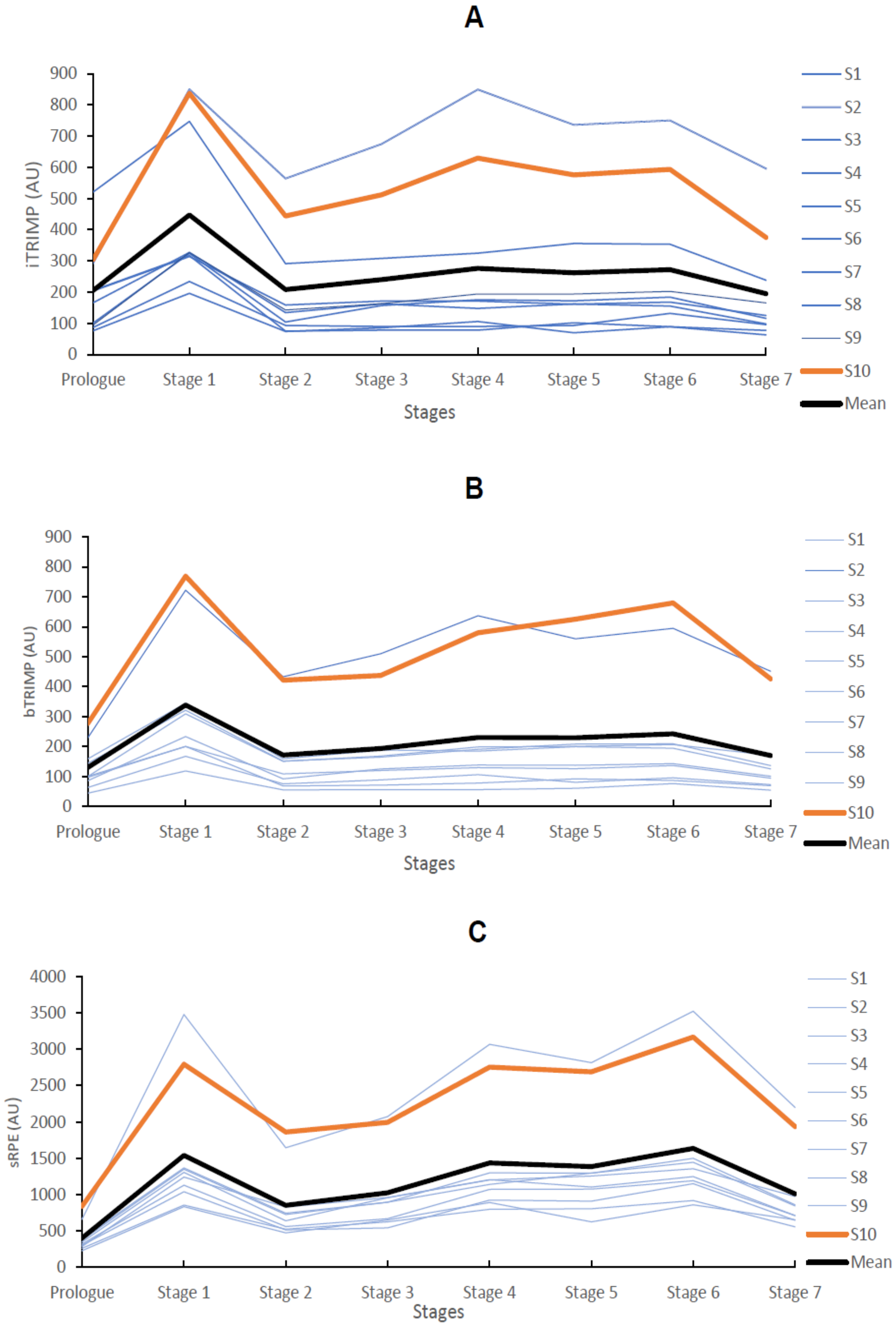

Figure 5.8 Race load calculated as for all participant as (A) iTRIMP, (B) bTRIMP and (C) sRPE. S10 depicts the only woman cyclist.

D. TRAINING LOAD INTENSITY DISTRIBUTION

1. Training intensity distribution of each participant during the preparation phase

Figure 5.9 shows the training intensity distribution for each participant during the preparation phase. Participant S6 followed the “polarized” model. S2, S3, S4, S8, S9 and S11 followed the “pyramidal” distribution model, while S7 and S10 followed the “high-volume low intensity” model. S1 and S5’s TID did not fit any of the known models. Most participants spent the majority of their training time in zone 1. S10 shows the data for the winner of the women’s category. She spent 84% of her training in zone 1, but no time at intensities above LT_2.

A weak correlation was found between percentage time spent in zone 1 during the preparation phase and total race time (r = -0.12; P = 0.75), while a moderate correlation was noted between time in zone 2 during preparation and total race time (r = 0.46; P = 0.18). A strong correlation was noted between total training time during the preparation phase and percentage time spent in zone 3 during the race (r = -0.68; P = 0.03). Correlation statistics are summarized in Table 5.7.

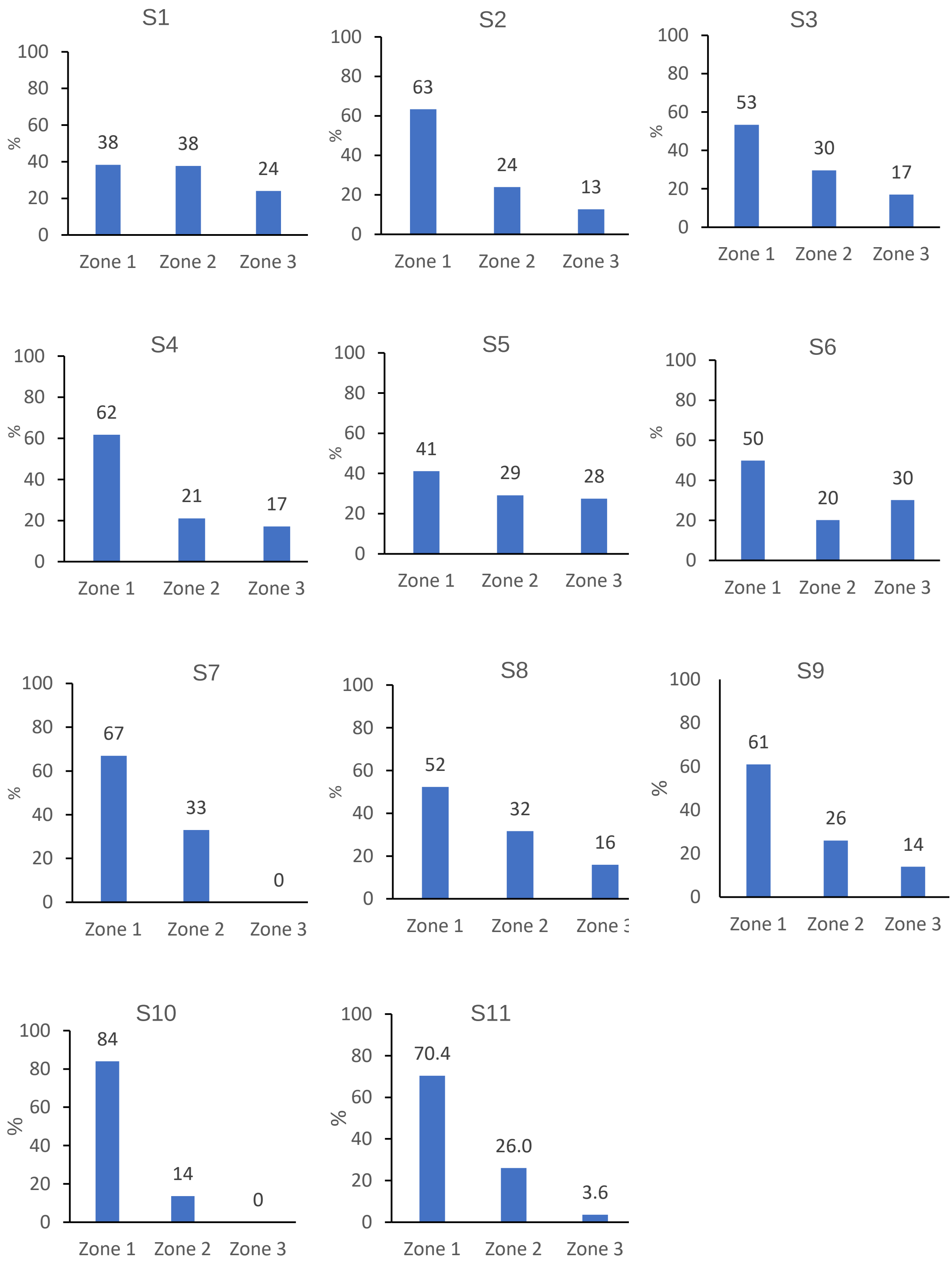

Figure 5.9 Training intensity distribution for each participant during the preparation phase. S10 and S11 depict the women cyclists.

2. Training intensity distribution (TID) for each participant during the Cape Epic

TID for the individual participants during the race is shown in figure 5.10. S11 could not provide data, as her heart rate monitor did not work during parts of the race. A clear "Threshold" distribution for participants S1, S2, S3, S5, S8 and S10 is visible. Participants S4, S6 and S7 had a "Pyramidal" distribution, while S9 spent 45% of the race time at intensities above LT_2 and did not fit any known model.

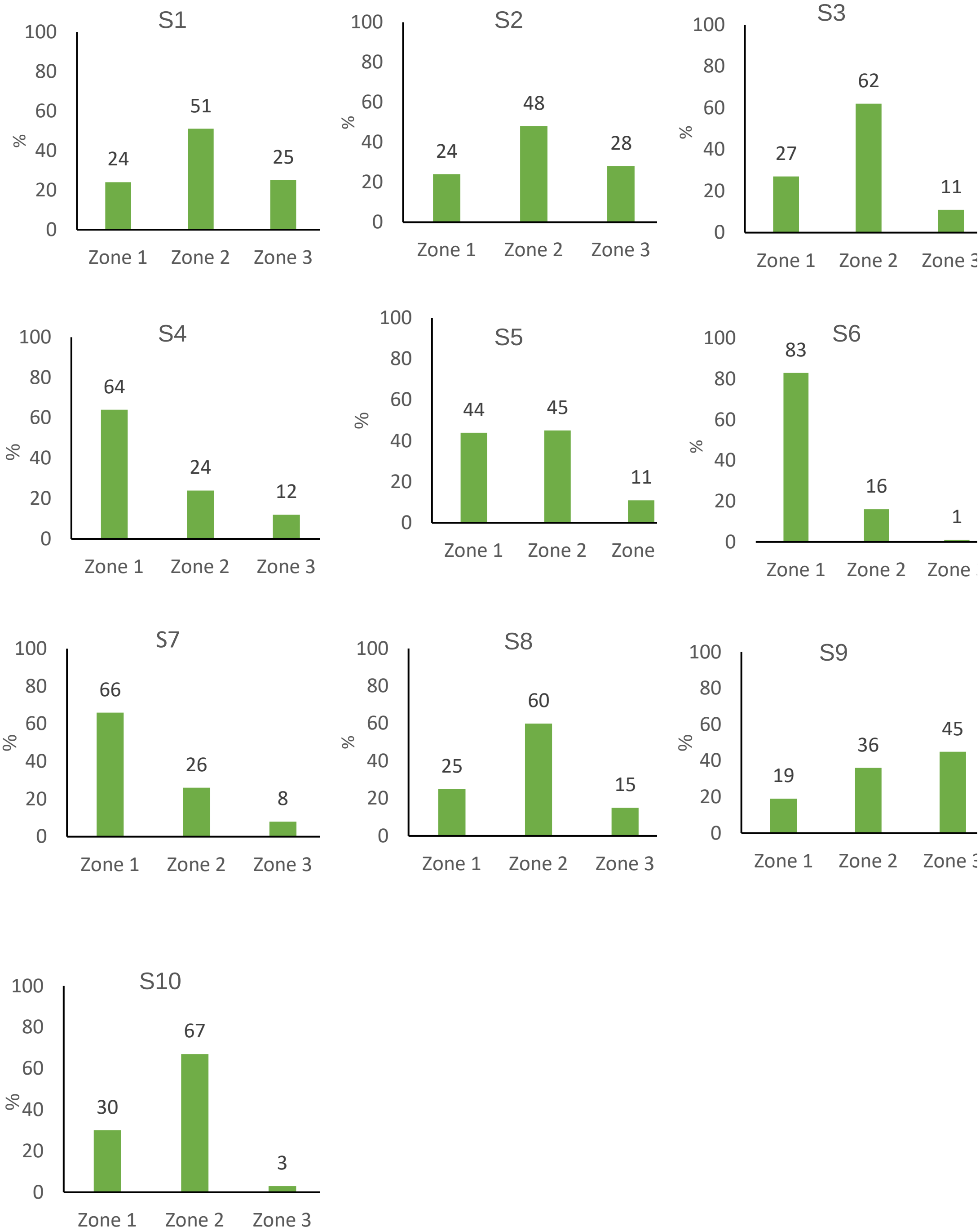

Figure 5.10 Intensity distribution for participants during the Cape Epic race.

3. Training distribution of all participants during the preparation phase and the race

Figure 5.11 compares the average training load intensity distribution (±SD) for the preparation phase and the race. Participants demonstrated a "Pyramidal" TID for the preparation phase, with 58% of the total training time spent in zone 1, 27% in zone 2 and 15% in zone 3. More than 80% of the race was spent at intensities below LT_2. Forty-two percent (42%) of the time was spent in zone 1, 41% in zone 2 and 17% in zone 3. There was no statistically significant difference between percentage time spent in zone 1, 2 or 3 during preparation and during the race, respectively.

When the percentage time spent in each zone during the preparation phase were correlated with the same zone in the race, the results were as follows: zone 1 ($r = 0.17$; $P = 0.64$), zone 2 ($r = -0.35$; $P = 0.33$) and zone 3 ($r = 0.24$; $P = 0.50$). A weak correlation was found between the percentage time spent in zone 1 during the preparation phase and the percentage time spent in zone 3 during the race ($r = -0.2$; $P = 0.57$).

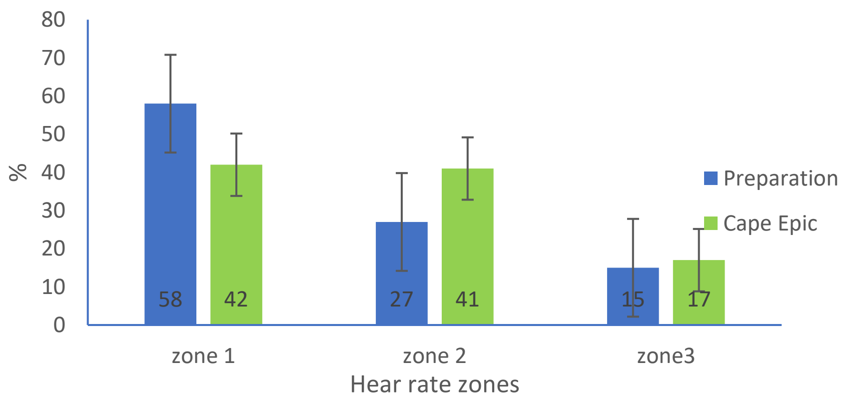

Figure 5.11 Intensity distribution (% time) of all participants during the preparation phase and 8- day race. Values are depicted as means ± SD.

4. Summary of correlation statistics for measures of training load

Table 5.6 Spearman-rank correlations for external and internal measures

	iTRIMP prep	**bTRIMP prep**	**sRPE prep**	**iTRIMP race**	**bTRIMP race**	**sRPE race**	**Ext TL**	**Race performance**
iTRIMP prep		0.72	0.86	0.85			-0.06	-0.56
bTRIMP prep			0.90	0.82	0.78		0.02	-0.53
sRPE prep				0.81	0.77	0.71	0.03	-0.41
iTRIMP race					0.9	0.79	-0.18	-0.78
bTRIMP race						0.94	0.01	-0.58
sRPE race							0.09	-0.36
Ext TL								-0.31

iTRIMP, Individualize training impulse; bTRIMP, Banister's training impulse; sRPE, session rate of perceived exertion; ext, external; TL, training load; prep, preparation

CHAPTER 6

DISCUSSION

A. INTRODUCTION

In the present study cyclists were monitored for thirteen weeks before, and including, the 8-day Absa Cape Epic mountain bike (MTB) race to determine the training load (TL) and the training intensity distribution (TID) for the pre-composition phase and the multi-stage event. The TL and TID are valuable information for cyclists and coaches to assist in program design and preparation for events. Limited studies have investigated MTB riders. The few studies mentioned in the literature (Impellizzeri *et al*., 2002; Warner *et al.,* 2002; Stapelfelt *et al.,* 2004; Wingo *et al.,* 2004; Impellizzeri *et al*., 2005; Wirnitzer and Kornexl, 2008) have investigated different levels of MTB riders participating in different types of events, and only the study by Wirnitzer and Kornexl, (2008) have recorded the race intensities of a multi-day event. This study is the first to monitor the preparation of cyclists for this particular event and could have important practical relevance to those involved in cycling.

B. CHARACTERISTICS OF THE PARTICIPANTS

1. Participants

This “real-world” study aimed to have a “sneak-peak” into the training styles of amateur riders, independently managing their training with little or no input from coaches or scientists. These cyclists take on the challenge to test themselves and the time management of their lives is drastically influenced by their will to succeed. The already heavy burden of juggling their lives and training made it hard to find participants to commit to something ‘extra’.

Recruitment of participants started two months before the laboratory test and included advertising at cycling events, cycle shops and by word of mouth. Fifteen participants (13 men, and 2 women) underwent the laboratory testing fourteen weeks prior to the start of the Cape Epic, of which eleven (9 men and 2 women) completed the 13-week preparation phase and the race. Technical difficulties with the synchronization of the software and the different HR-monitors (3) and injury (1) jeopardized the use of some data. A field study, such as this, is subjected to a number of limitations, of which the external validity is an important one. However, the sample size in this study compares favorably with existing studies on off-road cycling (Table 6.2 and 6.3). Furthermore, the strength of this study lies in its novelty and the contribution it makes towards research into the science of mountain biking. Participants in this study finished the race between 31 and 50 hours. In comparison, the winners of the men's category finished in just over 26 hours, while the last pair completed the race in 51 hours.

2. Body composition

Impellizzeri & Marcora (2007) investigated the physiology of world champions and elite cross-country MTB riders. Cross-country MTB events must feature a lap length of 4-6 km and a race time around 1:30-1:45 hours. They reported that the body fat percentage of the male world champion cross-country MTB riders were >6.4% and for the elite riders 8.5-14.3% (Table 6.1), suggesting an association between body composition and competitive level (Impelizzeri and Marcora, 2007).

In the present study, the body fat percentage of the men ranged from 11.1-19.2% (Table 5.1) and clearly indicate the difference in body composition associated with the lower competitive level. On the other hand, the values from this study were similar value than that of Warner *et al.* (2002) and Wingo *et al.* (2004) who described their participants as elite and experienced cyclists, respectively. The description of the level of sport participation is in itself a point worth mentioning. Sport science literature lack consensus of what exactly constitutes elite sport status and therefore the term should be used with caution. Furthermore, when comparing cyclists from different studies, careful consideration must be taken with regards to the event they are training for, the level of participation and the time in the season when the testing took place. Table 6.1 depicts the percentage body fat of the men in this study and data of off-road cyclists from other published studies.

Table 6.1 Percentage body fat values for male off-road cyclists.

Study	Cycle level	n	% Body fat
Lee *et al.* (2002)	Int	7	6.1 ±1.0
Impellizzeri *et al.* (2002)	Int	5	5.1 ± 1.6 (W)
			4.7 ± 1.4 (S)
Warner *et al.* (2002)	Elite	16	11.5 ± 2.7
Wingo *et al.* (2004)	Experienced	12	14.3 ± 1.0
Impellizzeri *et al.* (2005)	NAT and Int	13	5.3 ± 1.6
Present study	Amateur	9	13.5 ± 2.6

3. Physiological measures

The purpose of the incremental test in this study was twofold. Firstly, to categorize the participants in terms of their maximal exercise capacity and gain an understanding of their level of competitiveness. Secondly, to identify physiological threshold markers for individual training intensity zones, as well as for calculating individual weighting factors that were used in the individualized training impulse (iTRIMP) equation.

Comparisons between the physiological measures of published studies in off-road women and men cyclists are presented in Table 6.2 and Table 6.3, respectively. The men and women in this study had lower maximal aerobic capacities than off-road cyclists from other studies, as well as lower maximal aerobic capacities compared with cyclists from the US National Off-Road Bicycle Association (NORBA) (Wilber *et al*., 1997). Both the absolute and relative PPO of the men in this study were lower than the PPO of the NORBA cyclists (Wilber *et al*., 1997).

There were only two women in the present study and their physiological characteristics varied greatly; therefore, it is displayed separately in table 6.2. One of the women fit into the elite group, as her VO_{2max} were similar to that of elite, international and NORBA cyclists of the other studies. As expected, the absolute maximal aerobic capacity, absolute peak power output and power output at lactate threshold were statistically significantly greater in the men than in the women in this study. There were no other statistically significant differences in the remaining physiological responses between the men and women.

In this study, the lactate threshold (LT) was determined from the data obtained during the maximal aerobic capacity test. Similar data from other studies are depicted in Tables 6.2 and 6.3 for comparative purposes. The men in this study had lower values in all the criteria, except the PPO compared to participants in the study by Wirnitzer and Kornexl (2008). They tested five amateur men (age 34.7 ± 3.06 years, height 1.71 ± 0.4 m, body mass 63.3 ± 10.12 kg) and two amateur women (age 32 ± 2.83 years, height 1.63 ± 0.2 m, body mass 51 ± 1.41 kg) who had similar physiological characteristics than participants in the present study. However, the laboratory testing occurred seven days before the start of the race, while in the present study the tests were performed 14 weeks prior to the race. A re-test prior to the race would probably have shown improved results that are closer to those reported in other studies. A re-evaluation of the participants' maximal exercise capacity was unfortunately not something that some of individuals would agree to.

Table 6.2 Physiological measures of women off- road cyclists in published studies

Study	Cycling level	VO_2max (ml.kg^{-1}. min^{-1})	PPO (W)	PPO (W.kg^{-1})	PO_{LT} (W)	PO_{LT}-1 (W.kg^{-1})
Wilber *et al.* (1997) n=10	NORBA	58	313 ±2.4	5.4 ±0.4	204 ±20	3.6 ±0.3
Stapelfeldt *et al.* (2004) n=2	Elite	58	320	5.0	-	-
	Elite	61	28	4.5	-	-
Impellizzeri & Marcora (2007) n=10	NAT & INT	61	306 ±31	5.9 ±0.7	-	-
Wirnitzer & Kornexl (2008) n= 2	Amateur	-	242 ±40	4.1 ±0.6	-	-
Present study n=2	Amateur	46	212	3.8	160	2.8
	Elite	61	298	4.3	235	4

NORBA, National Off-Road Bicycle Association; Int, international level off road cyclist; NAT, national level off-road cyclists; VO_2max, maximal aerobic capacity; PPO, peak power output; LT, lactate threshold.

Table 6.3 Physiological measures of male off-road cyclists in published studies

Study	Cycling level	VO_{2max} (ml.kg^{1}.min^{-1})	PPO (W)	Relative PPO (W.Kg^{-1})	PO_{LT} (W)	Relative PO_{LT} (W.Kg^{-1})
Wilber *et al.* (1997) n=10	Int	70.0 ± 3.7	420 ± 42	5.9 ± 0.3	271 ± 29	3.8 ± 0.3
Lee *et al.* (2002) n = 7	Int	78.3 ± 4.4	413 ± 36	6.3 ± 05	-	-
Impellizzeri *et al.* (2002) n= 5	Int	75.9 ± 5.0	367 ± 36	5.7 ± 0.6	276 ± 17	4.3 ± 0.2
Warner *et al.* (2002) n=16	Elite	67.4 ± 4.6	-	-	-	-
Stapelfeldt *et al.* (2004) n= 9	Amateur	66.5 ± 2.6	368 ± 25	5.3 ± 0.3	-	-
Cramp *et al.* (2004) n= 8	Amateur	60.0 ± 3.7	-	-	-	-
Impellizzeri*et al.* (2005) n=13	NAT and Int	72.1 ± 7.4	392 ± 35	-	286 ± 32	-
Gregory *et al.* (2007) n=11	Elite	-	368 ± 32	5.1 ± 0.4	-	-
Impellizzeri and Marcora (2007) n=12	Comp	-	-	-	273 ± 30	-
Prins *et al.* (2007) n=8	Comp	63.6 ± 5.[illegible]	372 ± 37	5.1 ± 0.4	-	-
Wirnitzer & Kornexl (2008) n=5	Amateur	-	314 ± 43	4.8 ± 0.3	-	-
Present study n=9	Amateur	42.0 ± 6.5	341 ± 47	4.5 ± 0.6	267 ± 38	-

Comp, competitive Int, international level off road cyclist; NAT, national level off road cyclists; VO_2max, maximal aerobic capacity; PPO, peak power output; LT, lactate threshold.

C. TRAINING LOAD MEASURES

The aim of this study was to compare Banister's TRIMP (bTRIMP), the Individualized Trimp (iTRIMP) and session RPE (sRPE) when used to determine TL of Cape Epic mountain bike riders and to assess which of the measuring tools best relate to performance in multi-stage mountain bike (MTB) racing. The performance was described as the total race time in hours, minutes and seconds for each rider.

1. External load: Total training distance

External load during the preparation phase was recorded as total distance covered. Distances covered during the preparation phase demonstrated a wide range within the study sample (1974 km to 4338 km) (Table 5.3). Although there was a weak correlation between total distance covered and total race time ($r = -0.31$; $P = 0.36$), it was noticed that the winner of the women's category, with a time of 31 hours 57 minutes, trained 1108 km more than the closest participant. Further, participant S11, who completed the least amount of training (1415 km) during the training phase, finished the race in 50 hours 18 minutes, the slowest time within the study sample. For the men, the fastest time within the group was 32 hours and 45 minutes, and the slowest 49 hours and 14 minutes. The slowest rider covered the lowest mileage, however, the fastest man covered the second lowest mileage. It is worth mentioning that the latter rider was the most experienced in the study and completed his eighth Cape Epic. These findings suggest that both high mileage during the preparation phase and race experience have positive effects on total race time.

Average distances covered by the cyclists (Table 5.2) peaked in week 3, as six of the participants (including one woman) competed in a 3-day multi day race as part of their preparation. During the last two weeks before the race, the distances covered per week dropped drastically from being consistently between 200 km and 300 km per week (excluding week 3) to 175 ± 68 km in week 12 and 61 ± 43.6 km in week 13, indicating a long taper period.

2. Internal training load for preparation phase and race: a comparison of methods

Table 6.4 summarizes the correlations between the different measuring tools for internal training load from different studies. The results of the current study correspond well with findings by Foster *et al*. (2001), who demonstrated consistent similarities for basketball and cycling training between Edward's TRIMP and sRPE using regression analysis. Impellizzeri *et al.* (2004) recorded training that consisted of "small-sided" games, with sprint and plyometric exercises performed once a week. The increased use of the anaerobic energy system in the more intermittent type exercise involved in soccer might contribute to higher RPE values, which might explain some of the lower correlations reported in this study. Borresen and Lambert (2008) concluded that the session-RPE method provides reasonably accurate assessments of training load compared with HR-based methods. A limitation that was highlighted was that the summated HR-zones scores used weighting factors for Edwards (1-5) and for Lucia (1-3) that will not correlate well with the sRPE score on a scale of one to ten, meaning that a maximum effort exercise bout in Lucia's TRIMP will have a weighing factor of 3, in Edward's TRIMP a factor of 5, and an sRPE of 10.

All the studies above used bTRIMP and summated HR-methods to validate the use of sRPE in TL calculations. A suggestion might be to use a more sensitive scale than the 10-point scale, to assess internal training load and thus improve the validity of the sRPE measurement.

Table 6.4 The relationships between different measures of training load (r-values)

	iTRIMP and bTRIMP	iTRIMP and sRPE	bTRIMP and sRPE	Edwards TRIMP and sRPE	Lucia's TRIMP and sRPE
Present study preparation phase amateur cyclists	0.72 (P = 0.02)	0.86 (P < 0.01) *	0.90 (P < 0.01) *	-	-
Present study Cape Epic race amateur cyclists	0.90 (P < 0.01) *	0.79 (P < 0.01) *	0.94 (P < 0.01) *	-	-
Impellizzeri *et al.*, (2004) Junior soccer players	-	-	0.50 -0.77	0.54- 0.78	0.61-0.85
Borresen and Lambert(2008) Recreational athletes	-	-	0.76 (95% CI: 0.56 – 0.88)	0.84 (95%:CI 0.70 -0.92)	-

The bTRIMP equation includes a weighting factor (Y) that is used to emphasize high-intensity exercise in an attempt to avoid awarding disproportionate importance to higher volumes of low-intensity exercise compared with low volumes of intense activity. The Y weighting factor in the bTRIMP equation is based on the lactate profiles of trained men and women as exercise intensity increases (Banister, 1991). As such, Borressen and Lambert (2008) concluded that the use of a standard weighting factor (Y) in the bTRIMP equation, which is based on a fixed lactate–workload relationship, might be inappropriate for quantifying training load in persons who differ in training status. The very strong correlation between bTRIMP and sRPE in the present study might indicate that the participants had similar training status and that they did most of their training at steady state submaximal workloads (below LT_1). The coefficient of variance (CV) for VO_2max and PPO for the present cyclists were 15% and 13%, respectively, indicating a relatively homogenous group with regard to training status. Nonetheless, they were tested 13 weeks prior to the event and their responses to training could have been very different.

Edward's TRIMP focuses on the duration spent in five heart rate zones and it weighs each zone such that zone 1 is weighted the least and zone 5 is weighted the most. This weighting system might limit the accuracy of the TRIMP score. As a weighting factor is applied to each zone comprising a range of heart rates, the lowest heart rate and the highest heart rate in each zone will be weighted the same despite a difference in physiological load. Under certain circumstances, a change in heart rate of only 1 beat.min^{-1} will change the weighting factor of the zone, thereby increasing or decreasing the calculated load disproportionately. Another potential source of error in this equation is that the time spent below 50% of HR_{max} is not included in the calculation. This might only affect the accuracy of the calculation marginally (if at all) in high-intensity workouts, but it is nonetheless worth noting, especially when quantifying training load for submaximal or interval-training bouts.

Lucia's TRIMP method focuses on the duration spent in a 3-zone model, where zone 1 to 3 is weighted linearly, however, the zones are anchored around physiological markers (LT_1/VT_1 and LT_2/VT_2). Because of the limitations pointed out when using the summated HR-measures, these measures were excluded from the present study. Inconsistencies in the quantification of training load using above mentioned methods compelled researches to use a weighing factor that is not generic but accounts for individual response to training and incorporates physiological stress at high-intensity training. An example of this method is iTRIMP.

The present study incorporated the use of the iTRIMP method to analyse the TL of Cape Epic cyclists. The strong correlations between iTRIMP, bTRIMP and sRPE in both the preparation phase and the race indicate that these methods are appropriate to use for calculating TL of MTB cyclists during training and race conditions.

3 Training load measures and its relation to performance

Moderate correlations were found between the HR-based internal TL scores during the preparation phase and total race time (iTRIMP: r = -0.56, P = 0.85; bTRIMP: r = -0.53, P = 0.09). The relationship between sRPE and total race time was the lowest (r = -0.41, P = 0.20). These findings support the use of a training load method, such as iTRIMP, that integrates individual physiological characteristics (i.e. HR–blood lactate relationship), rather than mean exercise intensity values or arbitrary weighting factors.

Although in agreement with the findings of Manzi *et al.* (2009) and Sanders *et al*. (2016), they reported much stronger correlations between iTRIMP and performance during 5000 m (r = -0.77; P = 0.02) and 10,000 m track performances (r = -0.82; P = 0.01) and very strong relationships with training stress scores (TSS) (r = 0.81, P = 0.01) and power output at 2 mmol·L^{-1} (r = 0.75, P = 0.02), respectively. Moderate relationships were also observed for sRPE (r = 0.54) and bTRIMP (r = 0.54) in these studies. It should be noted, however, that their performance measure was either in the laboratory or on an athletics track and thus far more controlled than the performance measure in the field of the present study. Lower correlations observed in the present study compared to Sanders *et al.* (2016) is possibly related to the higher overall TL scores in their study, namely iTRIMP (1090 ± 220 AU vs 495 ± 169 AU), bTRIMP (891 ± 200 AU vs 458 ± 154 AU) and sRPE (4086 ± 1460 AU vs 1858 ± 573 AU). Evidently, the assumption is made that higher TL volumes per week is related to, but not the sole determinant, of improved performance in the field. Furthermore, Sanders *et al*. (2016) had twenty-three competitive road cyclists in their study. Not only was the sample size larger than in the present study, but the study population also differed. In general, competitive road cyclists perform higher volumes of training than amateur MTB riders.

It should also be considered that the relationship between TL and performance (the “dose-response” effect) is typically assessed with a specific measure of aerobic fitness or performance under controlled conditions. In the current study, the dose was described as the TL over 13-weeks and related to the “response” over an 8-day stage race, where the individuals’ performances were subjected to a plethora of factors that could not be controlled. The overall result of the multi-day race could be influenced by many factors, such as technical problems, injury, illness, environmental factors and the fact that participants compete in pairs and the total race time is not an individual effort.

A repeat of the laboratory exercise test prior to the race or a 40-km time trial before and after the 13-week training phase as a measure of performance would probably improve the strength of the relationships. Nevertheless, the moderate correlations obtained in this study, suggest that at least 28–31% of variance in the race performance of amateur, recreational cyclists in the Cape Epic is explained by TL accumulated during the preparation phase.

The complex interaction of many factors (e.g. hormone concentrations, personality traits, environmental conditions) that contribute to sRPE may explain the weaker dose-response relationship with race outcome in this study, compared to the other training load methods. Thus, less than 17% of the variance in race performance is accounted for by sRPE during preparation. Nevertheless, the current study observed a stronger TL and performance relationship for sRPE compared to previous research by Foster *et al*. (2001) (r = 0.29). The reason(s) for this difference are not apparent from the information provided in the article.

The weaker correlation between bTRIMP and race performance, compared with iTRIMP and race performance, in the current study, can be related to the assertions of Foster *et al*. (2001). They suggested that the accuracy of the bTRIMP equation might be limited by the inability of heart rate data to quantify high-intensity or non-steady-state exercises such as resistance training, high-intensity interval training, or plyometric exercise. Due to the interval nature of mountain biking, the use of average heart rate in the bTRIMP equation might thus not adequately represent very high-intensity exercise.

Although the iTRIMP equation account for individual responses to training, it still relies on HR-based methods to calculate the TL. A basic assumption of this method is that heart rate during exercise is a good marker of exercise intensity, however, this assumption does not always hold true. There are many factors, including environmental (temperature and humidity), physiological (i.e. state of hydration, diurnal change, state of training) and psychological factors which may affect the heart rate/exercise intensity relationship (Lambert and Borressen, 2010). To overcome this limitation when monitoring TL in cyclists, the use of a power meter and calculation of TSS have been suggested and used successfully in well-trained cyclists (Sanders *et al.,* 2016). However, the cost of power meters limits its use by amateur cyclists. Furthermore, power meters were also not considered for use in this study, as the possibility that participants may have encountered technical problems with data recording over the prolonged monitoring period and during the race posed too great a risk.

Statistically significant correlations were found between race time and iTRIMP scores during the race (r = -0.78, P <0.01), compared to moderate correlations for bTRIMP during the race and total race time (r = -0.58, P = 0.08), while a weak correlation was noted for sRPE during the race and race time (r = -0.36, P = 0.31). These findings reiterate the superior value of an individualized measure to calculate load. Furthermore, the weaker correlation for the bTRIMP results could be attributed to the possibility that there were high volumes of high-intensity exercise occurring during the race, while bTRIMP has been identified as a weak measure of intensity during interval type exercise. The weak correlation between sRPE and race performance might be explained by the fact that during the multi-stage race the perceived effort rating remained very high due to accumulated fatigue over 8 days, while the “real load”, if measured objectively, may actually be low.

D. TRAINING INTENSITY DISTRIBUTION

The second aim of this study was to determine if MTB riders employ a polarised training distribution in the preparation for the Cape Epic race. In training programs, the training load (TL) will be manipulated to achieve the desired outcome. This is often done by adjusting the training intensity on a day-to-day basis and distribute it throughout the training season. In a quest to evaluate the training distribution, the 3-zone training intensity model has been adopted by many coaches (Sanders *et al.,* 2017). Physiological thresholds based on blood lactate concentrations (LT_1, LT_2) or the first and second ventilatory thresholds (VT_1, VT_2) to define the training intensity zones are used to set individual-specific zones (Seiler & Kjerland, 2009). Time spent in these zones are subsequently used to evaluate the training intensity distribution (TID) over a training period.

To determine the training intensity distribution (TID) for cyclists preparing for the Cape Epic MTB race, the 3-zone method was used. In this method, the zones are anchored around the physiological markers of VT_1/ LT_1 and VT_2/ LT_2. The heart rate values at these markers were used to set individual zones and the time-spent-in zone approach was applied. The time-in-zone method has been used extensively in endurance sport (Esteve- Lanao *et al.,* 2005; Seiler and Kjerland, 2006; Esteve-

Lanao *et al.,* 2007; Yu *et al.,* 2012; Plews e*t al.,* 2014; Munoz *et al.,* 2014; Tonnessen *et al.,* 2014) and particularly in cycling (Lucia *et al.,* 2000; Zapico *et al.,* 2007; Neal *et al.,* 2013; Sanders *et al.,* 2017). HR is more often used than power output (PO) to set the individual zones, as it has been shown that the HR response of a specific type of exercise is more stable than the PO response (Hurts and Atkins, 2002; Stapelfeldt *et al.,* 2004; Hurts and Atkins, 2006). Jeukendrup and Van Diemen (1998) also suggested that HR might be a good indicator of whole body stress, whereas power output might be a good indicator of exercise intensity. Padilla *et al.* (2008) contended that since there are no indicators of exercise intensity that is without limitations, the use of HR to quantify the exercise intensity during cycling training and competitions are acceptable.

However, researchers are aware that HR monitoring, specifically during real-time events, is potentially affected by numerous factors. Duration of daily race, altitude, environmental conditions, terrain and type of bike (i.e. front suspension MTBs), cardiovascular drift and dehydration are some of the factors that could elevate the HR response, without an increase in exercise intensity. Since all participants in a certain race are exposed to most, if not all, of these factors and to a similar extent, it should be of limited influence on the differences in HR responses of cyclists. Moreover, the HR responses cannot be biased by race tactics (bunch building and/or drafting), as these tactics are not always easily accomplished and sometimes not even possible or permitted during MTBing.

1. Training intensity distribution (TID) of cyclists during the preparation phase

All participants in the study followed their own training plans and therefore a wide variety in TIDs during the preparation phase and the race were encountered. When the results were pooled for all participants, the TID for the preparation phase in Zone 1, 2 and 3 were 58%, 27% and 15%, respectively. This type of distribution has been described as a “pyramidal” distribution (Stöggl and Sperlich, 2015) and has been recorded during the pre-competition phases for cyclists (Lucia *et al.,* 2000; Zapico *et al.,* 2007; Sanders *et al.,* 2017) and runners (Esteve-Lanao *et al.,* 2005). Although all the above-mentioned studies lasted between six and nine months, however, only data from the pre-competition phases will be discussed.

Lucia *et al. (*2000) recorded a (78% / 17% / 5%), Zapico *et al.* (2007) (70% / 22% / 8%) and Esteve-Lanao *et al. (*2005) a TID of (71% / 21% / 8%) for zone 1, 2 and 3 respectively. The pyramidal distribution has been the most common TID model found in retrospective studies involving different types of endurance athletes, independent of the time in the season. The results of the present study do however indicate a reduced volume in zone 1 and increased volumes in zone 2, compared to the above-mentioned studies, where low-intensity training exceeded 70% of the total training, compared to 58% in the present study.

High volumes of low-intensity training have been linked to improved race performance (Steinacker, 1993; Esteve-Lanao *et al*., 2005; Seiler and Kjerland, 2006). Both longitudinal descriptive studies and experimental studies, pointed out that this kind of training is needed to achieve the necessary physiological adaptations that will lead to improved performance (Esteve-Lanao *et al*., 2005, 2007; Zapico *et al.,* 2007; Ingham *et al.,* 2008). An interesting finding of the present study was the strong inverse relationship between total training time during the preparation phase and percentage of time in zone 3 during the race ($r = -0.68$, $P = 0.03$). Thus, cyclists who logged high volumes of total training spent little time at high intensities during the race. This may suggest that these cyclists were aerobically fitter and did not require over-exertion during the race; this may be a particularly important factor during multi-stage races. On the other hand, the inverse relationship may be merely evidence of a better pacing strategy during the race. Both these factors, however, will have a positive effect on race performance. Nevertheless, the assertion of Costill *et al*. (1991), that when the amount of low-intensity training in elite athletes is doubled, no further improvement in performance is evident and that the participants' mood state can actually be negatively affected, should be noted. However, there is no indication in the literature of the optimal volume of low-intensity training necessary for multi-stage MTB events.

The lower percentage of training in zone 1 in the present study compared with other studies can be largely explained by the competitive level of the participants. Being an amateur means restricted time available to train and high volumes of low-intensity training is just not possible. Whether the participants deliberately choose to log more training time in zone 2 and 3 (to make up for the lower volume zone 1 training), is not clear. However, the only participants in the study who completed more than 70% of their training in zone 1, were the two women. The one was the ladies category winner who performed 84% of her training in zone 1. It has been reported that when the training volume is high, the majority of the training needs to be at lower intensities, as it is more tolerable and the risk for overtraining and fatigue is less (Stöggl & Sperlich, 2015).

While none of the participants in this study followed the threshold TID model during their preparation phase, the average amount of training in zone 2 was 26.7 ± 6.8% which is higher than the described training curves (polarised and pyramidal) for endurance athletes. Threshold (THR) training has been linked to less experienced athletes, with the reason being that they tend to train harder than prescribed during low-intensity sessions and not hard enough during prescribed high-intensity sessions (Seiler, 2010). However, THR was thought to be a fundamental part of elite endurance athletes' training program (7–22%) in distinct phases of the season (Lucia et al., 2000; Esteve-Lanao *et al*.,2005; Zapico *et al*., 2007; Sandbakk *et al*., 2011; Plews *et al*., 2014). Esteve- Lanao *et al*. (2007) found that exceeding threshold training by >20% and thus neglecting low-intensity training, may exert a negative impact on the autonomic nervous system, of which the consequence may be overtraining

In the present study, only one participant followed the "polarised" TID model. This model has been shown an effective strategy for some elite athletes during certain phases of the season (Stöggl & Sperlich, 2015). The high volume of zone 3 training might have been too strenuous for the participants in the present study. Alternatively, it may be a reflection of the absence of a well-structured program where a certain amount of interval training is usually prescribed.

2. Intensity distribution of cyclists during the Cape Epic

Knowing the intensity profile of the event can be useful to understand the physiological demands of the Cape Epic and assist in the structuring of training programs that will prepare the cyclists accordingly. It could also be useful to understand the training load imposed on cyclists, because many coaches incorporate races as part of their training sessions (Impellizzeri *et al*., 2004). However, the intensity profile of the current study should only be used as a guideline, as the route for the Cape Epic changes every year and environmental factors can greatly affect the TID of the race.

The TID of the pooled data for the Cape Epic race was 42 ± 23%, 41 ± 17% and 17 ± 13% in zone 1,2 and 3, respectively, suggesting a THR distribution race profile. These results showed some similarities with the 8-day Transalps MTB race

(Wirnitzer and Kornexl, 2008), namely 36 ± 12%, 58 ± 13%, 4 ± 8% and 2 ± 9% in the low, moderate, high and very high-intensity zones, determined using the time-in -zone method. (The combined high and very high-intensity zones will indicate intensities very different to zone 3 in the present study). When compared to unpublished data from the 2014 Cape Epic race where the intensity distribution was 51%, 43% and 7% in Zone 1,2 and 3 respectively (unpublished MSc thesis, Greeff 2014), the amount of time spent in zone 3 was much higher in the 2017 race. Reasons for the difference may relate to the different geographical routes, or the extreme temperatures experienced during the 2017 race.

The results with regards to the TID in this study is in agreement with the findings of Stöggl and Sperlich (2015) that there is no "optimal" TID in endurance athletes, and that the TID followed by individuals change according to the periodization phase that is studied and the methodology used to identify the training zones.

The present study found that the majority of the participants followed a "mild" pyramidal distribution during the preparation phase and that the race itself had a threshold distribution.

E. SUMMARY OF MAIN FINDINGS AND CONCLUSIONS

Hypothesis 1: *The iTRIMP method is an appropriate tool to quantify the TL in MTB cyclists*

Hypothesis 1 was accepted. The main findings of this study were that bTRIMP, iTRIMP and sRPE are good measuring tools of internal training load in MTB riders and that iTRIMP scores during preparation showed the best relationship to total race time. iTRIMP scores during the race also resulted in statistically significant correlations with race performance when compared to the other TL measures. 28 – 31% of the variance in the race performance of amateur, recreational cyclists in the Cape Epic is explained by TL accumulated during the preparation phase.

Hypothesis 2: *Cyclists will spend similar amounts of time in zone 1 training during the preparation phase and during the race.*

Hypothesis 2 was accepted. There was no statistically significant difference between percentage time spent in zone 1, 2 and 3 during preparation for the race and during the race.

Hypothesis 3: *There will be a statistically significant inverse relationship between training time in zone 1 and the cyclists' performance in the Cape Epic MTB race.*

Hypothesis 3 was rejected. There was only a weak correlation between percentage time spent in zone 1 during the preparation phase and total race time ($r = -0.12$; $P = 0.75$).

F. LIMITATIONS OF THE STUDY

The study sample only consisted of eleven participants of which only two were women, making a comparison between the men and women impossible, as well as affecting the strength of the correlations between TL methods. The small study sample also restricts the external validity of the study.

Cyclists compete in the Cape Epic race in teams of two; therefore, the stronger rider's HR can be affected by the slower rider in the pair. Furthermore, cyclists could experience technical difficulties during the race that will result in either lower or higher HR values. All these factors will influence the training load calculations, as these are all HR-based methods.

Incremental exercise tests in the laboratory were only performed 14 weeks prior to the Cape Epic and not repeated prior to the event. The effect of the 13-week preparation phase on their maximal exercise capacity, as well as their race performance, cannot be determined. It is therefore impossible to assess whether a particular TL monitoring method is more sensitive to changes in training adaptations than others. The objective measures used to determine the TL of the cyclists were all HR- based, assuming that HR is a valid and reliable measure of training and racing intensity in mountain biking.

Only the time-in-zone method was used to determine the training intensity distribution of the cyclists. Therefore, comparisons between different methods is not possible and no recommendation can be made regarding the preferred method for mountain biking.

G. FUTURE DIRECTIONS

In the quest to find a gold model to quantify TL, the inclusion of an individual sensitive measuring tool like iTRIMP is highly recommended in future studies on cyclists, and must be used in conjunction with power meters during preparation and the event. This would provide a direct assessment of the TL and HR -based methods to quantifying the training load and determining the best measurement tool for multi-day cyclists.

The present study was an attempt to identify how and how much the average participant train during the last three months leading up to the race. Future studies that compare the internal and external effects of these level of participants might be useful for coaches and sport scientist in preparing these athletes adequately for these races.

Laboratory exercise tests that can be linked to the dose response effect of these types of races will be valuable to track the progress of the training load performed by the athlete. These tests may potentially show which of the different TL quantification methods is the best indicator of physiological training adaptations, rather than using the performance in the eight-day race.

A suggestion for future studies is to compare the TID's from more than one year with each other to see if the intensity profiles are a function of the race characteristics.

Appendix A

Sportwetenskap
Sport Science
STELLENBOSCH
Sport Physiology Laboratory

PERSONAL DETAILS

FULL NAME:			
ADDRESS:			
TEL. NR:			
CELL:			
FAX:			
E-MAIL:			
DATE OF BIRTH:			
AGE:			
KNOWN DISEASE/ ABNORMALITY:			
DO YOU SMOKE? IF YES, SPECIFY:	YES	NO	
OTHER SPORTS:			
CYCLING: HIGHEST LEVEL OF COMPETITION:	NATIONAL		PROVINCIAL
	CLUB/LEAGUE		SOCIAL
DID YOU EAT/DRINK ANYTHING IN THE LAST 2 - 4 HOURS			
DO YOU HAVE PROOF OF AN ABSA CAPE EPIC 2014 ENTRY?	YES	NO	

Appendix B

American College of Sports Medicine (ACSM) health questionnaire

On this questionnaire, a number of questions regarding your physical health are to be answered. Please answer every question as accurately as possible so that a correct assessment can be made. Please mark the space to the left of the question to answer "yes". Leave blank if your answer is "no". Please ask if you have any questions. Your response will be treated in a confidential manner.

Name:____Date:______________________

Medical Screening – ACSM Medical Screening Questionnaire

__ Do you have any personal history of heart disease?

__ Do you have any personal history of metabolic disease (thyroid, renal, liver)?

__ Have you had diabetes for less than 15 years?

__ Have you had diabetes for 15 years or more?

__ Have you experienced pain or discomfort in your chest apparently due to blood flow deficiency?

__ Any unaccustomed shortness of breath (perhaps during light exercise)?

__ Have you had any problems with dizziness or fainting?

__ Do you have difficulty breathing while standing or sudden breathing problems at night?

__ Do you suffer from ankle oedema (swelling of the ankles)?

__ Have you experienced a rapid throbbing or fluttering of the heart?

__ Have you experienced severe pain in leg muscles during walking?

__ Do you have a known heart murmur?

__ Do you have any family history of cardiac or pulmonary disease prior to age 55?

__ Have you been assessed as hypertensive on at least 2 occasions?

__ Has your serum cholesterol been measured at greater than 5.4mmol/l?

__ Are you a cigarette smoker?

__ Would you characterize your lifestyle as "sedentary"?

Medical History

__ Are you currently being treated for high blood pressure?

If you know your average blood pressure, please enter: ________/________

Please Check All That Apply.

_ has doctor ever found an abnormal ECG?	_ Limited Range of Motion?	_ Stroke?
	_ Recently Broken Bones?	
_ Abnormal Chest X-Ray?	_ Arthritis?	Y _ Epilepsy or Seizures?
_ Rheumatic Fever?	_ Bursitis?	_ chronic Headaches or Migraines?
_ Low Blood Pressure?	_ Swollen or Painful Joints?	_ Persistent Fatigue?
_ Asthma?	_ Foot Problems?	_ Stomach Problems?
_ Bronchitis?	_ Knee Problems?	_ Hernia?
_ Emphysema?	_ Back Problems?	_ Anemia?
_ Other Lung Problems?	_ Shoulder Problems?	_ Are You Pregnant?

Has a doctor imposed any activity restrictions? If so, please describe:

____

____

____

Family History

Have your mother, father, or siblings suffered from (please select all that apply):

__ Heart attack or surgery prior to age 55

__ Stroke prior to age 50

__ Congenital heart disease or left ventricular hypertrophy

__ High cholesterol

__ Diabetes

__ Obesity

__ Hypertension

__ Osteoporosis

__ Asthma

__ Leukemia or cancer prior to age 60

Medications

Please Select Any Medications You Are Currently Using

_ Diuretics

_ Beta Blockers

_ Vasodilators

_ Alpha Blockers

_ Calcium Channel Blockers

_ Other Cardiovascular

_ NSAIDS/Anti-inflammatories (Motrin, Advil)

_ Cholesterol

_ Diabetes/Insulin

_ Other Drugs (record below).

Please list the specific medications that you currently take:

____

____

Emergency Contacts

Please list your general practitioner and person to be contacted in case of emergency

Doctor:______________________ Phone:______________________

Contact:______________________ Phone:______________________

Activities and Goals

On average, how many times do you exercise per week? ______

On average, how long do you exercise? ______ minutes

On a scale from 1 to 10, how intense is your typical workout (circle one):

Very Easy **1 2 3 4 5 6 7 8 9 10** Very Intense

For each activity that you participate in, indicate your typical exercise time in minutes per session:

Running/Jogging:	______	Weight Training:	______	Skiing/Boarding:	______
Walking:	______	Aerobics Classes:	______	Yoga/Martial Arts:	______
Stair Climbing:	______	Swimming:	______	Other:	______
Bicycle/Spinning:	______	Racquet Sports:	______		

Other

Please indicate any other medical conditions or activity restrictions that you may have. It is important that this information be as accurate and complete as possible.

____

Is any of this information critical to understanding your readiness for exercise? Are there any other restrictions on activity that we should know about?

Appendix C

Informed consent form

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CONSENT TO PARTICIPATE IN RESEARCH

Methods of monitoring the training load and its relationship to training load distribution in Cape Epic mountain bike riders

You are asked to participate in a research study conducted by Karin Winterbach (Honors in Sport Science) from the Sport Science Department at Stellenbosch University. The results will contribute to a Master's thesis. You were selected as a possible participant in this study because you intend to participate in the 2017 ABSA Cape Epic event.

PURPOSE OF THE STUDY

The primary aim of the study is to describe the training load distribution in Cape Epic mountain bike riders by means of different load measures.

1. **PROCEDURES**

If you agree to participate in the study, we asked that you do the following: You will be required to visit the sport science laboratory. On your visit you will be asked to complete questionnaires (Appendix A, B) to ensure that you meet the inclusion criteria, and give written consent.

Thereafter your body composition will be measured using a BodyMetrix BX2000. This procedure will take 10 minutes to complete.

You will be asked to do a maximal exercise test on the cycle ergometer. The aim of this test is to determine your VO_2 peak value (peak oxygen consumption). This will give us an indication of your functional capacity. Your capillary blood lactate concentration will be determined by a finger prick after each workload increment.

The test will continue until exhaustion. The procedure will take around 40 minutes varying from person to person.

Al the procedures will take place in the physiology laboratory at the Department of Sport Science.

You will wear a heart rate monitor during each training session, as well as during the Cape Epic. Your sessions will be downloaded from your personal device and exported to the researcher. You will also be required to complete the session RPE rating 30 minutes after each completed training session. Official stage times and total race times will be obtained from the race office after each stage. This will include information about any technical difficulties experienced with your bikes during the stage.

1. POTENTIAL RISKS AND DISCOMFORTS

There are no profound risks involved in this study. All the laboratory tests are standardized cycling tests with certain rules to ensure safety. You may experience dizziness and nausea during the tests on the cycle ergometer. If that is the case, exercise will be stopped immediately. You may also experience slight discomfort, such as muscle soreness and muscle stiffness, after the exercise test, but it won’t be more than after a hard training session.

2. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The results of all the tests and measurements will be made available to you, which may help you in your preparation for the Cape Epic.

The results of the study will help sport scientists to better understand the training load and training load distribution of participants.

3. PAYMENT FOR PARTICIPATION

You will receive no compensation for your participation in this study.

4. CONFIDENTIALITY

Any information that is obtained about this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

Confidentiality will be kept by storing the data on a computer with a confidential password. Only the researcher and the study leader will have access to the data.

The data will be stored on the study leader's computer (with a password) for 3 years after the study. Only the study leader has access to the computer.

If the article is published there will be no mentioning of participants' names. Only group results will be made available.

5. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You can refuse to answer certain questions and still participate in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. The following circumstance will allow termination; if you: do not comply with the regulations preceding the laboratory tests, do not complete all the stages of the event, have any serious injuries that would affect your cycling ability, have any health problem or use any chronic medication that may affect your heart rates and/or lactate values.

6. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact: Karin Winterbach at 0827750150 or 12343765@sun.ac.za, OR: Prof. Elmarie Terblanche, Chairperson at 021 808 2742/4915 or et2@sun.ac.za

7. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

Should you incur any research-related injury or incident during the laboratory exercise tests, all costs will be covered by the insurance of Stellenbosch University. To this end, you may contact Mr. van Kerwel (wvankerwel@sun.ac.za) for information on the issue of compensation and coverage of medical expenses in the event of a research-related injury.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me________________________________(name) by _____________________(researcher) in_____________________(language) and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

hereby consent voluntarily to participate in this study. I have been given a copy of this form.

____

____

Name of Participant

Name of Legal Representative (if applicable)

_____________________________________ _____________

Signature of Subject/Participant or Legal Representative Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to____________*]. [He/she*] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English*] and no translator was used.

_____________________________________ _____________

Signature of Investigator

Date

Bylae C

Ingeligte toestemmingsbrief

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INWILLIGING OM DEEL TE NEEM AAN NAVORSING

Die monitering van oefenlading en ladingverspreiding in amateur fietsryers in voorbereiding vir die Cape Epic bergfietswedren

Jy word gevra om deel te neem aan 'n navorsingstudie wat deur Karin Winterbach (Honneurs in Sportwetenskap) van die Departement Sportwetenskap aan die Universiteit Stellenbosch uitgevoer word. Die resultate sal bydra tot 'n Magistertesis. Jy is as moontlike deelnemer aan hierdie studie gekies omdat jy ingeskryf het vir die 2017 Cape Epic bergfietswedren.

1. DOEL VAN DIE STUDIE

Die primêre doel van die studie is om die oefenlading, en verspreiding daarvan, in bergfietsryers te beskryf in voorbereiding van die Cape Epic wedren deur middel van verskillende ladingsmetodes.

2. PROSEDURES

Indien jy inwillig om aan die studie deel te neem, vra ons dat jy die volgende moet doen:

Die Sportfisiologie laboratorium te besoek waartydens jy vraelyste sal voltooi oor geselekteerde persoonlike data en jou gesondheid om te verseker dat jy aan die insluitingskriteria voldoen, en jy sal ook geskrewe toestemming verskaf.

Jou persentasie liggaamsvet sal gemeet word met behulp van 'n infrarooi skandeerder (BodyMetrix BX2000) om jou persentasie liggaamsvet te bepaal. Hierna sal jy ‘n maksimale oefentoets op ‘n fietsergometer aflê om jou VO2 piek waarde (piek suurstofverbruik) te bepaal. Dit sal vir ons 'n aanduiding gee van jou uithouvermoë kapasiteit. Jou kapillêre bloed laktaatkonsentrasie sal bepaal word deur 'n vingerprik na elke werklading inkrement. Ons neem gemiddeld agt bloedmonsters van persone wat hierdie oefentoets doen en die totale volume bloed wat onttrek word sal nie meer as 2 mL oorskry nie. Die toets sal voortgaan tot jy uitputting bereik.

Jy sal gevra word om 'n hartspoedmonitor tydens elke oefensessie te dra vir die 12 weke voor die Cape Epic, sowel as tydens die wedren. Jou sessies sal afgelaai word by jou persoonlike toestel en elektronies na die navorser gestuur word. Jy sal ook gevra word om 30 min na elke oefensessie die sessie te evalueer in terme van jou persepsie van uitputting en moegheid. Jou amptelike tye vir elke dag van die wedren en jou totale wedrentyd sal van die Cape Epic kantoor verkry word.

3. MOONTLIKE RISIKO'S EN ONGEMAKLIKHEID

Daar is geen ernstige risiko's in hierdie studie. Al die laboratoriumtoetse is

gestandaardiseerde fietsrytoetse met sekere reëls om veiligheid te verseker. Duiseligheid en naarheid mag tydens die toetsing op die ergometer ondervind word. As dit die geval is, sal oefening onmiddellik gestaak word. Effense ongemak, soos spierpyn en spierstyfheid, kan ook ná die oefening toetse ervaar word, maar dit sal nie meer wees as wa jy ervaar na 'n harde oefensessie nie.

4. MOONTLIKE VOORDELE VIR PROEFPERSONE EN/OF DIE SAMELEWING

Die resultate van al die toetse en metings sal aan jou beskikbaar gestel word, wat jou kan help in jou voorbereiding vir die Cape Epic.

Die resultate van die studie sal sportwetenskaplikes help om beter te verstaan watter oefenladings benodig word om suksesvol die Cae Epic te voltooi.

5. VERGOEDING VIR DEELNAME

Jy sal geen vergoeding vir jou deelname aan hierdie studie ontvang nie.

6. VERTROULIKHEID

Enige inligting wat verkry word in hierdie studie en wat met jou geïdentifiseer kan word sal vertroulik bly en sal slegs bekend gemaak word met jou toestemming of soos deur die wet vereis.

Vertroulikheid sal verseker word deur die data op 'n rekenaar met 'n vertroulike wagwoord te stoor. Slegs die navorser en die studieleier sal toegang tot die data hê. Die data sal op die studieleier se rekenaar (met 'n wagwoord) vir 3 jaar na die studie bewaar word. Slegs die studieleier het toegang tot hierdie rekenaar. Indien 'n artikel van die resultate gepubliseer word, sal daar geen melding van name van deelnemers wees nie. Slegs groepresultate sal beskikbaar gestel word.

7. DEELNAME EN ONTTREKKING

Jy kan kies of jy wil deel wees van hierdie studie of nie. As jy vrywillig aan die studie deelneem, kan jy enige tyd onttrek sonder gevolge van enige aard. Jy kan weier om sekere vrae te beantwoord en nogsteeds aan die studie deelneem. Die navorser kan jou onttrek van hierdie navorsing indien omstandighede dit vereis. Die volgende omstandighede sal tot beëindiging van jou deelname lei; As jy nie aan die regulasies voor die laboratoriumtoetse voldoen nie, jy nie gesond voel tydens die maksimale oefentoets nie, jy nie al die stadiums van die Cape Epic wedren voltooi nie, as jy 'n besering opdoen wat jou oefenvermoë beïnvloed, jy enige gesondheidsprobleem opdoen of kroniese medikasie gebruik wat jou hartspoed of bloedlaktaatwaardes sal beïnvloed.

8. IDENTIFIKASIE VAN ONDERSOEKERS

Indien u enige vrae of kommentaar oor die navorsing, voel asseblief vry om ons te kontak:

Karin Winterbach: 0827750150 of 12343765@sun.ac.za

Alternatiewelik kan jy my studieleier kontak:

Prof. ElmarieTerblance, Departement Sportwetenskap, Universiteit Stellenbosch, Privaatsak X1, MATIELAND, 7602, of 021 808 2742/4915 of et2@sun.ac.za

9. REGTE VAN PROEFPERSONE

Jy kan te eniger tyd jou inwilliging terugtrek en jou deelname beëindig, sonder enige nadelige gevolge vir jou. Deur deel te neem aan die navorsing doen jy geensins afstand van enige wetlike regte, eise of regsmiddel nie. Indien jy vrae het oor jou regte as proefpersoon by navorsing, skakel met Me Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] van die Afdeling Navorsingsontwikkeling.

VERKLARING DEUR PROEFPERSOON OF SY/HAAR REGSVERTEENWOORDIGER

Die inligting hierbo is vir my, ____ (naam) deur

____ (Navorser) in (Afrikaans/Engels) verduidelik en ek is die taal magtig. Ek is die geleentheid gebied om vrae te vra en die vrae is bevredigend beantwoord.

Ek willig hiermee vrywillig in om deel te neem aan die studie. 'n Afskrif van hierdie vorm is aan my gegee.

____

Naam van deelnemer

____

Naam van regsverteenwoordiger (indien van toepassing)

____ ________________

Handtekening van deelnemer of regsverteenwoordiger Datum

VERKLARING DEUR ONDERSOEKER

Ek verklaar dat ek die inligting in hierdie dokument vervat verduidelik het aan ____ verduidelik het. Hy/ sy is

aangemoedig om enige vrae te vra. Hierdie gesprek is in Afrikaans / Engels gevoer en geen vertaler is gebruik nie.

____

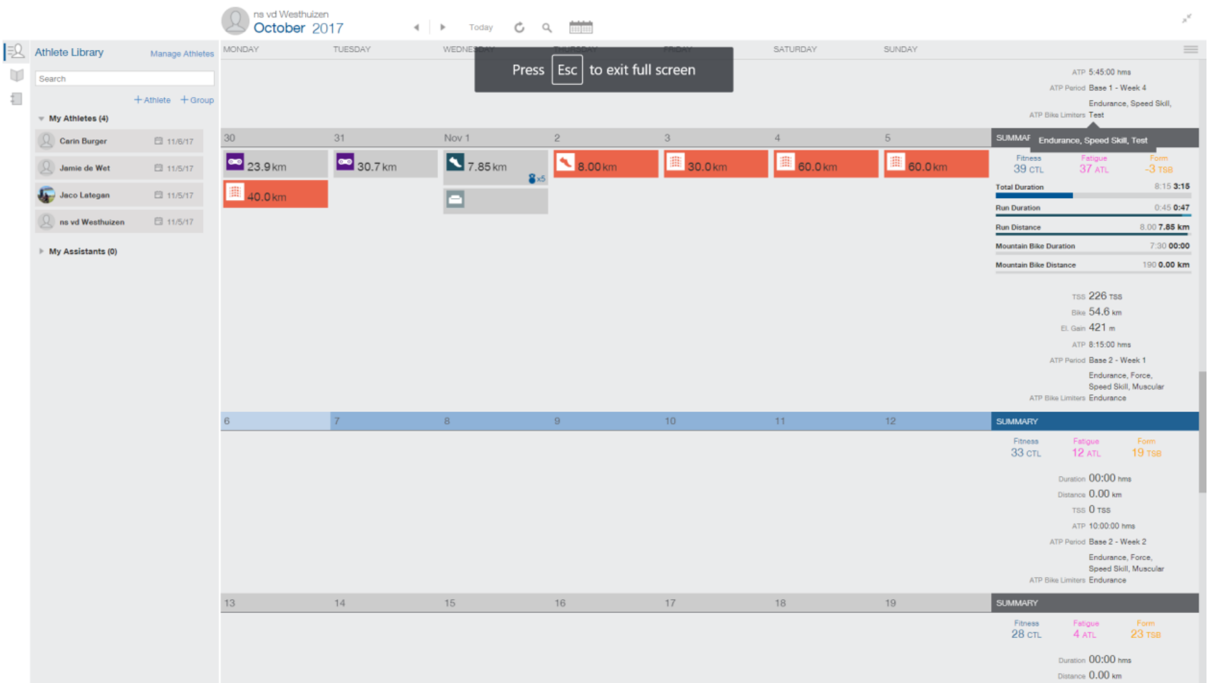
Handtekening van ondersoeker

Appendix D: CR -10 Scale

1 - 10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really, Hard
10	Maximal: Just like my hardest race

Appendix E

TrainingPeaks personal online diary



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