SUPRA-MAXIMAL SPEED INTERVAL TRAINING EFFECT ON A 40m STANDING START SPRINT AND TIMED 3000m RUNNING PERFORMANCE IN MODERATELY TRAINED FEMALE RUNNERS: ALTERG® ANTI-GRAVITY TREADMILL AND DOWNHILL RUNNING.

by

Tim Ellerbeck

Student No: 207056409

Submitted in partial fulfilment of the Master of Arts degree in Human Movement Science with Endorsement Sports Science in the Faculty of Health Sciences at the Nelson Mandela Metropolitan University

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Supervisor: Dr M L Baard

Co-supervisor: Mark Kramer

DECLARATION

I, Tim Ellerbeck, hereby declare that this is my own original work. All the sources used or quoted have been indicated and acknowledged by means of complete references. It has not previously been submitted for assessment or completion of any postgraduate qualification to another University or for another qualification.

Tim Ellerbeck

Date: March 2016

COMMITTEE MEMBERSHIP

TITLE: THE EFFECT OF SUPRA-MAXIMAL SPEED INTERVAL TRAINING ON AN ALTERG ANTI-GRAVITY TREADMILL AND A NORMAL WEIGHTED DOWNHILL INTERVAL TRAINING PROTOCOL ON A 40 METER STANDING-START SPRINT AND A TIMED 3000 METER RUN IN MODERATELY TRAINED FEMALE RUNNERS

Author: Tim Ellerbeck

Date submitted: December 2015

Supervisor: Maryna Baard, Ph.D.

Co-supervisor: Mark Kramer, M.Sc.

Statistician: Danie Venter, Ph.D.

ABSTRACT

The purpose of this study was to explore what the supra-maximal speed interval training effect was on a 40m standing start sprint and timed 3000m running performance was for two separate study groups when using either the AlterG® anti-gravity treadmill, or downhill running as a training intervention, for moderately trained female runners. The level of delayed onset of muscle soreness (DOMS) after each supra-maximal speed interval session was also captured. Data from 20 women was collected during initial pre-intervention testing; involving the 40m standing start sprint and 3000m timed trial run. During a four week training intervention the level of DOMS experienced by participants at increments of 24 hours, 48 hours and 72 hours, in each respective training group was recorded. Post-intervention testing was performed to once again measure the participants 40m standing start sprint and 3000m timed trial run values, results were analysed and compared to pre-intervention data.

Findings

Both training groups reported improvements when comparing pre-intervention to post-intervention times.

1) The mean post-intervention difference in 40m performance for the AlterG® and downhill training group was 0.31 and 0.27 seconds, respectively.
2) The mean post-intervention difference in 3000m timed trial run score for the AlterG® and downhill run groups was 41 and 36 seconds, respectively.
3) The AlterG® anti-gravity group experienced significantly lower levels of DOMS after supra-maximal speed sessions during the four week training intervention measured at 20.83% less when compared to the downhill run group.

Conclusion: The difference in improvement between the two training groups with regards to the reduction in time taken to complete the 40m and 3000m tests was not statistically significant; however the AlterG® anti-gravity group exhibited significantly lower levels of DOMS 24 hours, 48 hours and 72 hours after each supra-maximal training session.

An online search using Pubmed, Science Direct, Medline and Google scholar databases was conducted. The following keywords were used: anti-gravity treadmill,

downhill running, supra-maximal speed intervals, 40m sprint, 3000m run, female runner, and delayed onset of muscle soreness.

All articles thought to be relevant to the topic were reviewed.

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CHAPTER 1

FORMULATION OF THE RESEARCH PROBLEM

1.1 Introduction

Supra-maximal speed training for endurance athletes has long been recognised as an integral component of a successful training regime. Dating back to the 1930's when *fartlek* ("speed play" in Swedish) was developed as a means of interval training to stress both the aerobic and anaerobic systems through interval and continuous training (Bompa & Haff, 2014).

In order for athletes to achieve supra-maximal speed, they either need to increase stride rate, stride length or a combination of both. According to Gojancovic, Cutti, Shultz and Matheson (2012) it was essential to investigate the use of supra-maximal running in endurance runners because part of their training involved high-speed intervals that aimed to improve not only running technique and economy, but also cardiovascular capacity.

Traditional high-intensity interval training programmes for endurance athletes recommended no more than two high-intensity interval sessions a week to prevent the risk of muscular injury due to excessive ground reaction forces and eccentric loading commonly associated with supra-maximal speed training (Billat, Flechet, Petit, Muriaux, & Koralsztein, 1999). As far as the researcher was aware, no studies could be found that have used the AlterG® anti-gravity treadmill, a novel training device, for supra-maximal speed interval training to quantify improvement of a 40m standing start sprint and 3000m timed trial run, after undertaking a specifically designed four week training intervention. The traditional method of downhill supra-maximal speed interval training was followed in parallel to the AlterG® anti-gravity supra-maximal speed interval training with programmes as equivalent as possible in order to compare post-intervention results of two groups of female middle distance runners.

The benefit to this format of training could be of value to many athletes who have limited time available to train due to occupational and other commitments, as it allowed for short but very intense training sessions. These sessions could trade off into high-level middle distance running performance with the scope of further enhancing a training format for longer distances. Cicioni-Kolsky, Lorenzen, Williams and Kemp (2011) stated that concurrent improvements in aerobic and anaerobic capacities were of practical significance to sprinters and middle distance endurance runners. The authors continued to state that supra-maximal interval training had been shown to be most effective in improving sprint and repeated sprint performance in physically active individuals, without decrements in concurrent endurance gains (Cicioni-Kolsky, et al. 2011).

Chapter one narrated the context of the empirical research that was undertaken to provide a perspective on the supra-maximal training effect performed on two different training modalities; namely, the AlterG® anti-gravity treadmill and a 5.8° downhill slope, on the dependent variables of sprint performance as measured during the 40m start sprint – and 3000m sprint times, as well as the level of delayed onset of muscle soreness (DOMS) experienced 24 hours, 48 hours and 72 hours after each supra-maximal training session. A target group of 20 moderately trained, volunteer female runners between the age of 30 and 45 years, belonging to a registered running club in Hout Bay, Cape Town were selected, according to inclusion criteria set out in chapter three, to take part in the study.

1.2 Contextualisation of the Problem

Anaerobic interval training for the endurance athlete has recently received a large amount of attention in the scientific literature (Plisk, 2008). In contrast to traditional endurance training, high-intensity sprint interval training had generally been thought to have less of an effect on muscle oxidative capacity, substrate utilisation and endurance performance (Gibala, Little, van Essen, Wilkin, Burgomaster, Safdar, Raha, & Tarnopolsky, 2006; Psilander, Wang, Westergren, Tonkonogi, & Sahlin, 2010). Various physiological adaptations occurred due to high-intensity sprint interval training that impacted on the training frequency and performance of the athlete. These changes were described by Burgomaster, Heigenhauser, and Gibala (2006) as increased maximal activities of mitochondrial enzymes, reduced glycogen utilisation and lactate accumulation during matched-work exercise. Aforementioned metabolic adaptations improved performance during tasks that primarily relied on aerobic metabolism. Edge, Bishop and Goodman (2006) postulated that high-intensity sprint interval training could also be more effective than endurance training for improving other important determinants of endurance performance, such as muscle buffering capacity. According to Kent (2007) muscle-buffering capacity was the ability of muscles to neutralise acid accumulation during high-intensity exercise that resulted in delaying the onset of fatigue.

Gibala et al. (2006) postulated that muscle-buffering capacity was improved by regular anaerobic training, but apparently not by aerobic training. Low volume high-intensity supra-maximal speed interval training could therefore represent a time-efficient strategy to induce muscle and performance adaptations similar to high volume endurance training (Gibala et al. 2006). According to Gojancovic et al. (2012) it was essential to investigate the use of supra-maximal running in endurance runners because part of their training involved high-speed intervals that aimed to improve not only running technique and economy, but also cardiovascular capacity.

Literature reinforced the fact that weight-supported running using harnesses caused a reduction in both vertical ground reaction forces and metabolic work when compared to similar velocities and workloads without the support of body weight (Aaslund & Moe-Nilssen, 2008; Grabouwski & Kram, 2008; Grabouwski, 2010). Therefore, research to better understand, document, and to prescribe training recommendations is of interest to improve middle distance running performance using supra-maximal speed training intervals; and, in addition, to decrease the risk of injury when undertaking such training. For the purpose of this study, the reduction in metabolic cost for participants selected to train on the AlterG® anti-gravity treadmill was accommodated by increasing the cardiovascular stress experienced by means of supra-maximal speed running interval supplementation at percentages above those recommended for the traditional supra-maximal full body weight supported running. Calculations were done according to criteria discussed in the third chapter on methodology.

1.3 Problem Statement

The stress on the musculoskeletal – or cardiovascular system – in a weight bearing activity such as running was directly proportional to body weight if all other variables were kept equal [http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf, 2015]. The question thus arose whether un-weighted supra-maximal speed interval training on the AlterG® anti-gravity treadmill was superior to weighted supra-maximal speed interval training during downhill running in improving running performance as measured by speed in the 40m standing start and the 3000m timed run.

The reduction in ground reaction forces, and subsequent eccentric loading of the musculoskeletal system as a result of the "unweighting" nature of AlterG® running, should in theory also have elicited lower levels of DOMS experienced by the AlterG® anti-gravity treadmill participant group compared to the downhill running group. These supposed lower levels of ground reaction forces, eccentric loading and subsequent DOMS could therefore allow AlterG® anti-gravity treadmill users to run subsequent supra-maximal speed training intervals within a condensed period (twice a week as was proposed in this study) at a reduced risk of injury and at a higher quality of interval repeat ability. The assumption was that the sum of these combined benefits would ultimately transfer into improved performance in the 40m standing start sprint as well as the 3000m timed trial run. The implementation of the proposed training protocol could considerably save training time while simultaneously benefit the athlete by reducing the risk of musculoskeletal injuries. Such a recommended running intervention could benefit the female athlete who was severely time constrained and who would like to perform at a high level with a minimal risk of musculoskeletal injuries.

Due to the novelty of the AlterG® anti-gravity treadmill as a mode of sport performance enhancement for athletes, and in particular for female middle distance runners, as well as the lack of current research and quantifiable data on the performance benefits for middle distance runners when performing supra-maximal speed interval training on such a cutting edge modality, the researcher deemed this study necessary. The current study aimed to determine the difference in performance, if any, of a 40m standing start sprint and 3000m timed trial run when comparing baseline results obtained at the pre-test assessment with post-intervention test values following a four-week specifically designed training programme. The level of DOMS experienced at three different time periods after every training session (at 24 hours, 48 hours and 72 hours) by participants, was also evaluated and compared to ascertain whether any differences existed in the level of muscle pain experienced by the two training groups.

1.4 Significance of the Study

In order to formulate effective training programme prescription and recommendations for time-constrained middle distance runners, who were able to train on an AlterG® anti-gravity treadmill, research that was current was required to complement the scarcely published literature. A significant gap in the scientific knowledge of how a novel training modality such as the AlterG® anti-gravity treadmill compared to downhill running (which was a traditional supra-maximal speed training modality), in order to enhance performance without the risk of musculoskeletal injuries, existed. Furthermore, the question arose as to the level of muscle damage which could impact on subsequent training, and ultimately safety of athletes, when comparing DOMS levels experienced after supra-maximal interval training sessions between the two modalities.

Much of the literature published in the field analysed the effects of traditional supra-maximal speed training methods, such as towing, downhill sprinting and high-speed treadmill sprinting (Ebben, Davies, & Clewien, 2008). Literature was scant with regard to performance-enhancement training on the AlterG® anti-gravity treadmill. Gojancovic et al. (2012) further reiterated that specificity of training whilst using the AlterG® anti-gravity treadmill provides an alternative partial support system that is closer to normal running than any other method available (downhill running, elastic towing systems, and harness systems.

Grabowski and Kram (2008) postulated that the question of diminished impact forces and aerobic conditioning while training on an antigravity modality had been partially investigated only. Other studies (Hoffman, & Donaghe, 2011; Raffalt, Hovgaard-Hansen, & Jensen, 2013) ascertained the reduction of metabolic cost of ambulation with reduction in body weight using the AlterG® anti-gravity treadmill. To date, however, literature was limited pertaining to the effects of actual fast training speeds for a partially-weighted runner. No published study could be accessed which specifically analysed running performance outcomes over a set period of time when undertaking supra-maximal speed training on the AlterG® anti-gravity treadmill at reduced body weight.

The aforementioned was an important overlooked area of study, specifically with the increasing trend of athletes using supra-maximal speed training to improve performance while drastically reducing the amount of time needed to train according to a traditional training protocol. As a cutting edge piece of equipment that at the time was available at only a few high-performance institutes in South Africa, the potential performance benefits of training at supra-maximal speed on the AlterG® anti-gravity treadmill (with reduced ground reaction forces due to unweighting) and the comparison to the traditional supra-maximal speed training during downhill running, was the focus of this study.

1.5 Aim and Objectives

The primary aim of this study was to describe, explore and compare the effect of four weeks of supra-maximal speed interval training on the AlterG® anti-gravity treadmill and normal weighted downhill interval training on a 40m standing start sprint and a timed 3000m run in 20 moderately trained, female runners belonging to a registered running club in Hout Bay, Cape Town, who were between the age of 30 and 45 years. A secondary aim was to determine the level of DOMS in the experimental group (AlterG®) and the comparison group (downhill) every 24 hours, 48 hours, and 72 hours post supra-maximal speed interval training.

In order to achieve these aims, the following objectives were set to guide the study:

1.5.1 To determine anthropometric measures of height and weight for participants in order to calculate their Body Mass Index (BMI = height / weight ^{2}).

1.5.2 To conduct baseline assessments of 40m standing start sprint times and a 3000m timed run for every participant at the pre-test.

1.5.3 To design and implement the four week supra-maximal speed training intervention on the AlterG® anti-gravity treadmill experimental group and the downhill running comparison group.

1.5.4 To conduct post-test assessments of anthropometric measures, 40m standing start sprint times and a 3000m timed run for the participants in order to determine and compare post-intervention performances in moderately-trained female athletes.

1.5.5 To determine and compare the occurrence and rating of DOMS over the intervention period between the experimental group and the comparison group by using a numerical visual graphic rating scale (NVGRS).

1.6 Delineation of the Study

Suitable participants who met the inclusion criteria were selected, anthropometrical assessment of body weight and height was measured and BMI was calculated. Inclusion criteria required participants to be female and between 30 and 45 years of age. The participants had to be injury free for the six months prior to the study and free from any lower leg deformities or abnormalities. Participants were required to fall within a body mass index (BMI) of between 18.5 – 24.9 kg / m^2 (described as “normal” BMI according to the Centres for disease control and prevention [http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/, 2015] and be of at least a moderately-trained runner standard (see 1.7.5 for definition) to take part in the study.

In total 20 volunteer female participants were sampled conveniently from a registered running club in Hout Bay, Cape Town. Purposive sampling including a target sampling technique was used to identify and obtain participants (Brink, Van der Walt, & Van Rensburg, 2008). De Vos, Strydom, Fouchè and Delport (2009), defined purposive sampling as the selection of participants, based on accessibility and practicality, describing target sampling as the group from which the researcher wished to draw conclusions relative to the target population. Results were thus limited to female participants who met inclusion criteria for this study, and were not representative of the larger population of runners. A detailed description of the methodology is discussed in chapter three.

Confounding factors, such as reaction time for the 40m standing start sprint and average heart rate for the 3000m timed trial run, were excluded from the scope of the study, due to cost implications of necessary equipment and the required increase in duration of assessment time per participant. Dietary intake was excluded, as the scope of nutrition and dietetics fell outside the researcher's scope of practise (Panter & Sterba, 2011).

1.7 Concept Clarification

Key concepts used during the formulation of this treatise were defined under the following sub-headings:

1.7.1 Body Mass Index (BMI): Body Mass Index indicated an individual's body shape based on height and weight. It was an indicator of healthy, underweight and overweight body mass. BMI was calculated by dividing weight (kg) by squared height (m^2) (WHO, 2007: 1).

1.7.2 Supra-maximal speed training: Supra-maximal speed training involved work at intensities greater than 100% VO_{2max}, often with work to rest ratios ranging from 1:3 to 1:9 (Billat, 2001; Denadai, Ortiz, Greco, & de Mello, 2006; Esfarjani & Laursen, 2007; Iaia, Hellsten, Nielsen, Fernstrom, Sahlin, & Bangsbo, 2009; Laursen & Jenkins, 2002).

1.7.3 VO_{2max}: VO_{2max} was the maximal oxygen uptake or the maximum volume of oxygen that could be utilised in one minute during maximal or exhaustive exercise. It was measured as millilitres of oxygen used in one minute per kilogram of body weight (Figueroa, Wicke, Manning, Escamilla, & Santillo, 2012)

1.7.4 3000m run as an estimate of VO_{2max}: 3000m time-trial running velocity (AV) was used because a strong relationship between AV and running velocity at VO_{2max} (commonly used for determining training intensity) had been reported previously (Yoshida, Udo, Iwai, & Yamaguchi, 1993).

1.7.5 Moderately trained: For the purpose of the study, a moderately-trained runner was determined to be running at least three times a week, and have run at least two 10km races within the three months prior to participation. In addition, prospective participants also needed to have at least two years of running experience (see Appendix D: Section B, “experience” entailed a training history of at least two years of running, with an average of three runs a week).

1.8 Summary

Many individuals have a burning desire to compete at a competitive level in various sporting codes. Due to occupational and other commitments, time constraints play a major role in the amount of time that can be dedicated to training. Supra-maximal interval training for running has been shown to be most effective in improving sprint and repeated sprint performance and allowing concurrent improvements in aerobic and anaerobic capacities. This was of practical significance to sprinters and middle distance endurance runners to permit for short but very intense training sessions without decrements in concurrent endurance gains. The methods used for this form of training had become more specialised in the 21st century and current training regimes used a variety of methods to achieve desired results and included: towing, downhill sprinting, high-speed treadmill sprinting and the use of an unweighting treadmill training modality such as the AlterG® anti-gravity treadmill.

The purpose of the current study was to indicate the effect of supra-maximal interval training on the AlterG® anti-gravity treadmill when compared to supra-maximal interval training performed on a downhill slope (traditional training method) over a period of four weeks. Performance during a 40m standing start sprint and 3000m timed-trial run was assessed by means of pre- and post-intervention testing. The level of DOMs experienced 24 hours, 48 hours and 72 hours after each supra-maximal training session in moderately active female athletes from a registered running club in Hout Bay, Cape Town, was also determined.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Supra-maximal training has been more specialised in the 21st century and training regimes that were reviewed used a variety of methods to achieve desired results. Various supplementary methods, which achieved supra-maximal speed whilst training according to Ebben et al. (2008), included: towing, downhill sprinting, high-speed treadmill sprinting and the use of an unweighting treadmill training modality.

How effective an unweighting treadmill apparatus like the AlterG® anti-gravity treadmill is in improving performance, however, required investigation. Gojancovic et al. (2012) stated that the anti-gravity treadmill (AG) by AlterG® (Fremont, CA) was a new rehabilitation tool for weight-supported ambulation at the time. The use of the AlterG® anti-gravity treadmill as a mode of supra-maximal speed interval training was explored. This piece of equipment represented a relatively novel concept in training for performance enhancement in athletes. In contrast to this technologically advanced mode of supra-maximal speed interval training, the traditional approach to supra-maximal speed interval training on a downhill slope was addressed in this chapter. This review also contextualised and described delayed onset of muscle soreness (DOMS) as a physiological response to supra-maximal speed interval training. In addition, literature pertaining to physiology of performance, energy pathways used during sprint and middle distance running, and concepts to be considered in programme prescription for performance enhancement in middle distance athletes were addressed.

Each training intervention incorporated a supra-maximal interval training regime; the positive training effect on performance was explored in detail within the chapter. The effect and level of DOMS experienced by the two training groups using the AlterG® or downhill training modalities was also explored and unpacked within the chapter. Finally, the way in which moderately trained female athletes responded to the training intervention was also presented according to gathered research and first hand outcomes from this particular study.

2.2 Performance Physiology

Supra-maximal speed interval training enhanced physiological characteristics such as the activity and number of anaerobic and aerobic enzymes, substrate availability and oxygen kinetics in recreationally to well-trained individuals when compared to continuous sub-maximal training (Cicioni-Kolsky et al. 2011). Gojanovic et al. (2012) proposed that the challenge with repeated high-intensity interval training sessions was the risk of injury and the overall stress imposed on the musculoskeletal system of the athlete. Stress was good and necessary to elicit physiological adaptation in cells (muscles, cardiovascular organs, intracellular function, soft-tissue resistance), but could lead to over training and long-lasting musculoskeletal injuries. Billat et al. (1999) determined the effects of increasing the number of weekly high- intensity interval training sessions (HIIT) on exercise performance and stress hormone levels and found that increasing HIIT sessions to three times per week did not improve performance, but led to increased levels of norepinephrine. This enhanced level of the stress hormone predisposed the athlete to an increased risk of overtraining.

It was generally recommended that HIIT sessions should make up approximately 5 to 15 % of total training volume (Lindsay, Hawley, Myburgh, Schomer, Noakes, & Dennis, 1996; Ayers, & Sariscsany, 2011; Bompa & Haff, 2014; Daniels, 2014). However, the amount of HIIT sessions that the athlete could complete without increasing the risk of overtraining would be largely determined by the intensity of the session. It was general practice that two HIIT sessions would be the weekly upper training limit (in addition to a tempo session) in order to prevent the risk of overtraining. In addition, at least one of the weekly HIIT sessions would incorporate a submaximal session (e.g. 90 to 95 % VO_2max) (Neuman, Pfützner, & Berbalk, 2000; Jemma, Hawley, Kumar, Singh, & Cosic, 2005).

The use of an unweighting treadmill apparatus was a novel method through which supra-maximal speed training could be facilitated. According to Grabouwski and Kram (2008) running with weight support attenuated ground reaction forces and therefore, demanded less metabolic power than normal weight running. Thus an unweighting treadmill apparatus, such as the AlterG® anti-gravity treadmill, in theory, allowed athletes to reduce the amount of eccentric loading (through partial unweighting) experienced, while increasing leg speed and stride length (compared to normal weighted running). Thus, it could be hypothesised that utilising an apparatus, such as the AlterG® anti-gravity treadmill, could provide an athlete with the opportunity to repeatedly train the relevant physical, metabolic and neurological components essential for improving running speed, while significantly reducing the occurrence of delayed onset of muscle soreness (DOMS).

It would be logical to assume that due to increased ground reaction forces and subsequent eccentric loading, downhill running at supra-maximal speed (which was the traditional method of supra-maximal speed training in the absence of towing, high-speed treadmill sprinting, and the use of an unweighting treadmill training modality as assisted methods) would stress the musculoskeletal system the most when compared to AlterG® anti-gravity treadmill running at supra-maximal speed (Ebben et al. 2008). Therefore in order to improve maximal speed of running, the athlete would need to direct attention towards increased speed of limb movement.

Literature stated that increased maximum speed could be achieved by pre-competition training a variety of movement specific exercises, such as running at speeds faster than the competition rate (Ross, Ratamess, Hoffman, Faigenbaum, Kang, & Chilakos, 2009). The assisted method of reaching supra-maximal speed to create a running velocity greater than that which could be achieved under non-assisted conditions allowed all the systems of the body to adapt to high-speed movements that were then transferred to non-assisted competitive movements (Faccioni, 1994). Aforementioned research reported that increases in stride rate, integrated electromyography, ground reaction forces, muscle stiffness, stored elastic energy and increased efficiency of muscle contraction and running skill, occurred during supra-maximal running.

In order to compile a suitable training focus to improve 3000m run time, a study by Bragada, Santos, Maia, Colaço, Vítor, Lopes, and Barbosa, (2010) was identified whereby 18 well-trained male middle distance runners had various physiological and performance parameters measured three times a year over two competitive seasons. Results indicated that velocity at maximal oxygen uptake and velocity at 4 mmol L-1 allowed coaches to accurately predict an athlete’s 3000m performance when using a set formula, suggesting that improving the aforementioned physiological variables should receive the most attention in order to improve running performance. The physiological determinants of 16 highly-trained endurance athletes were analysed by

Jacobs, Rasmussen, Siebenmann, Díaz, Gassmann, Pesta, Gnaiger, Nordsborg, Robach, and Lundby, (2011) during a 26 km cycling timed trial and at maximal incremental power output. Results showed that skeletal muscle oxidative capacity and total body haemoglobin mass were important predictors for both measured variables and overall exercise performance correlated most strongly to both, as well as a high VO_{2max} (Jacobs et al. 2011). Table 2.1 summarised the articles obtained that assessed physiology of performance in endurance athletes.

Table 2.1: Summary of Articles that Assessed Performance Physiology in Endurance Athletes

Article	Study design	Participants	Testing performed	Results	Conclusion
Bragada, J.A., Santos, P.J., Maia, J.A., Colaço, P.J., Vítor, P.L., Lopes, P., & Barbosa, T.M., 2010. Longitudinal study in 3000m male runners: relationship between performance and selected physiological parameters.	Longitudinal Repeated measures design	18 well-trained male middle distance runners	The following parameters were measured: maximal oxygen uptake (VO_{2max}), running economy (RE), velocity at maximal oxygen uptake (vVO_{2max}), velocity at 4mmol L-1 blood lactate concentration (V4), and performance velocity (km·h-1) in 3000m time trials.	Values ranged from 19.59 to 20.16 km·h-1, running performance; 197 to 207 mL·kg-1·km-1. RE; 17.2 to 17.7 km·h-1, V4; 67.1 to 72.5 mL·kg-1·min-1, VO_{2max}; and 19.8 to 20.2 km·h-1, vVO_{2max}.	The best prediction formula for 3000m running performance was: y = 0.646 + 0.626x + 0.416z (R2=0.85); where y = V3000m velocity (km·h-1), x = V4 (km·h-1) and z = vVO_{2max} (km·h-1).
Jacobs, R.A., Rasmussen, P., Siebenmann, C., Díaz, V., Gassmann, M., Pesta, D., Gnaiger, E., Nordsborg, N.B., Robach, P., & C. Lundby, C., 2011. Determinants of time trial performance and maximal incremental exercise in highly-trained endurance athletes.	Literature review	16 highly-trained cyclists	Out of 150 separate variables, 10 principal factors responsible for hematological, cardiovascular, respiratory, musculoskeletal, and neurological variation in 16 highly trained cyclists were identified.	Oxidative phosphorylation capacity of the vastus lateralis muscle (*P* - 0.0005), steady-state submaximal blood lactate concentrations (*P* - 0.0017), and maximal leg oxygenation (sO2LEG) (*P* - 0.0295), accounting for 78% of the variation in time trial performance.	*1*) skeletal muscle oxidative capacity is the primary predictor of time trial performance in highly trained cyclists; *2*) the strongest predictor for maximal incremental power output is Hbmass; and, *3*) overall exercise performance correlates most strongly to measures regarding the capability for oxygen transport, high VO_{2max} and Hbmass,

2.3 Delayed Onset of Muscle Soreness (DOMS)

In addition to the physiological variables previously discussed, muscular and joint pain as a result of eccentric loading has proved to be of interest. DOMS has been described as damaged muscle tissue membranes combined with a secondary inflammatory condition as a result of unaccustomed eccentric contractions and maximal isometric contractions (Proske, & Morgan, 2001; Curtis, Fallows, Morris, & McMakin, 2010). In support of the DOMS theory Mathur, Sheel, Road, and Reid (2010) stated that high intensity, unaccustomed, or eccentric exercise could induce muscle damage, characterised by the disruption of myofilaments and cytoskeletal elements as well as inflammatory responses. Although many variables were reported in the quantification of muscle damage, the typical symptoms associated with DOMS were the loss of strength, pain, muscle tenderness, stiffness, swelling and elevated levels of the enzyme creatine kinase. Symptoms varied from mild muscle tenderness to severe debilitating pain (Curtis et al. 2010).

The quadriceps femoris muscle was particularly susceptible to fibre damage due to powerful action and frequent eccentric loading of the leg during sport and daily activities (Hedayatpour, Hassanlouei, Arendt-Nielsen, Kersting, & Falla, 2010). A commonly encountered example of eccentric exercise was downhill running with pain experienced as a result of DOMS, possibly causing an athlete to miss subsequent training sessions. Hedayatpour et al. (2010) further elaborated that altered muscle activity around the knee exposed structures of the knee joint to abnormal loading during exercise and contributed to sports-related injuries. Curtis et al. (2010) found that the soreness typically appeared between eight and 24 hours post-exercise, peaked at 48 hours and could last up to seven days. Although identification of the exact mechanisms pertaining to eccentric muscle damage and the occurrence of DOMS at the cellular level was beyond the scope of this study, it was important to note that eccentric muscle damage could and did typically impair athletic performance when an athlete was sore (Curtis et al. 2010). Athletes who used a training modality which could reduce the level of DOMS experienced as well as the negative effects experienced as a result of DOMS would be highly beneficial in the long term when following a training programme that involved supra-maximal speed interval training.

A randomised controlled study by Curtis et al. (2010), involving 35 healthy mixed gender participants, showed that levels of DOMS experienced 48 hours after maximal voluntary eccentric muscle contractions were highest when compared to 24 hours and 72 hours post-exercise time frames, when using a visual analogue scale. This finding was re-enforced when similar results occurred in a study by Hedayatpour et al. (2010) when bipolar EMG signals were recorded for various knee extensor and flexor muscles whilst performing maximal voluntary contraction. When compared to baseline, the 48 hour period post-exercise showed the greatest destabilisation perturbation. The influence of DOMS on subsequent muscle performance 4 hours, 24 hours and 48 hours post-exercise was investigated by Mathur et al. (2010), who acknowledged a reduction in subsequent performance, identified by means of a visual analogue rating scale.

A review of literature by Lewis, Ruby and Bush-Joseph (2012), went into detail about DOMS to describe the clinical presentation, cellular mechanisms, preventative measures, and management options. Gathered research pointed to the time period of 48 hours post-eccentric loading as eliciting the highest level of DOMS experienced by individuals. The results of a repeated measures controlled study involving 10 healthy volunteers who performed maximal voluntary eccentric contractions, and subsequently repeated the maximal voluntary eccentric contractions 24 hours after the initial exercise, showed a reduction in the level of maximal force produced and an elevated level of DOMS (Vila-Cha, Hassanlouei, Farina, & Falla, 2011). An earlier study by Lee, Goldfarb, Hedge, Patrick and Apperson (2002), which involved eccentric contractions performed well above the maximal isometric force of eight healthy individuals' non-dominant arms, showed that DOMS levels were highest 24 and 48 hours after the contractions. A summary of relevant literature pertaining to the role of DOMS in endurance athletes has been reported in Table 2.2.

Table 2.2: Summary of Articles that Assessed DOMS in Endurance Athletes

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Curtis, D., Fallows, S., Morris, M., & McMakin, C., (2010). The Efficacy of Frequency Specific Microcurrent Therapy on Delayed Onset Muscle Soreness.	Randomised controlled study	35 (18 male and 17 female) healthy participants.	Following a 15-min treadmill warm-up and 5 sub-maximal eccentric muscle contractions, participants performed 5 sets of 15 maximal voluntary eccentric muscle contractions, with a 1-min rest between sets, on a seated leg curl machine. Soreness was rated for each leg at baseline and at 24, 48 and 72 h post-exercise on a visual analogue scale (VAS).	No significant difference was noted at baseline p=1.00. Post-exercise there was a significant difference at 24 h (T=1.3 +/- 1.0, NT=5.2 +/- 1.3, p=0.0005), at 48 h (T=1.2 +/- 1.1, NT=7.0 +/- 1.1, p=0.0005) and at 72 h (T=0.7 +/- 0.6, NT=4.0 +/- 1.6, p=0.0005).	FSM therapy provided significant protection from DOMS at all time points tested.
Hedayatpour, N. H., Hassanlouei, L., Arendt-Nielsen, U., Kersting, G, & Falla, D., (2010). Delayed-Onset Muscle Soreness Alters the Response to Postural Perturbations.	Randomised controlled study	10 healthy men.	Bipolar surface EMG signals were recorded with 7 pairs of electrodes located on the knee extensor muscles (vastus medialis, rectus femoris, and vastus lateralis) and knee flexor muscles (the medial and lateral heads of the hamstring and the medial and lateral heads of gastrocnemius) of the right leg during rapid perturbations.	Maximal voluntary contraction force decreased by 24% +/- 4.9% immediately after exercise and remained reduced by 21.4% +/- 4.1% at 24 h and by 21.6% +/- 9.9% at 48 h after exercise with respect to baseline.	Reflex activity in leg muscles elicited by rapid destabilising perturbation was greatest 48 h after exercise when compared to baseline.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Mathur, S., Sheel, W.A., Road, J.D., & W. Reid, W.D., (2010). Delayed Onset Muscle Soreness Inspiratory Threshold Loading in Healthy Adults.	Randomised controlled study	10 healthy participants.	60 minutes of voluntary inspiratory threshold loading (ITL) at 70% of maximal inspiratory pressure. Maximal inspiratory and expiratory mouth pressures, delayed onset muscle soreness on a visual analogue scale and plasma creatine kinase were measured prior to ITL, and at repeated time points after ITL (4, 24 and 48 hours post-ITL).	Delayed onset muscle soreness was present in all subjects 24 hours following ITL (intensity = 22 +/- 6 mm; significantly higher than baseline p = 0.02).	An intense bout of ITL results in muscle soreness primarily in the accessory muscles of inspiration.
Lewis, P.B., Ruby, D., & Bush-Joseph, C.A., 2012. Muscle Soreness and Delayed-Onset Muscle Soreness.	Literature review	Novice and elite athletes	The sports medicine clinician needs to maintain this diagnosis among their active differential diagnoses. Associated symptomology of muscle soreness can be quite debilitating and the presentation of this phenomenon is as diverse as the population that experiences it.	Immediate or delayed-onset muscle soreness with a non-uniform intramuscular distribution may portray itself as a non-muscular injury with an unrecalled or vague traumatic event.	To describe the clinical presentation, cellular mechanisms, preventative measures, and management options related to DOMS.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Vila-Cha˜, C., Hassanlouei, H., Farina, D., & Falla, D., 2011. Eccentric Exercise and Delayed Onset Muscle Soreness of the Quadriceps.	Repeated measure controlled study	10 healthy volunteers	Maximum voluntary contractions (MVC) and explosive isometric contractions of the knee extensors followed by isometric contractions at 2.5, 5, 10, 15, 20, and 30% MVC at baseline, immediately after and 24 h after eccentric exercise of the quadriceps were performed. Twenty-four hours after exercise, the subjects rated their perceived pain intensity.	The maximum RFD and MVC of the knee extensors was reduced immediately post- and 24 h after eccentric exercise compared to baseline (average across both time points: 19.1 ± 17.1% and 11.9 ± 9.8% lower, respectively, P\0.05.	Eccentric exercise and subsequent DOMS of the quadriceps reduce the maximal force, rate of force development and force steadiness of the knee extensors.
Lee, J., Goldfarb, A.H., Rescino, M.H., Hedge, S., Patrick, S., & Apperson, K., 2002. Eccentric Exercise Effect on Blood Oxidative-Stress Markers and Delayed Onset of Muscle Soreness.	Controlled study	Eight healthy men	60 eccentric contractions at 135 - 150% dominant arm maximum isometric force (MIF) using their non-dominant arm elbow flexors were performed. DOMS, range of motion (ROM), MIF, and blood were obtained before, immediately after, and 24, 48, 72, and 96 h after the EE.	A significant decrease in MIF occurred at all times after the EE. ROM decreased from 24 to 96 h, and DOMS increased 24 to 72 h in the non-dominant arm as indicated by a repeated measure ANOVA.	The results suggest that 60 EE at 135 - 150% MIF can result in DOMS, with decreased muscle function and increases in plasma PC at 24 and 48 h.

2.4 Supra-Maximal Speed Interval Training

Gojancovic et al. (2012) reiterated that specificity of training while using the AlterG® anti-gravity treadmill was high, whereas questions of diminished impact forces and aerobic conditioning had been partially investigated only (Grabowski & Kram, 2008). Other studies (Hoffman & Donaghe, 2011; Raffalt et al. 2013) ascertained that the reduction of metabolic cost of ambulation with reduction in body weight occurred when using the AlterG® anti-gravity treadmill. To date, however, literature has been scarce pertaining to the effects of actual fast training speeds for a partially weighted runner. There was therefore a gap in existing literature pertaining to the use and efficacy of the AlterG® anti-gravity treadmill due to its novelty. The potential benefits of training at supra-maximal speed using the AlterG® anti-gravity treadmill while subsequently reducing ground reaction forces has therefore been explored as this mode of training was one of the focal aspects of this study.

Literature confirmed the fact that weight supported running using harnesses caused a reduction in both vertical ground reaction forces and metabolic work when compared to similar velocities and workloads without support (Aaslund & Moe-Nilssen, 2008; Grabouwski & Kram, 2008; Grabouwski, 2010). For the purpose of this study, the reduction in metabolic cost for participants selected to run on the AlterG® anti-gravity treadmill were accommodated by increasing the cardiovascular stress experienced by means of supra-maximal speed training interval supplementation at percentages above those recommended for the traditional supra-maximal full body weight supported running.

Iaia et al. (2009), declared that when already trained runners switched from regular endurance to speed endurance training, 10 km performance was unaltered despite a 65% reduction in training distance. Speed endurance training per se has shown to be sufficient in maintaining endurance performance of already trained subjects. Iaia and Bangsbo (2010) further elaborated that a considerable number of studies on untrained people have shown improvements in anaerobic enzymes activity after periods of training, including very short maximal / near maximal exercise bouts (5 to 30 seconds) interspersed with relatively long resting periods (45 seconds to 20 min). The aforementioned authors provided strong evidence that, although it occurred in brevity, speed endurance training led to performance improvements during several high-intensity short-duration exercises in already trained subjects (Iaia & Bangsbo, 2010). Furthermore, despite a marked reduction in training volume, the muscle oxidative potential, capillarisation and aerobic performance were unchanged; indicating that exercise at near maximal intensity was a powerful stimulus for maintaining physiological adaptation and performance gained from previous endurance training (Iaia & Bangsbo, 2010). On the other hand, when combined with a basic amount of aerobic training, it has been reported that speed endurance training improved endurance performance (Iaia & Bangsbo, 2010). When analysing research which focussed on endurance training regimes that incorporated supra-maximal speed training within training programmes, a literature review by Iaia and Bangsbo (2010) showed that a reduction in training volume coupled with speed endurance and supra-maximal speed training was of benefit to endurance athletes for performance enhancement.

The question of high-intensity or high-volume training has also been explored in a literature review by Laursen (2010) with reference to training for intense exercise performance. The critical analysis by Laursen (2010) concluded that 75% of the training volume should be performed at low intensity, and 10 to 15% should be performed at very high intensity. Favourable increases in performance were reported in elite athletes over a training period of only two to four weeks (Laursen, 2010). Table 2.3 reported a summary of relevant literature regarding supra-maximal training in endurance athletes.

Table 2.3: Summary of Articles that Assessed Supra-Maximal Training in Endurance Athletes

Article	Study design	Participants	Testing performed	Results	Conclusion
Iaia, F.M., Hellsten, Y., Nielsen, J.J., Maria Fernströom, M., Sahlin, K., & Bangsbo, J., 2009. Four Weeks of Speed Endurance Training Reduces Energy Expenditure During Exercise and Maintains Muscle Oxidative Capacity Despite a Reduction in Training Volume.	Repeated measures design	17 endurance trained runners	Runners were assigned to either a speed endurance training (SET; *n*-9) or a control (Con; *n*-8) group for a 4-week intervention (IT) period,	After the IT period, oxygen uptake was 6.6, 7.6, 5.7, and 6.4% lower (*P* - 0.05) at running speeds of 11, 13, 14.5, and 16 km/h, respectively, in SET, whereas remained the same in Con.	Speed endurance training can maintain muscle oxidative capacity, capillarisation, and endurance performance in already trained individuals despite significant reduction in the amount of training.
Iaia, F.M., & Bangsbo, J., 2010. Speed Endurance Training is a Powerful Stimulus for Physiological Adaptations and Performance Improvements of Athletes.	Literature review	Already trained endurance athletes.	Despite a reduction in training volume, speed endurance training of endurance-trained athletes can maintain the oxidative capacity and improve intense short duration / repeated high-intensity exercise performance lasting 30 s to 4 min, as it occurs in a number of sports.	Improvements appear to be related to a reduced energy expenditure during submaximal exercise and a higher expression of muscle Na1, K1 pump a-subunits, which via a higher Na1, K1 pump activity during exercise may delay fatigue development during intense exercise.	Athletes from disciplines involving periods of intense exercise can benefit from the inclusion of speed endurance sessions in their training programmes.

Article	Study design	Participants	Testing performed	Results	Conclusion
Laursen, P.B., 2010. Training for Intense Exercise Performance: High-Intensity or High-Volume Training?	Literature review	Olympic rowing, swimming, kayak, track running and track cycling athletes.	Aerobic energy supply dominates the total energy requirements after 75 s of near maximal effort, and has the greatest potential for improvement with training.	A short term period (six to eight sessions over 2 to 4 weeks) of high-intensity interval training (consisting of repeated exercise bouts performed close to or well above the maximal oxygen uptake intensity, interspersed with low-intensity exercise or complete rest) can elicit increases in intense exercise performance of 2 to 4% in well-trained athletes.	A polarised approach to training, whereby 75% of total training volume is performed at low intensities, and 10 to 15% is performed at very high intensities, has been suggested.

2.5 Duration of the Training Intervention

In a study by Lindsay et al. (1996) eight competitive cyclists were tested to gauge peak sustained power output during a progressive exercise test, a 40 km timed trial. The aforementioned study furthermore determined resistance to fatigue by measuring time to failure at 150% of peak power output (Lindsay et al. 1996). Following a four-week high–intensity interval training programme, the cyclists bettered performance over all previously measured tests, which proved the training intervention time frame was sufficient to elicit a significant improvement.

Jemma et al. (2005) analysed seven well-trained cyclists who were shown to elicit positive performance results for the 40 km timed trial as well as reducing surface electromyography signals when just three weeks of high-intensity interval training were implemented. However, in a study by Billat et al. (1999), four weeks of overload training that included interval training sessions by eight trained runners showed no change in performance or factors concerning performance. Mixed results in terms of the training duration for HIIT sessions had thus been found. Ross et al. (2009) showed than when 25 male runners performed treadmill sprint and weight resistance training over a course of seven weeks, the training resulted in significant kinematic and kinetic improvements and ultimately enhanced land-based performance.

Investigation by Cicioni-Kolsky et al. (2011) implemented a training intervention over a period of five weeks and included 55 moderately trained individuals undertaking three different training interventions. Females in the study who were part of the supra-maximal interval training group showed the most improvement over the 40m sprint and 3000m timed trial run. When 17 endurance trained runners performed a repeated measures study by performing speed endurance training or regular endurance training over a four-week period, the results showed that even with a significant reduction in weekly mileage, runners who supplemented training with frequent high-intensity sessions (as per the speed endurance protocol), were able to maintain muscle oxidative capacity, capillarisation and endurance performance (Iaia et al. 2009). A brief summary of research evidence about short duration endurance interventions complimented by supra-maximal interval training has been reported in Table 2.4.

Table 2.4: Summary of Articles that Assessed Short Duration Endurance Training Interventions Supplemented with Supra-Maximal Intervals

Article	Study design	Participants	Testing performed	Results	Conclusion
Lindsay, F.H., Hawley, J.A., Myburgh, K.H., Schomer, H.H., Noakes, T.D., & Dennis, S.C. (1996). Improved Athletic Performance in Highly Trained Cyclists after Interval Training.	Repeated measures design	Eight competitive cyclists	Pre-intervention, peak sustained power output (PPO) was measured during a progressive exercise test, muscular resistance to fatigue was determined during a timed ride to exhaustion at 150% of PPO (TF150), and a TT40 was performed on a cycle-simulator. Post-intervention testing was a repeat of pre-intervention testing.	HIT significantly improved TT40 (56.4 +/- 3.6 vs 54.4 +/- 3.2 min; P < 0.0001), PPO (416 +/- 32 vs 434 +/- 34 W; P < 0.01) and TF150 (60.5 +/- 9.3 vs 72.5 +/- 7.6 s; P < 0.01).	Results indicate that a 4-week programme of HIT increased the PPO and fatigue resistance of competitive cyclists' performances.
Jemma, T.J., Hawley, J., Kumar, D.K., Singh, V.P., & Cosic, I. (2005) Endurance Training Of Trained Athletes - An Electromyogram Study.	Repeated measures design	Seven well-trained endurance cyclists	Seven subjects undertook a 3-week training intervention, replacing 15% of their weekly endurance training with 6 sessions of laboratory-based high- intensity training (HIT). SEMG was used to assess neuromuscular changes before and after the 3 week training programme.	Three weeks of intensified training decreased the mean power frequency of the SEMG signal during the latter stages of HIT (interval seven) 50.2 ± 5.1 to 47.5 ± 4.2 Hz.	Results indicate that 3 weeks of HIT training is sufficient time to elicit a decrease in SEMG signal and improve 40 km time trial performance.

Article	Study design	Participants	Testing performed	Results	Conclusion
Billat, V.L., Flechet, B., Petit, B., Muriaux, G. & Koralsztein, J-P., 1999. Interval Training at VO_{2max}: Effects on Aerobic Performance and Overtraining Markers.	Repeated measures design	Eight trained runners	Pre-testing and post-intervention testing was performed to determine each participants VO_{2max} (vVO_{2max}) using a standard ramp treadmill protocol.	Normal training significantly improved their velocity associated with VO_{2max} (20.5 +/- 0.7 vs 21.1 +/- 0.8 km x h (-1), P = 0.02). As a result of improved running economy (50.6 +/- 3.5 vs 47.5 +/- 2.4 mL x min (-1) x kg (-1), P = 0.02), VO_{2max} was not significantly different (71.6 +/- 4.8 vs 72.7 +/- 4.8 mL x min (-1) x kg (-1)).	Performance and aerobic factors associated with the performance were not altered by the 4 week of intensive training at vVO_{2max}.
Ross, R.E., Ratamess, N.A., Hoffmann, J.R., Faugenbaum, A.D., Kang, J., & Chilakos, A. (2009). The Effects of Treadmill Sprint Training and Resistance Training on Maximal Running Velocity and Power.	Repeated measures design	25 male athletes	Peak 30 m sprint times, power and average velocity attained during maximal sprint trials on the treadmill, and 1-repetition maximum (1RM) squat were determined pre and post training.	The 30 m sprint times improved significantly only in the SRT group, and a trend for improvement (p = 0.06) was observed in the ST group. All groups significantly increased treadmill sprint velocity. All training groups increased 1RM squat strength significantly by 6.6 – 8.4 kg, with no differences observed between groups.	The results of this study showed that seven weeks of sprint training on a newly- designed treadmill resulted in significant kinematic and kinetic improvements in sprint performance.
Cicioni-Kolsky, D., Lorenzen, C., Williams, M.D., & Kemp, J.G., 2011. Endurance and Sprint Benefits of High-Intensity and Supramaximal Interval Training	Randomised (restricted randomisation) control trial	55 moderately trained individuals (23 male and 32 female)	Pre- and post-testing consisted of a 3000m time-trial and repeated 40m sprint tests.	3000m time-trial: 1) high-intensity training, 2) supra-maximal interval training and control group improved time to complete 3000m by 7.9%, 6.2%, and 0.3% (males), 8.5%, 10.5% and 8,6% (females) respectively. Sprint ability: Only the supra-maximal interval training group improved sprint time by 0.16 s (males) and 0.24 s (females) respectively.	Supra-maximal interval training proved to be the most effect of the three training groups.

2.6 Modalities of Supra-Maximal Training

2.6.1 THE ALTERG® ANTI-GRAVITY TREADMILL® PRO 200:

As a result of precise unweighting technology, the AlterG® anti-gravity treadmill allowed the individual to push training further than before by reducing gravity's impact by selecting any weight between 20% and 100% of body weight in 1% increments. This adjustment allowed for a significant reduction in the stress to joints and muscles [http://www.alterg.com/products/anti-gravity-treadmills/p200/athletic-trainer 18/7/2015].

A case controlled study by Grabowski and Kram (2008) presented a gender mix of 10 healthy recreational runners who performed multiple trials over two days at various speeds and body weight support on the AlterG® anti-gravity treadmill. As velocity increased, so did vertical impact ground reaction force (GRF), and when weight support increased, so GRF decreased (Grabowski & Kram, 2008). A follow-up study by Grabowski (2010) revealed that when using a repeated measures design and 10 healthy subjects, various velocities and body weight support combinations resulted in similar aerobic demands. Certain combinations illustrated that by manipulating these factors when using an AlterG® anti-gravity treadmill, runners could reduce GRF, yet maintained cardiorespiratory demand, which has proven to be highly effective for rehabilitative or performance (with a reduced risk of injury) training (Grabowski, 2010). Hoffman and Donaghe (2011) examined 12 active adults who walked and ran on a treadmill capable of body weight support. The authors came to the conclusion that partial body weight support did not alter the relationship of heart rate with VO_{2max} during exercise and had a minimal effect on the relationship of rating of perceived exertion. When Raffalt et al. (2013) used a regular treadmill and a lower body positive pressure treadmill (LBPPT) to measure the VO_{2max}, heart rate, ventilation and breathing frequency, as well as vertical ground reaction force and stride characteristics of 12 moderately-trained runners, the researchers concluded that VO_{2max} could be achieved on a LBPPT by manipulating speed and incline relative to those undertaken on a regular treadmill, while at the same time drastically reducing vertical ground reaction force. A study that assessed (the) use of a treadmill with and without a harness, and on a treadmill with 30% dynamic and static body weight support by Aaslund and Moe-Nilssen (2008) showed that the use of a harness resulted in more restricted vertical acceleration with static body weight support and elicited larger differences than dynamic body weight support in 28 healthy individuals.

The aforementioned findings were confirmed in research conducted by Sainton, Nicol, Cabri, Barthelemy-Montfort, Berton, and Chavet, (2014) involving 11 healthy males that demonstrated during short-term unweighting of an individual while treadmill running, lower impact and peak forces were experienced. This ultimately led to lower overall muscle activity amplitude and further illustrated findings in which VO_{2max} levels were similar across all conditions (Sainton et al. 2014). When 14 trained runners of mixed gender were tested at various body weights, the shortfall in metabolic work performed was compensated for by runners attaining faster running speeds than normally feasible, to achieve maximal exercise intensity (Gojanovic et al. 2012). Evidence that summarises the use of an AlterG® anti-gravity treadmill specifically for running training has been reported in Table 2.5.

Table 2.5: Summary of Articles Specific to the Use of an AlterG® Anti-Gravity Treadmill Specific to Running Training.

Article	Study design	Participants	Testing performed	Results	Conclusion
Grabowski, A. M. & Kram, R., 2008. Effects of Velocity and Weight Support on Ground Reaction Forces and Metabolic Power During Running.	Case controlled study	10 healthy recreational runners (seven male and three female)	Participants ran 3.0 m/s at 100%, 75%, 50% and 25% body weight, 4.0 m/s at 100%, 75%, 50% and 25% body weight and 5.0 m/s at 50% and 25% body weight.	At all levels of weight support, vertical impact ground reaction force (GRF), active peak GRF, and loading rate increased linearly with velocity. Vertical impact peak GRF, active peak GRF, and loading rate decreased linearly with weight support at all velocities.	The AlterG® anti-gravity treadmill accommodates running at very fast, yet sustainable, velocities
Grabowski, A.M., 2010. Metabolic and Biomechanical Effects of Velocity and Weight Support Using a Lower-Body Positive Pressure Device During Walking.	Repeated measures design	10 Healthy volunteer subjects	Subjects walked 1.00, 1.25, and 1.50m/s on a force-measuring treadmill at normal weight (1.0 body weight [BW]) and at several fractions of BW (.25, .50, .75, .85 BW).	At faster velocities, peak GRFs and metabolic demands were greater. In contrast, walking at lower fractions of BW attenuated peak GRFs and reduced metabolic demand compared with normal weight walking.	Manipulating velocity and weight using an LBPP device during treadmill walking can reduce force yet maintain cardiorespiratory demand.
Hoffman, M.D. & Donaghe, H.E., 2011. Physiological Responses to Body Weight–Supported Treadmill Exercise in Healthy Adults.	Repeated-measures design	12 Healthy, active adults	Oxygen consumption rate Vo(2), heart rate, rate of perceived exertion (RPE), and ground reaction forces (GRFs) were measured during walking and running at 3 levels (0%, 25%, 50%) of BWS.	Standing heart rates were 7 beats/min lower ($P<.05$) and systolic blood pressures were 10mmHg higher ($P<.001$) at 50% BWS compared with 0% BWS, but mean blood pressure while standing and the relationship of heart rate with Vo(2) during walking and running were not altered by BWS.	Because partial BWS does not alter the relationship of heart rate with Vo(2) during exercise and has minimal effect on the relationship of RPE with Vo(2), training heart rate and RPE values do not appear to require adjustment with partial BWS.

Article	Study design	Participants	Testing performed	Results	Conclusion
Raffalt, P.C., Hovgaard-Hansen, L. & Jensen, B.R., 2013. Running on a Lower-Body Positive Pressure Treadmill: VO_{2max}, Respiratory Response, and Vertical Ground Reaction Force.	Case controlled study	12 moderately trained runners	VO_{2max} tests were performed on a regular treadmill and a lower-body positive pressure treadmill (LBPPT). Participants performed steady-state running (10 km/hr, 14 km/hr, and 18 km/hr) and high-speed running (20 km/hr and 22 km/hr) at four different body weights (BWs) on the LBPPT.	VO_{2max} could be obtained on both treadmills, although time to exhaustion was 34.5% longer on the LBPPT. VO_2, ventilation, and heart rate decreased linearly with increasing BW support at steady-state running, while breathing rate remained unaffected by increasing BW support. Ground reaction force was markedly reduced with increasing BW support.	VO_{2max} can be achieved on an LBPPT at 100% BW with an incline-running protocol. The LBPPT is a suitable training device for athletes and allows training at high running speeds and high aerobic stimuli with the benefit of low vGRF and a near-normal movement pattern.
Aaslund, M. K., & Moe-Nilssen, R., 2008. Treadmill Walking with Body Weight Support Effect on Treadmill, Harness and Body Weight Support Systems.	Case controlled study	28 healthy individuals	Gait assessment included measuring trunk movements during different conditions. Walking over ground and on a treadmill with and without harness, and on a treadmill with 30% dynamic and static body weight support, was assessed.	On the treadmill, cadence increased, the trunk tilted more forwards, vertical acceleration increased and anteroposterior acceleration became more variable. Wearing a harness resulted in more restricted vertical acceleration. Walking with body weight support restricted acceleration in all directions.	Static body weight support gave larger differences than dynamic body weight support.

Article	Study design	Participants	Testing performed	Results	Conclusion
Sainton, P., Nicol, C., Cabri, J., Barthelemy-Montfort, J., Berton, E., & Chavet, P., 2014. Influence of Short-Term Unweighing and Reloading on Running Kinetics and Muscle Activity.	Randomised controlled study	11 healthy males	Three successive running conditions of 3 min [at 100% body weight (BW), and 60 or 80% BW] were measured.	In both running series, the unloaded running pattern was characterised by a lower step frequency (due to increased flight time with no change in contact time), lower impact and active force peaks, and also by reduced loading rate and push-off impulse.	The combined neuro-mechanical changes suggest that LBPP technology provides runners with an efficient support during the stride.
Gojanovic, B., Cutti, P., Shultz. R, & Matheson, G.O., 2012. Maximal Physiological Parameters During Partial Body-Weight Support Treadmill Testing.	Case controlled study	14 trained runners (nine male and five female)	Four identical treadmill incremental tests (48 hrs apart) on an AlterG® anti-gravity treadmill at body weights of 100%, 95%, 90% and 85%	VO_{2max} was similar across all conditions ((men: CON = 66.6 (3.0), AG100 = 65.6 (3.8), AG95 = 65.0 (5.4), AG90 = 65.6 (4.5), and AG85 = 65.0 (4.8); women: CON = 63.0 (4.6), AG100 = 61.4 (4.3), AG95 = 60.7 (4.8), AG90 = 61.4 (3.3), and AG85 = 62.8 (3.9))	The AlterG® anti-gravity treadmill can be used at maximal exercise intensities at body weight of 85% to 95% reaching faster running speeds than normally feasible.

2.6.2 DOWNHILL RUNNING

Downhill running is a simple and cost effective way to increase running speed. Downhill running creates an over-speed effect due to the effects of gravity. Klika (2010) reported enhanced stride frequency and neuromuscular coordination in athletes when using downhill running as a supra-maximal training modality. Ebben et al. (2008) postulated that a hill decline prescription of 5.8° and running intervals at 110% of velocity at VO_{2max} (vVO_{2max}) elicited the most favourable results, when undertaking a supra-maximal speed interval training regime during downhill running

[http://strengthandconditioningfitness.com/speed-training-methods/18/7/2015]. Cognisance was taken of the suggested gradient in the downhill training programme prescription – which was addressed in chapter 3.

A randomised repeated measures study by Ebben et al. (2008) was sourced to distinguish the most effective slope angle to perform supra-maximal speed training in terms of yielding optimal results. When 44 high-level athletes performed trials at various slope angles, a decline of 5.8° proved to be most effective (Ebben et al. 2008). A downhill slope on Chapmans Peak Drive matching the aforementioned recommendation in terms of angle and distance was used for the downhill participants during supra-maximal speed interval training. A summary of the evidence obtained pertaining to slope recommendation for supra-maximal downhill speed training has been shown in Table 2.6.

Table 2.6: Summary of an Article with Slope Recommendation for Downhill Supra-Maximal Speed Training.

Article	Study design	Participants	Testing performed	Results	Conclusion
Ebben, W.P., Davies, J.A., & Clewien, R.W., 2008. Effect of the Degree of Hill Slope on Acute Downhill Running Velocity and Acceleration.	Randomised repeated measures study	44 NCAA division III level male athletes	Participants completed seven random 40 yard sprints at various hill slopes at 0.0°, 3.4°, 4.0°, 4.8°, 5.8°, & 6.9°.	The 5.8° slope represented the largest difference in 40 yard sprint time when compared to 0.0 degree baseline times. The 6.9° slope produced the smallest difference for the same comparison.	The downhill slope of 5.8° yielded optimal sprint times.

2.7 Physiological Performance Energy Pathways

2.7.1 40M STANDING START SPRINT

The anaerobic 40m standing-start sprint partially depleted the adenosine triphosphate (ATP) and phosphocreatine (PC) substrates and three to five minutes were necessary to replete those energy stores (Duffield, Dawson, & Goodman, 2005). Glaister (2008) provided research evidence of physiological responses to sprint work which indicated that during a single short sprint, ATP was resynthesised primarily from a combination of phosphocreatine (PCr) degradation and anaerobic glycolysis, and a minimal contribution (<10%) from aerobic metabolism. Recent findings also suggested that the impairment of muscle function previously attributed to H+ accumulation was largely a result of accumulated inorganic phosphate (as a result of the rapid rate of ATP turnover during sprints) and corresponding inhibitory effects on sarcoplasmic reticulum calcium release (Glaister, 2008). Table 2.7 reflected the detail of the research acquired pertaining to physiology of performance in the 40m standing start sprint.

Table 2.7: Summary of an Article which Analysed Performance Physiology of a 40m Standing Start Sprint.

Article	Study design	Participants	Testing performed	Results	Conclusion
Glaister, M., 2008. Multiple-sprint work: methodological, physiological, and experimental issues.	Literature review	Male and female athletes	Repeated sprint ability to evaluate the basic physical characteristics of speed and endurance necessary to excel in various multiple-sprint sports.	When performing a single short sprint, ATP is resynthesised primarily from a combination of phosphocreatine (PCr) degradation and anaerobic glycolysis, with a minimal contribution (<10%) from aerobic metabolism.	Impairment of muscle function previously attributed to H+ accumulation was largely a result of accumulated inorganic phosphate.

2.7.2 3000M TIMED TRIAL RUN

The 3000m timed-trial run relied primarily on the relative aerobic energy system contribution (based on accumulated oxygen deficit measures for the 3000m) which utilised the oxidative metabolic pathway to fuel performance, causing recovery to take 24 hours or more to fully occur. The ATP-CP energy system only supplied energy during the first 10 seconds of exercise (Duffield et al. 2005). From 10 seconds to approximately 3 minutes the major source of energy was derived from glycolysis. The involvement of the aerobic energy system increased and predominated as the duration of exercise progressed (Spencer & Gastin, 2001).

In a case controlled study by Duffield et al. (2005), 14 mixed gender participants performed a graded exercise test in order to calculate their energy system contributions during 3000m running. The results showed that 94% of relative energy was from the aerobic energy system and 6% anaerobic, in female participants (Duffield et al. 2005). An earlier research paper by Spencer and Gastin (2001) exploring the relative contribution of the aerobic energy system was assessed for various middle distance running events in a case controlled study of 20 highly-trained athletes, Results indicated that there was a predominant crossover to the aerobic energy system supply between 15 and 30 seconds for middle distance events, with the actual percentage being calculated by subtracting 15 to 30 seconds from the total time taken to complete the event (Spencer & Gastin, 2001). A summary of the articles found that referred to physiology of performance of a 3000m timed-trial run has been reported in Table 2.8.

Table 2.8: A Summary of Articles that Analysed Performance Physiology of a 3000m Timed Trial Run.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Duffield, R., Dawson, B., & Goodman, C. (2005) Energy System Contribution to 1500- and 3000-metre Track Running.	Case controlled study	14 (ten male, four female) participants for the 1500 m and 10 participants (eight male, two female) trained track athletes.	Athletes performed a graded exercise test in the laboratory and two time-trials over 1500 or 3000m.	The relative aerobic energy system contribution (based on AOD measures) for the 3000m was 86% (male) and 94% (female).	Results of the present study conform with some recent laboratory-based measures of energy system contributions to these events.
Spencer, M.R., & Gastin, P.B., 2001. Energy System Contribution During 200- to 1500-m Running in Highly Trained Athletes.	Case controlled study	20 highly-trained athletes.	The relative aerobic and anaerobic energy system contribution during high-speed treadmill exercise was calculated using the accumulated oxygen deficit (AOD) method.	The relative contribution of the aerobic energy system to the 200-, 400-, 800-, and 1500-m events was 29 ± 4, 43 ± 1, 66 ± 2, and 84 ± 1% ± SD, respectively.	The crossover to predominantly aerobic energy system supply occurred between 15 and 30 s for the 400-, 800-, and 1500-m events.

2.8 Physiological Performance Differences in Athletes Due to Gender

Daniels and Daniels (1992) reported that male runners were six to seven percent more economical than women of equal VO_{2max} at set velocities, the results however were expressed per kg body mass. According to Marieb and Hoehn (2007) the average female however differed from the average male and elicited a lower total body mass and a higher percentage of fat. The authors subsequently cautioned that it was important to scale for body mass when comparing genders in athletes. In cycling, Yasuda, Gaskill, and Ruby (2007) reported that no gender-specific differences in mechanical efficiency during leg-cycling at intensity relative to ventilatory threshold were apparent. However, according to Weber and Schneider (2002) there may have been a gender specific difference in aerobic and anaerobic efficiency, as these authors showed that untrained women tend to have lower maximal accumulated oxygen deficit than untrained men after all out cycling, even when corrected for active muscle mass.

Pepe, Balci, Revan, Akalin and Kurtoglu (2009) compared oxidative stress and anti-oxidant capacity before and after running exercise in eight healthy male and nine healthy female university students. Despite significant differences in physical characteristics, participants had similar responses to exercise at the same absolute workload with regard to changes in the various measures (Pepe et al. 2009). A four-week training protocol was used in a repeated measures study for 12 female soccer players by Wagganer, Williams, and Barnes (2014), who stated that the implementation of primary and secondary speed training methods over the four-week training period elicited statistically significant reductions in 40 yard sprint times.

A literature review by Weston, Taylor, Batterham, and Hopkins (2014), assessed the effects of low-volume high-intensity training (HIT) on fitness in male and female subjects older than 18. The meta-analysis on aerobic fitness and sprint power indicated moderate improvements of active non-athletic and sedentary subjects and concluded that more studies were needed to resolve the unclear modifying effects of gender on HIT. Gender influence and the effect on maximal accumulated oxygen deficit after HIT was furthermore assessed by Weber and Schneider (2002) with seven untrained men and woman undertaking four and eight week HIT interval training programmes. Results indicated both genders enhanced their ability to produce ATP while male subjects displayed superior oxidative metabolism ability, which suggested there are basic gender differences to specific metabolic adaptations after HIT (Weber & Schneider, 2002).

A literature review by Jones (2006) investigated various factors which influenced performance enhancement of the world record holder for the women's marathon. A systematic and gradual improvement in all physiological parameters was found over a 15-year period of high-level training, with the most significant improvement occurring with regards to running economy (Jones, 2006). Aforementioned review suggested consistent and long-term improvement was required in all facets of training to reach a world record level (Jones, 2006).

A mixed gender case controlled study was performed by Daniels and Daniels in 1992 to assess the economy of 65 elite runners. When comparing economy, in terms of absolute velocities, men used less oxygen; however, at relative VO_{2max} intensities, there were no gender differences. The final comparison indicated that when men and women of equal VO_{2max} of equal economy were matched, men showed a better aerobic profile (Daniels & Daniels, 1992). In contradiction to the aforementioned findings, Yasuda et al. (2007) performed a case controlled study consisting of nine recreationally active men and women, which focused on economy and mechanical efficiency during both arm cranking and leg cycling. Various intensities were implemented for a period of 5 min to determine the economy and efficiency of the participants. Results indicated that no sex differences were found in either economy or efficiency relative to participant ventilatory threshold (Yassuda et al. 2007). Evidence acquired in literature has been reported in short in Table 2.9.

Table 2.9: Summary of Articles that Assessed the Role of Physiology of Performance in Gender Differences of Athletes.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Pepe, H., Balcı, S.S., Revan, S., Akalın, P.P., & Kurtog-lu, F., 2009. Comparison of Oxidative Stress and Antioxidant Capacity Before and After Running Exercises in Both Sexes.	Repeated measure controlled study	Eight male and nine female healthy university students.	Participants performed running exercise tests at distances of 800, 1500, and 3000m at a speed of 10 km/h.	Height, weight, and maximum oxygen consumption values were significantly higher in men than in women (P = 0.01). Significant gender effects were found in LPO levels at 3000m (F = 5.51; P = 0.03) and in SOD activity at 800 m (F = 7.92; P = 0.01) and 3000m (F = 6.05; P = 0.03).	Men and women had similar responses to exercise at the same absolute workload, despite significant differences in physical characteristics.
Wagganer, J.D., Williams, R.D. (JR), & Barnes, J.T., 2014. The Effects of a Four Week Primary and Secondary Speed Training Protocol on 40 yard Sprint Times in Female College Soccer Players.	Repeated measures study	12 female collegiate soccer players	Forty yard sprint times were assessed pre and post protocol.	The average sprint time decreased by 0.248 seconds (pre=5.463+0.066 vs post=5.215+0.053).	A four week speed training protocol of primary and secondary techniques may play a significant role in reducing 40 yard sprint times in college female soccer athletes.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Weston, M., Taylor, K.L., Batterham A.M., & Hopkins, W.G., 2014. Effects of Low-Volume High-Intensity Interval Training (HIT) on Fitness in Adults: A Meta-Analysis of Controlled and Non-Controlled Trials.	Literature review	Male and female subjects aged >18 years.	Estimation of meta-analysed mean effects of HIT on aerobic power (maximum oxygen consumption [VO2max] in an incremental test) and sprint fitness (peak and mean power in a 30 s Wingate test).	Improvement in the VO2max of active non-athletic males (6.2%; 90% confidence limits ±3.1%), when compared with control. There were possibly moderate improvements in the VO2max of sedentary males (10.0%; ±5.1%) and active non-athletic females (3.6%; ±4.3%) and a likely small increase for sedentary females (7.3%; ±4.8%).	Low-volume HIT produces moderate improvements in the aerobic power of active non-athletic and sedentary subjects.
Weber, C.L., & Schneider, D.A., 2002. Increases in Maximal Accumulated Oxygen Deficit after High-Intensity Interval Training are not Gender Dependant.	Repeated measures study	Seven untrained men and women	Participants cycled at 120% of pre-training peak oxygen uptake (V˙O 2 peak) to exhaustion (MAOD test) pre-, mid-, and post-training. A post-training timed test was also completed at the MAOD test power output.	There was a 14.3 ± 5.2% increase in MAOD observed in men after 4 wk of training and was not different from the 14.0 ± 3.0% increase seen in women (P > 0.05). MAOD increased by a further 6.6 ± 1.9% in men, and this change was not different from the additional 5.1 ± 2.3% increase observed in women after the final 4 weeks of training.	The increase in MAOD with training was not different between men and women. However, the increase in V˙O 2 peak and AO2 uptake obtained in male subjects after training indicates improved oxidative metabolism in men but not in women.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Jones, A., 2006. The Physiology of the World Record Holder for the Women's Marathon.	Literature review	Female marathon World Record holder	A review of the physiological determinants of endurance exercise performance by using the data of the World Record holder for the women's marathon (PR) was made, to illustrate the link between an athlete's physiology and success in distance running.	PR's data demonstrate a 15% improvement in running economy between 1992 and 2003.	PR's data demonstrate how 15 years of directed training have created the 'complete' female distance runner.
Daniels, J., & Daniels, N., 1992. Running Economy of Elite Male and Elite Female Runners.	Case controlled study	20 female and 45 male middle- and long-distance runners.	Each subject completed a VO2max and a series of sub-max treadmill runs, for the purpose of comparing heart rate (HR), VO2, and blood lactate (HLa).	Men were taller, heavier, and had a lower six-site skinfold sum and higher VO2max, than the women (P less than 0.05); there was no difference in age. When comparing running economy, men used less oxygen (ml.min-1.kg-1) at common absolute velocities, but VO2 (ml.km-1.kg-1) was not different between men and women at equal relative intensities (%VO2max).	At absolute running velocities, men are more economical than women, but when expressed in ml.km-1.kg-1 there are no gender differences at similar relative intensities of running.

Article	Study Design	Participants	Testing Performed	Results	Conclusion
Yasuda, N., Gaskill, S.E. & Ruby, B.C., 2007. No Gender-Specific Differences in Mechanical Efficiency During Arm or Leg Exercise Relative to Ventilatory Threshold.	Case controlled study	Nine recreationally active men and nine recreationally active women.	Economy and mechanical efficiency in men and women during both arm cranking (AC) and leg cycling (LC) at 70%, 85%, 100%, and 115% of mode-specific ventilatory threshold (Tvent with similar values for % $\dot{V}O_2$peak at Tvent served as subjects. All subjects performed 5 min of exercise at each intensity of 70%, 85%, 100%, and 115% of Tvent for both AC and LC.	Economy and efficiency during LC were greater than during AC in men and women. During AC or LC exercise, no sex differences were found in either economy (P=0.93 for AC, 0.98 for LC), GE (P=0.88 for AC, 0.75 for LC), or DE (P=0.57 for AC, 0.51 for LC).	Men and women show similar economy and efficiency during both AC and LC exercise when subjects have similar % $\dot{V}O_2$peak at Tvent.

2.9 Principles of High Intensity Speed Interval Programme Prescription

The following subsections were included in order to present the rationale behind the supra-maximal speed interval program prescription as discussed within chapter three. The subsections under laid the principles which provided the framework of the content of what the programme prescription was based on.

2.9.1 PERIODISATION

The term *periodisation* originated from the word *period*, which was a way of describing a portion or a division of time. According to Bompa and Haff (2014), periodisation was a method by which training was divided into smaller, easy-to-manage segments that were typically referred to as phases of training. Training periodisation was meant to offer coaches basic guidelines for structuring and planning training.

2.9.2 MICROCYCLE

The term microcycle was rooted in the Greek word *micros*, which meant “small”, and the Latin word *cyclus*, which referred to a regular sequence of events. In training methodology, a microcycle was a weekly or three to seven day training programme within an annual training programme (Bompa & Haff, 2014). The structure and content of the microcycle determined the quality of the training process and was set according to the objectives, volume, intensity and methods that were the focus of the training phase. Physiological and psychological demands placed on the athlete could not be steady – they needed to change according to the athlete’s working capacity, need for recovery and the competition plan (Bompa & Haff, 2014).

2.9.3 MACROCYCLE

The term macrocycle was derived from the Greek word *macros*, which meant “large”. According to Bompa and Haff (2014), a training macrocycle was a phase that lasted two to seven weeks and therefore contained two to seven microcycles. Whereas a microcycle was used to plan for the immediate future, the macrocycle projected the structure of a training programme several weeks in advance. Coaches could therefore think of the macrocyle as the general structure of the training, and the microcycle, as the exact method used to accomplish the targeted goals (Bompa & Haff, 2014).

The training programmes utilised for the study therefore encompassed four microcycles and as a whole represented one macrocycle.

2.10 Summary

Taken together, studies examining the effects of performance over a 40m standing start sprint and 3000m timed trial run as well as the characteristics and influence of DOMS, were sourced to provide a theoretical framework from which to establish a training intervention and means in which to monitor DOMS for the purpose of the current study. Should the study have indicated that there was a significant benefit to this format of training, it would be of value to many athletes who have limited time to train due to occupational and other commitments, as it would allow for short but very intense training sessions. These sessions would trade off into high-level middle distance running performance to further enhance a training format for longer distances. To date, no evidence was found that examined the prolonged use of supra-maximal speed training on the AlterG® anti-gravity treadmill and the effect on middle distance sport-specific performance in women.

The question thus arose whether unweighted supra-maximal speed interval training on the AlterG® anti-gravity treadmill was superior to weighted supra-maximal speed interval training during downhill running in improving running speed over the 40m standing start and the 3000m timed run over a four week period of training. The level of DOMS experienced by each training group was also significant in terms of subsequent training and the reduction of injury risk through supra-maximal speed training.

The current literature reviewed evidence pertaining to selected aspects of performance physiology, DOMS, supra-maximal speed interval training modalities and gender differences in athletes.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The purpose of this study was to measure performance improvement over a 40m standing-start sprint and 3000m timed trial run after a four-week supra-maximal speed training programme had been completed. Of secondary concern was to rate the level of delayed onset of muscle soreness (DOMS) experienced by participants every 24 hours, 48 hours and 72 hours after each supra-maximal speed training interval. Results for the dependent variables were compared to participants who performed supra-maximal speed run intervals on the AlterG® anti-gravity treadmill (experimental group) to participants who performed downhill running (comparison group) on a 5.8° downhill slope of asphalt over the same four week intervention period.

This study compared a group of female runners training on an AlterG® anti-gravity treadmill and a group of runners training on a downhill slope using respective supra-maximal speed interval training programmes. Interval sessions were performed twice a week over a period of four weeks (plus one week in total for the pre-intervention and post-intervention testing). This chapter described the participants, study design, testing protocol, measuring instruments, the four-week supra-maximal training intervention (AlterG® and downhill running), statistical analysis as well as the ethical principles considered during the conduction of the research.

3.2 Research Design

The research approach was explorative, descriptive and quantitative in nature. Research was deemed qualitative when it comprised a study of the status quo, which employed objective research and thorough descriptions to solve problems (Hair, Babin, Money, & Samuel, 2003; Thomas & Nelson, 2001). These authors advised that an exploratory design was useful when there was little scientific information available, relative to the research problem. As there was a scarcity of literature pertaining to the effect of supra-maximal training on the AlterG® anti-gravity treadmill when comparing unweighted and normal weight training regimes for endurance athletes, this study design was thought to be most fitting.

A quasi-experimental research design was utilised as a blueprint for gathering data as proposed by De Vos et al. (2009). Such a design required the researcher to obtain a control group, either by randomisation or through matching, often referred to as a comparison group (Brink et al. 2008). Both the AlterG® anti-gravity experimental group and the downhill running comparison group were evaluated with a pre-test and a post-test assessment for all three of the selected dependent variables of timed performance for the 40m standing-start sprint and 3000m timed trial run, as well as the level of DOMS experienced as a result of the four week supra-maximal training intervention on the two different modalities. The research design which was followed has been illustrated in figure 3.1 below.

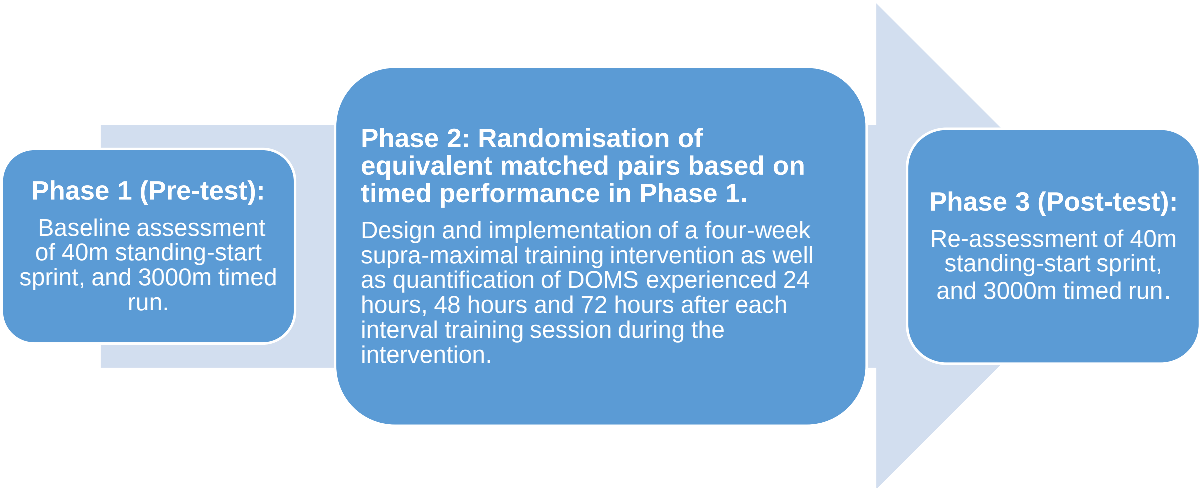


Figure 3.1: Phases of the Research Design

Participants were matched into pairs as closely as possible in terms of their 3000m run time. One participant from each pair was randomly selected to ensure that each participant had an equal opportunity to be chosen for either the AlterG® anti-gravity treadmill or downhill training group (a jar was used whereby names for each pair were deposited, an independent individual was used to draw one name without looking into the jar – the first name drawn was included in the AlterG® anti-gravity treadmill group and the remaining participant was included in the downhill group). The AlterG® anti-gravity treadmill participant performed four weeks of supra-maximal speed interval training on the AlterG® anti-gravity treadmill (75% body weight) at the Velocity Sports Lab in Hout Bay, Cape Town. The other paired participant performed four weeks of supra-maximal speed interval training on a downhill stretch of road on Chapmans Peak Drive, which had a decline of 5.8%. Thus, an experimental pre- post-test design with matched paired equivalent groups randomly assigned to either an experimental (AlterG® training) or comparison (downhill running) group was used. The random assignment to either of the two groups was an effort to minimise selection bias, one of the proven limitations inherent to purposive sampling (De Vos et al. 2009). Randomised assignment was implemented as an unbiased sampling technique, ensuring that each participant had an equal chance of being selected for inclusion into the experimental group and was considered the gold standard when selecting a sample (De Vos et al. 2009).

3.3 Sampling

Purposive sampling included a target sampling technique to identify and obtain 30 female participants from a registered running club in Hout Bay, Cape Town (Brink et al. 2008). De Vos et al. (2009) defined purposive sampling as the selection of participants, based on accessibility and practicality; describing target sampling as the group from which the researcher wished to draw conclusions, relative to the target population. Results were thus limited to participants in this study, and were not representative of the larger population of runners. The sampling frame was a selection of the target population and was the most practical given the catchment area of female runners and the geographical proximity of the AlterG® anti-gravity treadmill specialist equipment used for one of the training groups.

3.3.1 SAMPLING METHODS

A short presentation (Appendix A) on the rationale of the study, the study design, assessment procedures and training programmes and handing out of a formal letter to potential study participants (Appendix B) was undertaken by the researcher at a run time trial evening at a registered running club in Hout Bay, Cape Town. Interested participants were asked to fill in an informed consent form (Appendix C); following that, a questionnaire consisting of demographical information, health and injury history as well as running history as presented in Appendix D was given to the target sample group which originally consisted of 30 female runners.

3.4 Participants

Participants were recruited on a voluntary basis, provided a small representative profile of moderately trained female runners, were all aerobically trained and healthy as assessed by a health history questionnaire and record of physical activity. Anthropometrics, such as height and weight as well as age, were captured prior to the start of testing. Inclusion criteria for the study was as follows: female runners who were between the age of 30 and 45 years, who were free from injury for the preceding six months, who fell within a body max index (BMI) of 18.5 - 24.9 kg/m2 (described as "normal" BMI for adults according to the Centres for Disease Control and Prevention [http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/]), had at least two years of running experience, ran at least three times a week and had run 10 km (in one session) at least twice over the preceding three months ensuring they were moderately trained (see 1.7.5 for definition). Participants were all informed of the study requirements, benefits, and risks of the study and the researcher answered all questions put forward by the participants.

Of the total respondent group, 25 runners replied and returned the completed questionnaires, which indicated a response rate of 83%. However, only 20 of the 25 respondents met the inclusion criteria and thus constituted the participant group for the study making a total of 20 volunteer female participants (10 participants per group) with a mean age of 37 years, and BMI of 22 kg/m^2. Two pairs of running shoes were used as lucky draw prizes as an incentive for participants to complete the study.

3.5 Data Collection

Measuring Instruments

The following measuring instruments were used to record baseline assessment data at the pre-test and during the post-test assessment after the four-week training intervention.

3.5.1 Biographical information was collected by means of a questionnaire pertaining to age, anthropometrical measures, such as height and body weight, to calculate BMI (Appendix E), running history and history of lower limb injury.

3.5.2 Height and weight were measured by using a calibrated stadiometer (Micro Digital Physician Scale [T3PW]).

3.5.3 A portion of a flat 1000 m tarred loop was used to perform the 40m standing-start sprint and three loops were run to measure the 3000m timed trial run time.

3.5.4 The Speedtrap I photocell electronic timing system was used to capture the 40m standing-start sprint test times and 3000m run time for all participants before and after the training intervention.

3.5.5 A Suunto Ambit altimeter was used to identify a suitable gradient (5.8°) for the downhill running group.

3.5.6 Interval speeds (AlterG® group) and distances (downhill group) specific to each participant were calculated using Microsoft Excel 2010, based on their results from the pre-intervention 3000m timed trial run.

AlterG® group: 125% of average speed for the 3000m TT was used over a set interval time (which increased every week) for each participant.

Downhill group: 110% of average speed for the 3000m TT was used to calculate the distance which individual participants needed to cover each week.

3.5.7 The AlterG® Anti-Gravity Treadmill® Pro 200 was used for the AlterG® group. This device used a regular treadmill enclosed in an airtight canopy attached at waist level by ‘‘zipping in’’ the athlete using specially designed shorts. The runner was free to move in all directions with limited horizontal restriction. After calibrated pressurisation, positive pressure was applied to the lower body, effectively ‘‘lifting’’ the runner and reducing body weight (refer to figure 3.2 for a visual representation).

Figure 3.2: AlterG® Pro 200; Photo Courtesy of AlterG® Website (2015)

3.5.8 A tarred downhill stretch of straight road with a 5.8° decline was used for the downhill group when performing supra-maximal speed intervals during the four week intervention.

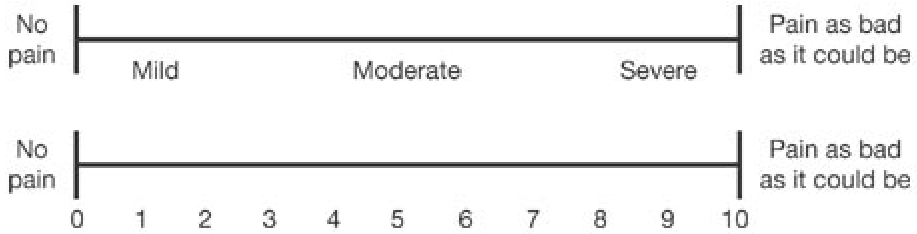
3.5.9 A Borg scale (6-20) perceived effort rating of 12 was used for all participants during recovery runs to remain below 60% of maximal aerobic capacity (Appendix F).

3.5.10 A Numerical Graphic Rating Scale (NVGRS) was used to quantify the level of DOMS experienced by participants in both training groups in 24 hour, 48 hour, and 72 hour increments after interval training sessions and prior to subsequent interval training sessions via email during the four-week training intervention.

3.6 Measurement of Dependent Variables

For the study, there were two separate measures that were of concern. The first involved the difference in pre-intervention times for the 40m standing-start sprint and 3000m timed trail run when compared to the post-intervention times for the 40m standing-start sprint and 3000m timed trail run.

The second was based on a numerical visual graphic rating scale (NVGRS - Wewers & Lowe, 1990) used to determine the extent of DOMS experienced by participants every 24 hours, 48 hours and 72 hours after every supra-maximal speed interval training session and has been graphically presented in figure 3.3. This measure included descriptive numbers on a scale of 1 – 10 and was labelled as follows: 0 = no pain, 1-3 = mild pain, 4-6 = moderate pain, 7-9 = severe pain, 10 = pain as bad as it could be.



[http://www.nature.com/nrrheum/journal/v3/n11/full/ncprheum0646.html]

Figure 3.3: Numerical Visual Graphical Rating Scale (NVGRS) for Delayed Onset of Muscle Soreness (DOMS)

3.7 Timeline of Field Tests

All participants performed testing during the same time period consisting of two visits to Velocity Sports Lab, in Hout Bay, over five weeks. Table 3.1 displays the order of tests and a description of the procedures that were followed at each of the assessment sessions.

Table 3.1: Timeline of Field Tests

	Pre-intervention test	Post-intervention test
w/up: 5min (easy jogging)		
40m standing start sprint		
5min easy jog		
3000m timed trial run		
c/down: 5 min (easy jogging)		

Participants were asked to do a warm-up of five minutes of jogging at a self-selected speed on a flat tar strip. Participants then lined up one behind the other to do a 40m standing-start sprint. When the last participant completed the 40m sprint (and walked back to the start point), all participants again undertook an easy five minutes jog at a self-selected speed. Participants then lined up behind the start line and began the 3000m timed trial run.

3.8 Testing Protocol

The testing protocol for the 40m standing-start sprint and 3000m timed trial run was explained to the participants. A standard five minute warm was undertaken before commencement of the 40m standing-start sprint and 3000m run pre-test procedure.

The 40m standing-start sprint test was carried out on a straight and level asphalt strip of road. A distance of 40m was measured using a calibrated trundle wheel (Grip Measuring Wheel, China) following a taught string, with double-beam timing gates (Speedtrap I electronic timing system, Perform Better, U.S.A.) placed at each end. Participants started in a standing position 5cm behind the timing gate mark to ensure that the beam was not broken prematurely. Participants were instructed to sprint maximally until they reached a point beyond the timing gates at 40m, and to commence when ready. Sprint time was captured once the second timing gate beam had been passed after 40m. The time taken to cover the 40m distance was recorded.

For the 3000m timed trial run, all participants ran three laps of 1000m on a level asphalt loop as fast as possible to establish initial baseline 3000m run times. The flat asphalt loop road was measured using a calibrated trundle wheel (Grip Measuring Wheel, China). In the week leading up to pre-testing, all participants were familiarised with the course in the same manner – an aerial map was used to illustrate the direction and turn points which constituted each 1000m asphalt loop. On testing days, all participants performed a warm-up comprising a five-minute aerobic run at a self-selected pace, the five-minute aerobic run at a self-selected pace was repeated once all participants had completed the 40m sprint test. For the 3000m time-trial, all participants were instructed to run to their maximum effort and not to run alongside others in order to avoid pacing. The total time taken to perform the run test was recorded.

Aforementioned testing order was in compliance with the recommended test order of the NSCA (Coburn & Malek, 2012) and further stated that the rationale for using this sequence was based on the effect of fatigue and the ability to recover between test items. Participants performed all of their scheduled exercise tests in the morning after an overnight fast. They were allowed to drink water the morning of the test, but no solid foods, caffeine, or other beverages were allowed. Participants were asked to consume the same meal the evening before each test. Throughout the study, participants trained, and were tested using the same running shoes.

3.9 Participant Selection for Respective Training Programmes

Following pre-testing, participants were ranked (stratified) by their 3000m time-trial run and randomly allocated into one of two training groups (AlterG® or downhill), to ensure that participants in the two groups were matched. Training intensity for each participant was determined by each individual's average 3000m time trial running velocity (AV).

The prescription of supra-maximal speed interval training on the AlterG® anti-gravity treadmill was calculated at 125% of the average speed taken for athletes to perform the initial 3000m run test at 75% body weight (Grabouwski & Kram, 2008). Literature indicated that weight supported running may not provide the same cardiovascular stress as normal weight running (Farley & McMahon, 1992). The decision to use the aforementioned values was that athletes engaging in unweighted supra-maximal speed interval training on the AlterG® anti-gravity treadmill might not experience a sufficient training stimulus to improve physiological parameters related to improved running speed.

The stress on the system (be it the musculoskeletal or cardiovascular system) in a weight bearing activity such as running was identified as being directly proportional to body weight if all other variables were kept equal [http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf, 2015]. Therefore a runner that was unweighted by 25% and bearing only 75% of his or her body weight would do 25% less work (Figueroa, Wicke, Manning, Escamilla, & Santillo, 2012). However, this phenomenon might in the short term be more than offset by the supra-maximal speed interval training. Thus, since work = force x distance = speed x sin θ x time x body weight [Brianmac biomechanics, 2015], if a runner were to be unweighted, he or she could still perform the same amount of work as a normal weighted runner by manipulating the speed of running. The participant would in essence have to run at a proportionately higher speed.

The AlterG® anti-gravity treadmill group would in theory benefit from a faster speed of limb movement as well as a longer stride length during training due to the higher speed attained while reaching supra-maximal speed (due to the higher % prescribed for supra-maximal speed intervals as opposed to the downhill running group, in order to elicit the same metabolic cost). According to Ross et al. (2009) running velocity is determined by stride rate and stride length. These researchers asserted that a linear increase in both stride length and stride frequency occurred at the onset of a middle distance running training session up until a speed of approximately seven m.s ($^{-1}$), after which there was a smaller increase in stride length and a greater increase in stride frequency (Ross et al. 2009).

During downhill running (for the downhill running group) the prescription of supra-maximal speed intervals was calculated at 110% of the average speed taken for each athlete to perform the initial 3000m time trial run and at a 5.8° hill decline. Ebben et al. (2008) postulated that the interval percentage and hill decline mentioned above (110% of average 3000m TT speed and a 5.8° hill decline) has been shown to elicit the most favourable results, when undertaking a supra-maximal speed interval training regime, during downhill running.

To assist each participant with meeting individual training intensity in the downhill group, a personal identifying marker was placed beside a cone corresponding to the distance required to be covered within the allocated time. Progressive overload (Chandler & Brown, 2008) was applied to the two interval training groups by increasing the number of repetitions in a session across the training programme. The interval distance (downhill group) was specific to each participant and was based on their respective timed trial run results, whereby 110% percent of their average speed over the 3000m was used – each week, the distance that needed to be covered and the stipulated amount of time within which to cover the distance was increased. Participants would run from the start point to their individual distance marker, identified by a cone.

The interval speed (the AlterG® anti-gravity treadmill group) was specific to each participant and was based on their respective timed trial run results, whereby 125% of their average speed taken over the 3000m was used – each week, the stipulated amount of time that participants needed to run at their individualized speed was increased.

3.10 Training Programmes

A progressive supra-maximal speed interval training programme was provided to both groups for a period of four weeks which also included recovery and medium-distance runs which were undertaken on the same route for all participants of both groups (a flat loop of 1000 m run on an asphalt surface) over the four-week training period.

The training programme as undertaken in the study consisted of two supra-maximal speed interval sessions a week (Monday and Thursday), two recovery runs (Tuesday and Friday) and a medium-distance run undertaken on the Saturday. There were two rest days within the week (Wednesday and Sunday) for a total of eight "doses" of supra-maximal speed intervals, eight "doses" of recovery running and four "doses" of medium-distance running over the four-week training intervention period. The participants did not undertake any other form of exercise during the four-week training intervention other than the specified runs.

Maximal effort bouts progressively increased for participants starting at 20 seconds in the first week and peaked at 30 seconds in the fourth week of training. Recovery intervals were three times longer than the work interval throughout the four weeks of training. Recovery intervals consisted of a walk back to the starting point for downhill running participants, while a 6km/h walk for the recovery interval of AlterG® participants was undertaken

Supra-maximal speed training involved the following intervals

Week one	7 x 20 s supra-maximal speed intervals	60 s active recovery walk
Week two	8 x 22 s supra-maximal speed intervals	66 s active recovery walk
Week three	9 x 25 s supra-maximal speed intervals	75 s active recovery walk
Week four	10 x 30 s supra-maximal speed intervals	90 s active recovery walk

Recovery runs were performed twice a week and remained constant over the four-week training intervention period, and consisted of 20 min and were run at a perceived exertion rating of 12 on the Borg scale (Appendix F). One medium-distance run was performed each week while the duration also remained constant throughout the four-week intervention period, and consisted of 40min run at an intensity of 11 on the Borg scale. Recovery and medium-distance runs were undertaken on the same route for all participants of both groups (a flat loop of 1000 m run on an asphalt surface) over the four-week training period. A standard warm up and cool down period was implemented for every training session.

For respective training programs, the AlterG® anti-gravity treadmill group performed all interval training indoors in a controlled environment. The downhill training group performed all interval training outdoors, and thus were exposed to uncontrolled environmental conditions – interval sessions were performed at 7am in an attempt minimise excessive wind and heat influence. Training principles have been adhered to as discussed in chapter two in section 2.9., according to Bompa and Haff (2014). Table 3.2 below, shows an example of a typical training micro cycle for a 10 000 m running programme that has been followed by both experimental and comparison groups on non-supra-maximal speed interval training days (Bompa & Haff, 2014).

Table 3.2: Typical 10 000m Run Training Programme Followed on Non-Supra-Maximal Speed Interval Training Days.

Day	Mon	Tues	Wed	Thurs	Fri	Saturday	Sunday
Workout	Rest day						
Endurance Training		Interval	Recovery	LSD	Interval	LSD	Fartlek
Total Duration		30-40min*	60 min	120 min	30-40min	45 min	45-60 min
Interval duration		30 s	60 min	120 min	30 s	45 min	-
Recovery		60 s	0	0	60 s	0	-
Number of Intervals		6			6		
Work/rest Ratio		1:2	1:0	1:0	1:2	1:0	-
Intensity		Maximal			Maximal		-

Note: This micro cycle was based on a weekly training volume of 5-6 hours.

LSD = Long slow distance.

*Included a 5 minute warm up and cool down.

3.10.1 ALTERG® ANTI-GRAVITY TREADMILL TRAINING PROGRAMME

The AlterG® anti-gravity treadmill participants in experimental group one (N=10) trained at 125% (which was calculated according to each participants initial 3000m time trial run) supra-maximal speed, 75% body weight and with the treadmill gradient set at 1° incline (Jones & Doust, 1996). Recovery intervals consisted of a 6 km/h walk for the recovery period on the AlterG® anti-gravity treadmill. The complete training programme followed by the AlterG® anti-gravity treadmill group over the four-week intervention period has been tabulated in Table 3.3.

Table 3.3: AlterG® Anti-Gravity Treadmill Four-week Training Programme

Day	Mon	Tues	Wed	Thurs	Fri	Saturday	Sunday
Workout			Rest day				Rest day
Endurance Training	Interval	Active recovery		Interval	Active recovery	Medium long	
Work/rest Ratio	1:3	1:0		1:3	1:0	1:0	
Unweighting	25%			25%			
Gradient	1%			1%			
Speed	125%	RPE 12		125%	RPE 12	RPE 11	
Week 1							
Total Duration	20 min*	20 min		20 min*	20 min	40min	
Interval Duration	20 s	20 min		20 s	20 min	40min	
Recovery	60 s	0		60 s	0	0	
Number of Intervals	7			7			
Week 2							
Total Duration	22 min*	20 min		22 min*	20 min	40min	
Interval Duration	22 s	20 min		22 s	20 min	40min	
Recovery	66 s	0		66 s	0	0	
Number of Intervals	8			8			
Week 3							
Total Duration	25 min*	20 min		25 min*	20 min	40min	
Interval Duration	25 s	20 min		25 s	20 min	40min	
Recovery	75 s	0		75 s	0	0	
Number of Intervals	9			9			
Week 4							
Total Duration	29 min*	20 min		29 min*	20 min	40min	
Interval Duration	30 s	20 min		30 s	20 min	40min	
Recovery	90 s	0		90 s	0	0	
Number of Intervals	10			10			

*Included a 5 minute warm up and cool down

3.10.2 DOWNHILL RUN TRAINING PROGRAMME

The downhill participants in experimental group two (10 participants – 3 injured; n = 7) performed intervals at 110% (which was calculated according to each participant's initial 3000m time-trial run) supra-maximal speed on a 5.8° downhill decline. Recovery intervals consisted of a walk back to the starting point for downhill running participants.

The entire training programme followed by the downhill running group over the four-week intervention period has been tabulated in Table 3.4.

Table 3.4: Downhill Run Four Week Training Program

Day	Mon	Tues	Wed	Thurs	Fri	Saturday	Sunday
Workout			Rest day				Rest day
Endurance Training	Interval	Active recovery		Interval	Active recovery	Medium long	
Work/rest Ratio	1:3	1:0		1:3	1:0	1:0	
Gradient	5.8 %			5.8 %			
Speed	110%	RPE 12		110%	RPE 12	RPE 11	
Week 1							
Total Duration	20min*	20min		20min*	20min	40min	
Interval duration	20s	20min		20s	20min	40min	
Recovery	60s	0		60s	0	0	
Number of Intervals	7			7			
Week 2							
Total Duration	22 min*	20 min		22 min*	20 min	40min	
Interval Duration	22 s	20 min		22 s	20 min	40min	
Recovery	66 s	0		66 s	0	0	
Number of Intervals	8			8			
Week 3							
Total Duration	25 min*	20 min		25 min*	20 min	40min	
Interval Duration	25 s	20 min		25 s	20 min	40min	
Recovery	75 s	0		75 s	0	0	
Number of Intervals	9			9			
Week 4							
Total Duration	29 min*	20 min		29 min*	20 min	40min	
Interval Duration	30 s	20 min		30 s	20 min	40min	
Recovery	90 s	0		90 s	0	0	
Number of Intervals	10			10			

*Included a 5 minute warm up and cool down

3.11 Data Capturing

Data for each participant was saved on Excel electronic data sheets according to the data collection protocol. Coding was done using numerical values assigned to each participant with sub values used for the respective trials. Once coding had been inputted, confidentiality was ensured by destroying any paperwork that contained participant details with the exception of a private log book which was kept in the researcher's possession under lock and key. This information was kept in order to contact any participant if needed. Electronic information was stored on a personal laptop and confidentiality was guaranteed as numbers were assigned to participants instead of names.

3.12 Statistical Analysis

A qualified statistician based at the Nelson Mandela Metropolitan University was consulted to assist in the analysis and interpretation of the data. Descriptive statistics such as measures of central tendency (mean, mode, standard deviation and frequency distribution) were used to describe and analyse the data. Graphical representation in the form of figures was used to highlight findings (Thomas, Nelson, & Silverman, 2006). Inferential statistics incorporating the U test were used to determine differences in the selected variables between the experimental and comparison group. Cohen's d was applied to ascertain the effect size and practical significance of differences between the two groups.

All analyses in this study were carried out using Statistica StatSoft, Incorporated (2014). A quasi-experimental design was used to determine the difference in values observed by each training group. All data for age (yr), height (cm), body mass index (BMI), 40m standing-start sprint (s), and 3000m timed-trial run (min), delayed onset of muscle soreness (DOMS), were presented as a mean and standard deviation (± SD). Post-intervention testing outcomes were adjusted using a Mann-Whitney non-parametric U test ($p > 0.05$). Data were subsequently analysed using non-parametric statistics, with the maximum a priori level being set at 0.05. Standardised mean differences were expressed as U and p-values and effect size was reported as Cohen's d. Interpretation of effect sizes has been based on Gravetter and Wallnau (2009), where $d < 0.20$ was considered not significant, a d- value from 0.20 – 0.49

indicated small effect sizes, a d–value from 0.50 – 0.79 showed medium effects, and d > 0.8 reported large effects.

All effect sizes were considered large; where Cohen's d > 0.80. U represented the Mann-Whitney U test (a nonparametric test of the null hypothesis that two samples came from the same population against an alternative hypothesis, especially that a particular population tended to have larger values than the other) and p (a non-parametric measure of the overlap between two distributions and defined as the probability of obtaining a result equal to or "more extreme" than what was actually observed, assuming that the hypothesis under consideration was true) represented the level of significance.

For the reliability component of the study, systematic bias from Trial 1 to Trial 2 was observed based on the smallest worthwhile effect (d < 0.20). To determine if performance improved after completing the eight supra-maximal training interventions in any of the two groups running on different training modalities, dependent U-tests were used to compare pre- and post-test scores for the 40m standing start sprint and 3000m time-trial run. The same U-tests were used to assess the level of DOMS experienced by the AlterG® and downhill training groups every 24 hours, 48 hours and 72 hours following supra-maximal speed interval sessions.

3.13 Ethical Considerations

De Vos et al. (2009) described ethics as a set of moral principles which was suggested by an individual or group, subsequently widely accepted, and which offered rules and behavioural expectations about the most correct conduct towards experimental participants and respondents, employers, sponsors, other researchers, assistants and students.

As the study required human participants, the researcher was concerned about any circumstances in the research setting or activity that could harm the participants. Harm was interpreted to mean to frighten, embarrass or negatively affect the participants. Thus the following ethical issues were considered in order to prevent harm to the participants.

- The right to privacy and nonparticipation – the researcher did not ask unnecessary information or force participation in this study;
- The right to confidentiality – the researcher explained that the study focused on group data and codes associated with participants' names, with codes being used when analysing data;
- The researcher also informed the participants as to whom had access to the link between the actual name of each participant and the associated codes; and
- The right to expect experimenter responsibility – the researcher was well-meaning and sensitive to human dignity.

Permission to conduct this study as well as ethical approval for this study was sought and subsequently approved by the Faculty of Research, Technology and Innovation Committee as well as from the Nelson Mandela Metropolitan University (NMMU) Research Ethics Committee (Human), (REC-H #: **H15-HEA-HMS-002**). REC-H forms were displayed in Appendix G. Prior to the onset of the study each participant also gave verbal and written consent to participate in the study, informed consent forms are displayed in Appendix C.

3.14 Limitations

Purposive sampling was used to identify and obtain participants from a specific geographic area in the proximity of the supra-maximal training venue in Hout Bay where the AlterG® anti-gravity treadmill was situated. Due to the limited time provided by the business company to use the AlterG® anti-gravity treadmill for research purposes, a small number of participants who met the inclusion criteria were targeted. Data obtained from this small sample size is not representative of the larger population of female middle distance runners and, thus, no definitive findings could be generated. Trends could however have been observed.

The relatively short intervention period consisted of eight supra-maximal speed sessions within a four-week period which is not the ideal duration to obtain enhanced performance-related outcomes; but, due to race commitments, participants were only willing to commit to a maximum of five weeks to conduct pre- and post-intervention testing as well as the training intervention.

3.15 Summary

This chapter focused on the methods and procedures followed in order to address the objectives set out in chapter one. The target population consisted of 20 moderately trained female participants, between the age of 30 and 45 years, from a registered running club in Hout Bay, Cape Town, where 10 participants followed a novel training method of incorporating supra-maximal speed intervals (AlterG®) into a training programme. The performance outcomes were compared to those of the remaining seven participants who followed a traditional method of supra-maximal speed interval (downhill) training over a period of four weeks. The level of DOMS experienced during the training intervention was also evaluated during the respective training programmes undertaken by the participants in an attempt to analyse the outcomes, and formulate a safe and effective intervention programme for time-constrained individuals who are partial to above-average levels of middle distance running performance.

Supra-maximal training programmes for each respective training group were constructed according to the principles of overload and progression. Specific pace was calculated for each participant based on their 3000m timed-trial run result for the supra-maximal interval portions, within Monday and Thursday interval sessions. Over a period of four weeks, the duration, number of supra-maximal speed intervals and recovery time between intervals progressed. Participants from each respective training group also quantified the level of DOMS experienced every 24 hours, 48 hours, and 72 hours after each supra-maximal speed training interval session with the use of a numerical visual graphic rating scale.

CHAPTER 4

RESULTS

4.1 Introduction

Chapter four presents' results of the data analysis for participants in this study aimed at assessing performance maintenance or improvement when undertaking a four-week supra-maximal speed interval training programme. Female participants were between the age of 30 and 45 years, and belonged to a running club in Hout Bay, Cape Town. A pre-intervention 40m standing-start sprint and 3000m timed-trial run were used to establish base line parameters. Following the four-week supra-maximal training intervention, the post-intervention 40m standing-start sprint and 3000m timed-trial run were repeated to quantify performance differences that could have occurred.

The level of delayed onset of muscle soreness (DOMS) experienced by each participant was also rated and captured every 24 hours, 48 hours and 72 hours following respective supra-maximal speed interval sessions for either of the two, AlterG® or downhill run, participant groups. Anthropometric data obtained during initial data collection at the pre-test, specifically age, height and subsequent Body Mass Index (BMI) scores were analysed to assess whether participants qualified for the study. These variables were reassessed at the post-test after the twice weekly training intervention that lasted for four consecutive weeks. In total, 20 participants met the inclusion criteria and were randomly assigned into two equivalent groups based on the pre-test performance scores obtained. During the four-week training intervention, three participants from the downhill run training group dropped out of the study as a result of lower back injuries, and a foot injury. A narrative synthesis of findings is presented in the discussion that followed. Related to intervention

4.2 Results

Results of the selected variables of anthropometric data, 40m standing start sprint 3000m time-trial run and delayed onset of muscle fatigue (DOMS) are discussed in terms of statistical analysis as explained in Chapter 3.12.

4.2.1 ANTHROPOMETRIC MEASURES

Measurements were taken pre- and post- intervention to ascertain whether changes in body mass had occurred after the four-week supra-maximal run training on the AlterG® and downhill run modalities. No significant differences were found for body mass changes among the participants of the two different training modalities.

Table 4.1 illustrates the means, and standard deviations of the BMI scores obtained by the total group of participants. The average pre-intervention BMI score was 21.75 kg/m^2 with a standard deviation of 2.39 kg/m^2, n = 20.

Table 4.1: Pre-Test Means and Standard Deviations for Age and Anthropometric Data of Total Participant Group

Variable	Mean	SD
Age (years)	37	4.89
Height (cm)	168	6.85
Weight (kg)	61	7.65
BMI (kg/m^2)	21.75	2.39

Table 4.2 illustrates the mean, and standard deviation of the BMI scores obtained for each respective training group once randomised allocation into equivalent participant groups was done based on baseline assessment at the pre-test of 40m standing start sprint and 3000m time-trial run performances. The average pre-intervention BMI score was 22.13 kg/m^2 with a standard deviation of 1.99 kg/m^2 for the AlterG® training group and 21.19 kg/m^2 with a standard deviation of 2.79 kg/m^2 for the downhill run training group.

Table 4.2: Pre-Test and Post-Test Means and Standard Deviations for Age and Anthropometric Data for AlterG® and Downhill Run Training Groups

	Pre-Intervention Values				Post-Intervention Values			
Training group	**AlterG® (n = 10)**		**Downhill (n = 10)**		**AlterG® (n = 10)**		**Downhill (n = 7)**	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Age (years)	38.10	5.11	37.04	5.02	38.10	5.11	36.29	4.68
Height (cm)	166.2	4.72	169.55	6.73	166.2	4.72	169.29	6.27
Weight (kg)	61.26	7.44	60.66	7.86	61.40	7.27	60.59	7.00
BMI (kg/m^2)	22.18	1.93	21.19	2.79	22.18	1.93	21.17	2.51

Post-intervention test scores of anthropometric data for the AlterG® and downhill run training groups is also illustrated in Table 4.2 and is presented as means and standard deviations. The average post-intervention BMI score for the AlterG® training group was 22.18 kg/m^2 with a standard deviation of 1.93 kg/m^2 and the average post-intervention BMI score for the downhill run training group was 21.17 kg/m^2 with a standard deviation of 2.51 kg/m^2. Three participants from the downhill run training group withdrew during the study for reasons mentioned in the introduction of this chapter, leaving a total of seven participants who completed the study in the supra-maximal downhill run training modality.

4.2.2 40M STANDING-START SPRINT AND 3000M TIMED-TRIAL RUN

Table 4.3 illustrates the mean, rank sums, U test results, p-values and Cohen's d effect sizes to indicate practical significance of results obtained for each respective training group before and after the supra-maximal training intervention.

Table 4.3: Pre- and Post-Test Results for AlterG® and Downhill Run Training Groups for the 40m Standing-Start Sprint and 3000m Timed-Trial Run.

	AlterG® (n = 10)		Downhill (n = 7)		Rank Sums				
Variable	**Mean**	**SD**	**Mean**	**SD**	**AlterG®**	**Downhill**	**U**	**p-value**	**Cohen's d**
40m (pre)	7.89	1.03	7.63	0.96	92.0	61.0	33.0	.884	0.25
40m (post)	7.57	0.94	7.36	0.70	93.0	60.0	32.0	.807	0.25
40m (diff)	0.31	0.27	0.27	0.34	93.5	59.5	31.5	.770	0.14
40m (diff %)	3.87	3.30	3.25	3.97	92.0	61.0	33.0	.884	0.17
3000m (pre)	16.43	2.86	15.70	2.19	94.0	59.0	31.0	.733	0.28
3000m (post)	15.75	2.43	15.10	2.08	94.0	59.0	31.0	.733	0.28
3000m (diff)	0.68	0.57	0.60	0.32	93.0	60.0	32.0	.807	0.17
3000m (diff %)	3.81	2.81	3.74	2.17	93.0	60.0	32.0	.807	0.03

*40m (diff) was the difference (improvement) in time taken to complete the 40m standing-start sprint when subtracting the post-intervention sprint time from the pre-intervention time.

*40m (diff%) was the percentage improvement in participants performance when comparing 40m standing-start sprint post-intervention results to that of pre-intervention results.

*3000m (diff) was the difference (improvement) in time taken to complete the 3000m timed-trial run when subtracting the post-intervention sprint time from the pre-intervention time.

*3000m (diff%) was the percentage improvement in participants performance when comparing 3000m timed-trial run post-intervention results to that of pre-intervention results.

4.3 40m Standing Start Sprint

When compared to the AlterG® anti-gravity treadmill group, the downhill run group was slightly inferior in terms of reducing their sprint time from pre-intervention to post-intervention testing. The mean post-intervention difference in 40m performance for the AlterG® and downhill training group was 0.31 and 0.27 seconds, respectively, representing a 3.87% and 3.25% overall performance improvement, with a standard deviation of 0.27 for the AlterG® and 0.34 for the downhill run group.

The rank sum difference for the AlterG® anti-gravity treadmill and downhill run groups was 93.5 and 59.5 respectively. Although the AlterG® anti-gravity treadmill group obtained a reduction in performance time in the post-intervention 40m standing-start sprint, further statistical analysis indicated a U test result of 31.5 that was not statistically significant as a p-value of 0.770 ($p > 0.05$) was achieved. The Cohen's d result was not significant ($d < 0.20$), thus indicating no statistical significant practical effect size. Results of the performance differences for the two supra-maximal training groups for the 40m standing sprint performance are graphically displayed in Figure 4.1.

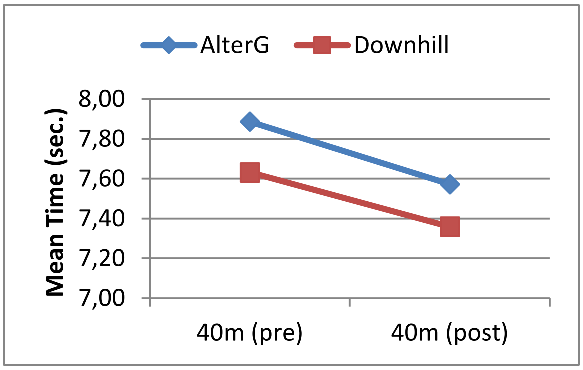


Figure 4.1: Pre- and Post-Test Mean 40m Standing Sprint Results for the AlterG® and Downhill Run Training Groups

4.4 3000m Timed-Trial Run

When compared to the AlterG® anti-gravity treadmill group, the downhill group was slightly inferior in terms of reducing their 3000m timed-trial run from the pre-test to the post-test assessment. The mean post-intervention difference in 3000m timed trial run score for the AlterG® was 41 seconds representing a 3.81% overall performance improvement after eight supra-maximal training sessions. The downhill training group obtained a mean post-intervention score of 36 seconds representing a 3.74% performance enhancement. The post-test standard deviation for the AlterG® anti-gravity treadmill training group was more heterogeneous (SD of 0.57) than that of the downhill training group (SD of 0.32).

The rank sum difference for the AlterG® anti-gravity treadmill and downhill groups was 93 and 60 respectively, with a U test result of 32 and p-value of .807 ($p > 0.05$), thus indicating no statistically significant differences in post-intervention performance in 3000m timed-trial run. Although a reduction in performance time in the post-intervention 3000m timed-trial run was obtained by the group training on the anti-gravity treadmill, no practically significant effect size was indicated by Cohen's d (d = < 0.20). A visual display of the results obtained for participants on both supra-maximal training modalities were presented in Figure 4.2.

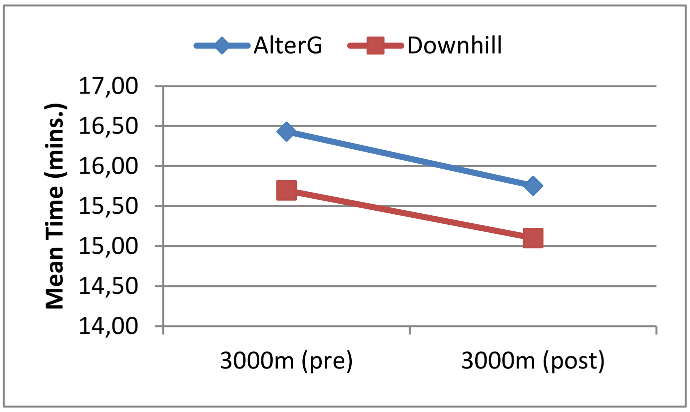


Figure 4.2: Pre- and Post-Test Mean 3000m Results for the AlterG® and Downhill Run Training Groups

4.5 Delayed Onset of Muscle Soreness (DOMS)

A numerical graphic rating scale (NVGRS) was used to attain the level of DOMS experienced by participants in both training groups at 24 hour, 48 hour, and 72 hour increments after supra-maximal interval training sessions and prior to subsequent interval training sessions via electronic mail during the four-week intervention period. These findings are presented in Table 4.4 and visually displayed in Figure 4.3.

Participants on average throughout the four-week training intervention performing supra-maximal speed intervals on the AlterG® experienced a 7.25% lower level of DOMS, 24 hours after the Monday training and experienced a 14.9% lower level of DOMS, 24 hours after the Thursday training session, when compared to the downhill run group.

Participants on average throughout the four-week training intervention performing supra-maximal speed intervals on the AlterG® experienced a 28.23% lower level of DOMS, 48 hours after the Monday training session and experienced a 35.45% lower level of DOMS, 48 hours after the Thursday training session in comparison to the downhill run group.

Of significance, results for DOMS 48 hours after the third Monday indicated a mean of 1.6 (±1.35 SD) for the experimental- and a mean of 3.0 (1.15 SD) for the comparison group. The rank sum differences were 69 for the experimental and 84 for the comparison group. Mann-Whitney U test results were significant when a p- value of 0.045 ($p > 0.05$) was obtained. Cohen's d indicated a large practical effect size of 1.10.

Participants on average throughout the four-week training intervention performing supra-maximal speed intervals on the AlterG® experienced a 26.89% lower level of DOMS, 72 hours after the Monday training session and experienced the same level of DOMS, 72 hours after the Thursday training session when compared to the downhill run group.

The level of DOMS experienced when combining the Monday and Thursday supra-maximal speed sessions and three data collection periods for each day (24 hours, 48 hours and 72 hours), over a four-week period showed that the overall level of DOMS experienced by the AlterG® anti-gravity treadmill group was reported to be at a 20.83% lower level when compared to the downhill run group. Results were displayed in Table 4.4 and 4.5. Figure 4.3 provides a graphical display to compare results obtained for DOMS as perceived and reported by both groups at the three different time intervals (24 hours, 48 hours and 72 hours). Values observed were spread from "not significant" to "large" ($d = < 0.20 – > 0.80$).

Table 4.4: Delayed Onset of Muscle Soreness Perceived Rating of Total Group

	AlterG (n=10)		Downhill (n=7)		Rank Sums				
Variable	Mean	SD	Mean	SD	AlterG	Downhill	U	p-value	Cohen's d
W1M.24H	1.50	1.58	1.57	1.13	85.5	67.5	30.5	.696	0.05
W1M.48H	2.80	2.10	2.71	1.11	85.5	67.5	30.5	.696	0.05
W1M.72H	1.20	1.03	1.57	1.27	83.5	69.5	28.5	.558	0.33
W1M.24-72H	1.83	1.38	1.95	1.04	84.0	69.0	29.0	.591	0.09
W1T.24H	1.50	2.12	2.00	1.29	79.5	73.5	24.5	.329	0.27
W1T.48H	1.20	1.23	2.71	1.60	70.0	83.0	15.0	.057	1.09
W1T.72H	1.10	1.73	1.57	1.13	80.5	72.5	25.5	.380	0.31
W1T.24-72H	1.27	1.25	2.10	1.21	77.5	75.5	22.5	.242	0.67
W2M.24H	1.70	1.89	1.29	1.38	93.5	59.5	31.5	.770	0.24
W2M.48H	1.90	2.23	2.86	1.68	76.0	77.0	21.0	.188	0.47
W2M.72H	1.40	2.22	1.57	1.13	80.0	73.0	25.0	.354	0.09
W2M.24-72H	1.67	2.07	1.90	1.36	80.0	73.0	25.0	.354	0.13
W2T.24H	1.90	2.64	1.57	0.98	84.0	69.0	29.0	.591	0.15
W2T.48H	2.10	1.45	3.14	1.86	78.0	75.0	23.0	.262	0.64
W2T.72H	1.20	1.40	1.86	1.68	81.0	72.0	26.0	.407	0.43
W2T.24-72H	1.73	1.77	2.19	1.37	81.0	72.0	26.0	.407	0.28

Variable	Mean	SD	Mean	SD	AlterG	Downhill	U	p-value	Cohen's d
W3M.24H	0.90	1.29	1.57	0.98	75.0	78.0	20.0	.157	0.57
W3M.48H	1.60	1.35	3.00	1.15	69.0	84.0	14.0	.045	1.10
W3M.72H	1.10	1.10	1.43	1.27	84.5	68.5	29.5	.626	0.28
W3M.24-72H	1.20	0.95	2.00	0.88	73.5	79.5	18.5	.118	0.87
W3T.24H	1.20	1.03	1.86	1.21	78.5	74.5	23.5	.283	0.59
W3T.48H	1.90	1.10	2.71	1.70	78.0	75.0	23.0	.262	0.59
W3T.72H	1.90	1.91	1.43	0.79	91.5	61.5	33.5	.922	0.30
W3T.24-72H	1.67	1.09	2.00	1.02	81.5	71.5	26.5	.435	0.31
W4M.24H	1.20	0.92	1.29	1.11	88.5	64.5	33.5	.922	0.09
W4M.48H	1.80	0.79	2.71	0.76	70.0	83.0	15.0	.057	1.18
W4M.72H	1.00	1.15	1.86	1.07	72.5	80.5	17.5	.097	0.76
W4M.24-72H	1.33	0.83	1.95	0.87	74.5	78.5	19.5	.143	0.73
W4T.24H	1.60	1.17	1.86	1.07	83.0	70.0	28.0	.526	0.23
W4T.48H	1.90	1.60	2.43	1.27	78.5	74.5	23.5	.283	0.36
W4T.72H	1.50	1.35	0.86	0.69	100.0	53.0	25.0	.354	0.57
W4T.24-72H	1.67	1.28	1.71	0.83	88.0	65.0	33.0	.884	0.04

*DOMS experienced by the AlterG® and downhill running group over four weeks of training was as follows: W1M.24 = week 1 Monday, 24 hours after the supra-maximal speed interval session, W1T.24 = week 1 Thursday, 24 hours after the supra-maximal speed interval session – this format was followed each 24 hours, 48 hours and 72 hours over the course of four weeks of training intervention. W1M.24-72H = week 1, Monday and the average of the three measured DOMS levels (24 hours, 48 hours and 72 hours). Each week that encompasses the Monday and Thursday supra-maximal interval training was assigned an average DOMS value.

Table 4.5: Average Delayed Onset of Muscle Soreness Perceived Rating of Total Group

	AlterG (n = 10)		Downhill (n = 7)		Rank Sums				
Variable	**Mean**	**SD**	**Mean**	**SD**	**AlterG**	**Downhill**	**U**	**p-value**	**Cohen's d**
W1-4M.24H	1.33	1.10	1.43	0.64	80.5	72.5	25.5	.380	0.11
W1-4M.48H	2.03	1.51	2.82	0.87	70.5	82.5	15.5	.064	0.62
W1-4M.72H	1.18	1.09	1.61	0.84	76.5	76.5	21.5	.205	0.43
W1-4M.24-72H	1.51	1.20	1.95	0.74	72.0	81.0	17.0	.088	0.43
W1-4.T24H	1.55	1.57	1.82	0.76	78.0	75.0	23.0	.262	0.21
W1-4T.48H	1.78	0.93	2.75	1.19	71.0	82.0	16.0	.071	0.94
W1-4T.72H	1.43	1.42	1.43	0.90	83.0	70.0	28.0	.526	0.00
W1-4T.24-72H	1.58	1.23	2.00	0.88	76.0	77.0	21.0	.188	0.38

*DOMS experienced by the AlterG® and downhill running group over four weeks of training was as follows: W1-4M.24 = week 1-4 average level of DOMS experienced on Monday, 24 hours after each supra-maximal speed interval session, W1-4T.24 = week 1-4 average level of DOMS experienced on Thursday, 24 hours after each supra-maximal speed interval session – this format was followed for an average level of DOMS experienced every Monday and Thursday every 48 hours and 72 hours post supra-maximal interval session over the course of four weeks of training intervention.

The last row of each day combined the level DOMS experienced over the entire four weeks (24 hours, 48 hours and 72 hours post training) for Monday and Thursday supra-maximal speed interval training sessions.

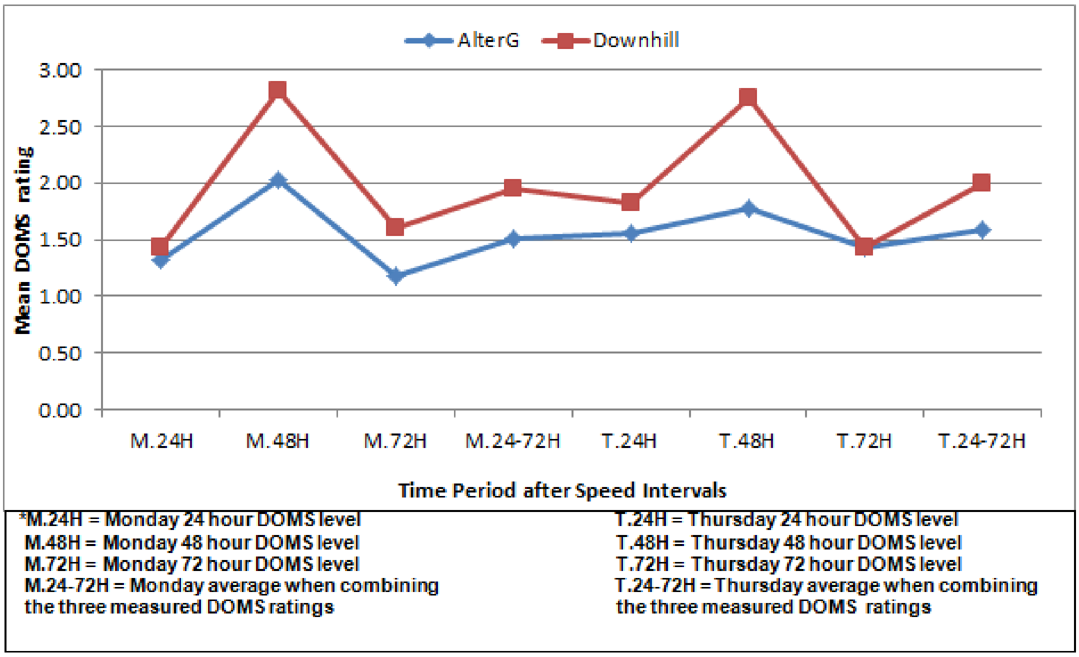


Figure 4.3: Comparison of Mean DOMS Results for the AlterG® and Downhill Run Group over Four Weeks

4.6 Summary

The AlterG® training group improved slightly more than the downhill training group when comparing results of the post-intervention 40m standing start sprint and 3000m timed-trial run to the pre-intervention results while both groups showed a slight improvement overall for both tests (40m standing start sprint and 3000m timed-trial run) after undertaking the four-week training intervention.

Both training groups experienced the highest levels of DOMS 48 hour's post-supra-maximal interval training, whilst the AlterG® training group however experienced significantly lower levels of DOMS subsequent to each supra-maximal interval training session when compared to the downhill training group.

CHAPTER 5

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

As early as the 1930s, endurance athletes had long recognised supra-maximal speed training as an integral component of a successful training regime. It was known, even in those early years, that a combination of interval and continuous training was necessary to stress both the aerobic and anaerobic energy systems (Bompa & Haff, 2014). Experts in the field had long advocated the need to accurately investigate the use of supra-maximal speed training in endurance runners, not only on the basis of improving running economy and technique but also cardiovascular capacity (Gojancovic et al. 2012).

Many individuals, who have limited schedules which subsequently restricted time available for quality exercise, could benefit from this format of training. Occupational and other commitments often reduce the luxury of being able to focus on high-level physical activity without severe time constraints, the proposed training structure would allow for short but very intense training sessions which could trade off into superior level middle distance running performance.

Stress has been shown to be good and necessary to elicit physiological adaptation; general recommendations indicate that high-intensity interval training sessions should make up approximately 5 to 15% of total training volume (Lindsay, et al. 1996; Billat et al. 1999; Bompa & Haff, 2014; Daniels, 2014). Increased maximum speed could be achieved by pre-competition training of a variety of movement specific exercises, such as running at speeds faster than the competition rate (Ross et al. 2009). Concurrent improvements in aerobic and anaerobic capacities were of practical significance to sprinters and middle distance endurance runners (Cicioni-Kolsky et al. 2011) and supra-maximal interval training proved to be most effective in improving sprint and repeated sprint performance in physically active individuals, without decrements in concurrent endurance gains.

Therefore, against this background, the primary aim of this study was to describe, explore and compare the effect of four weeks of supra-maximal speed interval training on the AlterG® anti-gravity treadmill and normal weighted downhill interval training. Performance measures encompassed a 40m standing-start sprint and a timed 3000m run in 20 moderately trained, female runners from a registered running club in Hout Bay, who were between the age of 30 and 45 years. A secondary aim was to determine the level of DOMS in the experimental group (AlterG®) and the comparison group (downhill) every 24 hours, 48 hours and 72 hours post supra-maximal speed interval training. Results for the dependant variables, limitations and recommendations for future studies are discussed in this chapter.

5.2 Discussion of Anthropometrical Measures

There was no significant difference in anthropometric measures over the course of the study. The average pre-intervention BMI score was 22.13 kg/m^2, which fell within the "normal" BMI for adults, according to the Centres for Disease Control and Prevention [http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf, 2015]. Initial scores were 21.18 kg/m^2 for the AlterG® training group and 21.19 kg/m^2 for the downhill run training group. The average post-intervention BMI score for the AlterG® training group was 22.18 kg/m^2 and the average post-intervention BMI score for the downhill run training group was 21.17 kg/m^2

Anthropometric measures were insignificant (if any) which was an indicator that the training intervention did not cause undue overload, the training intervention was over too short a period to cause significant BMI changes. Dietary intake was not altered by any study participants during the training intervention which would also aid a stable BMI measure. The results were therefore not included as a variable.

5.3 The Effect of Supra-Maximal Interval Training

Supra-maximal speed interval training enhanced physiological characteristics such as: the activity and number of anaerobic and aerobic enzymes, substrate availability and oxygen kinetics in recreationally- to well-trained individuals when compared to continuous sub-maximal training (Cicioni-Kolsky et al. 2011). The amount of supra-maximal speed training sessions that the athlete could complete without increasing the risk of overtraining would largely be determined by the intensity of the session.

Gojancovic et al. (2012) further stated that specificity of training while using the AlterG® anti-gravity treadmill was high, however the questions of diminished impact forces and aerobic conditioning had been partially investigated only (Grabowski & Kram, 2008). Other studies (Hoffman & Donaghe, 2011; Raffalt et al. 2013) have ascertained the reduction of metabolic cost of ambulation with reduction in body weight when using the AlterG® anti-gravity treadmill. To date, however, literature was scarce pertaining to the effects of actual fast training speeds for a partially weighted runner. There was therefore a gap in existing literature pertaining to the use and efficacy of the AlterG® anti-gravity treadmill due to its novelty. As a cutting edge piece of equipment, the potential benefits of training at supra-maximal speed while subsequently reducing ground reaction forces made using the AlterG® anti-gravity treadmill an exciting modality to train on and was the focus of this study.

Literature confirmed the fact that weight-supported running using harnesses caused a reduction in both vertical ground reaction forces and metabolic work when compared to similar velocities and workloads without support (Aaslund & Moe-Nilssen, 2008; Grabouwski & Kram, 2008; Grabouwski, 2010). For the purpose of this study, the reduction in metabolic cost for participants selected to run on the AlterG® anti-gravity treadmill was accommodated for by increasing the cardiovascular stress experienced by means of supra-maximal speed training interval supplementation at percentages above those recommended for the traditional supra-maximal full body weight supported running.

5.3.1 PERFORMANCE RELATED TO THE 40M STANDING-START SPRINT

Performance related to the 40m standing start sprint improved for both the AlterG® anti-gravity treadmill group and the downhill run group, even after a relatively short intervention period of four weeks. The mean post-intervention difference in 40m performance for the AlterG® and downhill training group was 0.31 and 0.27 seconds, respectively, representing a 3.87% and 3.25% overall performance improvement.

The rank sum difference for the AlterG® anti-gravity treadmill and downhill run groups was 93.5 and 59.5 respectively. Although the AlterG® anti-gravity treadmill group obtained a reduction in performance time in the post-intervention 40m standing-start sprint, further statistical analysis indicated a U test result of 31.5 that was not statistically significant as a p-value of 0.770 ($p > 0.05$) was achieved.

The improvement in performance following the four-week training intervention was consistent with research by Ross et al. (2009) and Wagganer et al. (2014) who presented evidence of reductions in 40 yard sprint times by participants when supra-maximal speed training was performed over a period of seven and four weeks respectively.

The anaerobic 40m standing-start sprint partially depleted the adenosine triphosphate and phosphocreatine substrates (Glaister, 2008). Experts in the field have long advocated the need to accurately investigate the use of supra-maximal speed training in endurance runners, not only on the basis of improving running economy and technique, but also cardiovascular capacity (Gojanovic, 2012). When compared to the AlterG® anti-gravity treadmill group, the downhill run group was marginally inferior in terms of reducing their sprint time post-intervention. The reduction in metabolic cost of participants in the AlterG® anti-gravity treadmill group was accommodated for by increasing the cardiovascular stress experienced by means of supra-maximal speed training interval supplementation at percentages above those recommended for the traditional supra-maximal full body weight-supported running.

Small improvements were observed by all participants due to the positive training effects of supra-maximal speed training. Due to the short intervention period and small sample size, statistically significant results were not observed.

5.3.2 PERFORMANCE RELATED TO THE 3000M TIMED TRIAL RUN

The 3000m timed-trial run relies primarily on the relative aerobic energy system contribution predominating and increasing as the duration of exercise progresses (Spencer & Gastin, 2001; Duffield et al. 2005). When compared to the AlterG® anti-gravity treadmill group, the downhill group was slightly inferior in terms of reducing their 3000m timed-trial run from the pre-test to the post-test assessment. The mean post-intervention difference in 3000m timed-trial run score for the AlterG® and downhill run groups was 41 and 36 seconds, respectively, representing a 3.81% and a 3.74% performance enhancement over a period of four weeks.

The rank sum difference for the AlterG® anti-gravity treadmill and downhill groups was 93 and 60, respectively, with a U test result of 32 and p-value of .807 ($p > 0.05$), which indicated that there were no statistically significant differences in post-intervention performance with regards to the 3000m timed-trial run. Although a reduction in performance time in the post-intervention 3000m timed-trial run was obtained by the group training on the anti-gravity treadmill, no practical effect size was indicated by Cohen's d ($d = < 0.20$).

The progression in performance following the four-week training intervention was consistent with research by Iaia et al. (2009); Iaia and Bangsbo (2010); and Laursen (2010) who illustrated that supra-maximal speed training within an endurance training plan lead to improvements in middle distance endurance performance. The 3000m timed trial run relies primarily on the relative contribution of the aerobic energy system that increases as the duration of exercise progresses (Duffield et al. 2005). The mean post-intervention difference in the 3000m timed run for the AlterG® and the downhill run group represents a 3.8% and 3.7% performance enhancement for the respective groups. Although the improved performance over such a relatively short distance is noteworthy, both Cicioni-Kolsky et al. (2011) and Ross et al. (2009) reported that a time period of five and seven weeks, respectively, is necessary for the indication of statistically significant results.

Results affirm that the partially weight-supported AlterG® anti-gravity treadmill is an effective training modality for performance enhancement (that utilises both aerobic and anaerobic metabolism) in female middle-distance and endurance runners.

5.4 Delayed Onset of Muscle Soreness (DOMS)

DOMS has been described as damaged muscle tissue membranes combined with a secondary inflammatory condition as a result of unaccustomed eccentric contractions and maximal isometric contractions – these responses typically impaired athletic performance or caused an athlete to miss subsequent training sessions (Curtis, et al. 2010; Hedayatpour et al. 2010; Mathur, et al. 2010). Soreness associated with DOMS typically appeared between eight and 24 hours post-exercise (Vila-Cha et al. 2011), peaked at 48 hours (Lee, et al. 2002; Hedayatpour et al. 2010; Lewis et al. 2012), and could last up to seven days (Hedayatpour et al. 2010).

Programme prescription for middle distance- and endurance athletes typically recommends no more than two high-intensity interval sessions a week to prevent the risk of injury associated with supra-maximal speed training due to excessive ground reaction forces and eccentric loading of the musculo-skeletal system. (Billat, et al.1999). These negative metabolic responses typically impair athletic performance or cause an athlete to miss subsequent training sessions. (Curtis, et al. 2010; Hedayatpour et al. 2010) Notably, in this regard, two of the three participants in the downhill run training group who dropped out of the study did so as a result of musculo-skeletal running-related injuries within the relatively short training intervention period.

5.4.1 THE LEVEL OF DOMS EXPERIENCED BY PARTICIPANTS DURING THE STUDY

Participants were randomly selected to train in either the AlterG® anti-gravity treadmill or downhill group and exhibited the following results. Participants, on average, who throughout the four-week training intervention performed supra-maximal speed intervals on the AlterG® experienced a 7.25% lower level of DOMS 24 hours after the Monday training, and a 14.9% lower level of DOMS 24 hours after the Thursday training session; a 28.23% lower level of DOMS 48 hours after Monday supra-maximal training session, and a 35.45% lower level of DOMS 48 hours after the Thursday supra-maximal training session; a 26.89% lower level of DOMS 72 hours after the Monday supra-maximal training session, and experienced the same level of DOMS 72 hours after the Thursday supra-maximal training session when compared to the downhill run group.

The level of DOMS experienced when combining the Monday and Thursday supra-maximal sessions, as well as the three data collection periods for each day (24 hours, 48 hours and 72 hours), over a four-week period showed that the overall level of DOMS experienced by the AlterG® anti-gravity treadmill group was reported to be 20.83% lower when compared to the downhill run group.

These results coincided with various articles which stated that AlterG® anti-gravity treadmill users were able to increase velocity, but at the same time drastically decrease vertical ground reaction force, by reducing gravity's impact via body weight attenuation, which ultimately led to a significantly reduced occurrence of DOMS (Grabowski & Kram, 2008; Grabowski, 2010; Raffalt et al. 2013; Sainton et al. 2014).

Literature confirmed that downhill running was a simple and cost effective way to increase running speed due to an over-speed effect as a result of gravity, and performed at 110% of velocity at vVO_{2max} on an optimal hill decline of 5.8° (Ebben et al. 2008; Klika, 2010) for peak results. However the drawback of performing eccentric exercise during downhill running had been shown to contribute to sports-related injuries (Curtis et al. 2010; Hedayatpour et al. 2010). This ultimately resulted in three participants dropping out of the downhill training group due to injuries sustained while taking part in supra-maximal speed training sessions.

The AlterG® training group improved slightly more than the downhill training group when comparing results of the post-intervention 40m standing start sprint and 3000m timed-trial run to the pre-intervention results while both groups showed a slight improvement overall for both tests (40m standing start sprint and 3000m timed-trial run) after undertaking the four-week training intervention. Jemma et al. (2005) and Lindsay et al. (1996) have shown that a three as well as a four-week high-intensity training programme was sufficient to elicit positive results in cyclists undertaking a 40 km time trial respectively. A longer intervention period than four weeks would have been ideal to conduct the current study in order to realise more statistically significant results; however, specialised equipment and time constraints did not allow for a longer than four-week training intervention period for study participants.

Moreover, it is noteworthy that the AlterG® group experienced a statistically significant lower rating of DOMS 48 h after the fifth training session in week three. The question arising from this finding is whether it is possible to perform more than two supra-maximal high intensity sessions in a periodised training block when training on such a technologically advanced apparatus while minimising the detrimental effects of DOMS? This positive physiological phenomenon could possibly allow athletes to include more supra-maximal interval training sessions into a training block while minimising the detrimental effects of DOMS. Although the aforementioned result was not a definitive finding due to the limitations inherent to the initial sampling method, it may still be able to serve as a springboard for further research exploration to validate the aforementioned prospect.

Due to the mean values at baseline and SD for both groups being close, this indicated homogenous groups with results that were almost equivalent.

5.5 Limitations

As with every study performed, certain limitations arose. Firstly, a limited number of female participants who met the inclusion criteria to take part in the study were sourced, which ultimately resulted in a small representation of moderately trained female runners. Selection criteria involved stringent parameters whereby recent running and injury history, as well as anthropometric measures, were assessed in order to reduce the likelihood of injury. Participants also needed to be between the ages of 30 and 45 years and belong to a registered running club in Hout Bay.

Secondly, the time frame in which the researcher had available to implement the training intervention for study participants was short, allowing for just four weeks within which to incorporate a supra-maximal interval training programme. Participant commitments to future running races, the need to use specialised equipment (AlterG® anti-gravity treadmill group) and changing weather conditions (downhill training group) restricted time available for this particular study. When one uses a true experimental design with randomized controlled studies (i.e. indoors), there is a better quality of design. In this instance, it was not possible to have downhill runners performing supra-maximal speed intervals indoors due to the distance and slope required, they were therefore exposed to variable weather conditions which differed from those experience by the AlterG® anti-gravity treadmill group who ran indoors in a stable environment – which ultimately may have had an effect on post-intervention results.

Evidence which confirmed that three to four weeks of supra-maximal speed training was sufficient to elicit statistically significant performance results was sourced (Lindsay, et al. 1996; Jemma, et al. 2005; Iaia, et al. 2009) to justify the relative short intervention period. Mixed evidence as reported by Ross et al. (2009) and Cicioni-Kolsky et al. (2011) however, necessitated a time period of seven and five weeks, respectively, in order to achieve statistically significant results.

Thirdly, the difference in training loads experienced were impossible to quantify in terms of exact metabolic loads experienced by each group . Taking into account each individuals weight, interval speed, gradient (AlterG® group), and slope (downhill group) near equivalent loads of those know factors were calculated for – however external factors were impossible to ensure irrefutably identical metabolic training loads between the two training groups.

Lastly, a Numerical Visual Graphic Rating Scale (NVGRS) was used to quantify the level of DOMS experienced by participants as perceived 24 h, 48 h, and 72 h after each supra-maximal speed interval session to differentiate between the effectiveness of using a traditional method of downhill running and a more technological advanced anti-gravity treadmill modality. Since the NVGRS is a subjective measuring tool, further research is warranted that utilises objective analysis of the physiological and metabolic markers in the muscle tissue itself.

Articles sourced to determine whether there was an irrefutable difference between male and female athletes performance after taking part in a supra-maximal interval training programme proved inconclusive. Some studies stated that there were similar responses irrespective of gender (Yasuda et al. 2007; Pepe et al. 2009). Other researchers declared that the average female differed from the average male with regards to performance results (Daniels & Daniels, 1992; Weber & Schneider, 2002; Marieb & Hoehn, 2007).

Due to initial convenience sampling, no definitive findings could be generated even though equivalent groups based on performance at the pre-test were identified as well as applied randomisation being utilised for the sample group, once paired. In light of the aforementioned, generalisations regarding a training regime to suit all runners should be made with caution.

The main shortcoming of this study was the small sample size which impeded generalisation of results to the wider population of middle distance and endurance athletes.

5.6 Future Recommendations

The AlterG® anti-gravity treadmill was a novel training modality with a scarcity of scientifically backed studies to substantiate effectiveness as a performance enhancement tool when implementing supra-maximal interval training. There was therefore a large gap in available literature and further studies on a national and international level were needed.

Further research into the use of the AlterG® anti-gravity treadmill as a performance enhancement training tool should be addressed, to provide additional evidence and insight necessary to design and implement strategies and methods needed to formulate safe and effective supra-maximal interval training routines when using the device. It would be ideal to develop a nationally representative gender and age group database across South Africa, as well as internationally where possible, in order for strategies and methods to be modified according to the aforementioned variables. A study with a greater number of males or a combination of mixed genders would need to be performed in order to resolve any questions regarding training improvement, according to gender.

Using heart rate values for study participants may provide a more accurate means of quantifying the workload performed during future studies. This would allow researchers to quantify the aerobic output / metabolic cost of a given training intervention.

5.7 Conclusions

Supra-maximal interval training has proven to be most effective in improving sprint and repeated sprint performance in physically active individuals, without decrements in concurrent endurance gains and enhances physiological characteristics in recreationally to well-trained individuals, when compared to continuous sub-maximal training (Cicioni-Kolsky et al. 2011). This has implications for Exercise Science where traditional programme prescription prescribes at least two supra-maximal speed interval sessions per week and reassures that aerobic capacity will be enhanced.

The benefit to this format of training may be of value to many athletes who have limited time available to train due to occupational and other commitments, as it allowes for short but very intense training sessions. Gojancovic et al. (2012) stated that specificity of training while using the AlterG® anti-gravity treadmill was high and when compared to a traditional method of supra-maximal interval training (downhill running), vertical ground reaction forces could be greatly reduced through weight attenuation. This in turn greatly reduced the level of DOMS experienced by individuals who trained at supra-maximal speeds.

Both training groups reported improvements when comparing pre-intervention to post-intervention times, the AlterG® anti-gravity group however was marginally better in terms of time improvement overall for both the 40m standing start sprint and 3000m timed trial run. The mean post-intervention difference in 40m performance for the AlterG® and downhill training group was 0.31 and 0.27 seconds, respectively, representing a 3.87% and 3.25% overall performance improvement. Results also indicated that the AlterG® anti-gravity treadmill group was slightly superior in terms of reducing their 3000m timed-trial run from the pre-test to the post-test assessment. The mean post-intervention difference in 3000m timed-trial run score for the AlterG® and downhill run groups was 41 and 36 seconds, respectively, representing a 3.81% and a 3.74% performance enhancement.

Further empirical research is needed to determine long-term supra-maximal training effects on physiologically- related variables, such as delayed onset of muscle fatigue to improve running performance. The AlterG® anti-gravity treadmill furthermore allows for short but very intense training sessions irrespective of weather conditions and is suited to athletes who have limited training time available due to occupational and other commitments. When compared to the traditional method of downhill running, the weight attenuation as a result of the partial weightedness of the athlete greatly reduces vertical ground reaction forces. This in turn reduces the musculo-skeletal load and therefore the risk of the occurrence of running-related injuries in athletes. Future research into the use of the AlterG® anti-gravity treadmill as a partially weighted training modality could provide evidence of more frequent weekly supra-maximal training sessions for the endurance athlete with the potential to enhance performance without the fear of obtaining musculo-skeletal injuries.

Irrespective of the modality used in performing supra-maximal speed interval sessions during a four-week training period, both groups perceived the largest effect of delayed onset of muscle soreness 48 h post-exercise for all of the eight interval sessions. The level of DOMS experienced by the anti-gravity treadmill group however, was consistently lower for all three incremental measuring intervals (24 h, 48 h and 72 h) than that of the downhill running group. Level of perceived DOMS was however significantly lower 48 h after the third Monday measurement in the AlterG® group. Over a four-week period, the overall level of DOMS experienced by the AlterG® anti-gravity treadmill group was reported to be at a 20.83% lower level when compared to the downhill run group. In comparison to the downhill run group from which two of the three who withdrew during the intervention because of the negative loading of the musculo-skeletal system, none of the participants in the AlterG® group obtained any running injuries even though they trained at 125% over-speed. This study contributes to the limited evidence that currently exists on the use of the AlterG® anti-gravity treadmill as a novel training modality with the potential of minimising running injury risk while performing high intensity workloads. This is a noteworthy finding of the current study.

This explorative study could be used to modify and improve current supra-maximal speed training programmes on the AlterG® anti-gravity treadmill for future training.

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APPENDICES

APPENDIX A: PRESENTATION TO THE CLUB RUNNERS

The [redacted] club run is every Tuesday at 6 pm; the researcher had clearance from the club chairman to introduce a short presentation to the runners on the Tuesday the 28th of April. The presentation was used as an opportunity to share details of the proposed study and also explained what would be required of prospective participants (in terms of initial testing, training intervention and subsequent post-intervention testing commitments).

The researcher was available to answer any questions and also ensured that all prospective participants understood all relevant information and that the paperwork required for participation in the study was completed and signed as necessary.

APPENDIX B: LETTER TO POTENTIAL PARTICIPANTS

Nelson Mandela Metropolitan University
for tomorrow

PO Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth 6031
South Africa
www.nmmu.ac.za
April 2015

Dear [redacted] members

I'd like to prescribe a supra-maximal speed (over speed) interval training program over four weeks as part of a Master's study in endurance sport. I require a minimum of 30 female runners between the ages of 30-45, who have been absent from injury for at least 6 months, and are of at least a moderate fitness level and currently run at least three times a week totalling a minimum of 90 minutes.

The study would include a pre- and post- training intervention test. The testing will consist of warm up and cool down protocols, with a 40m timed sprint (standing start) followed by a short rest period (approx. 5-10 minutes) and then a 3000m all-out effort time trial run – performed on a flat asphalt loop at the base of Chapmans Peak drive in Hout Bay. The average speed for the above mentioned two tests will be used to construct an interval training program of four weeks in duration.

Of the total group, 15 runners will be randomly selected to participate in supra-maximal speed training on the AlterG® anti-gravity treadmill at The Velocity Sports Lab in Hout Bay for a period of four weeks (two x interval sessions a week – Monday and Thursday), whilst the other remaining runners will perform supra-maximal speed training on a suitable downhill stretch of road (Chapmans Peak drive; with the desired decline and distance required) for the same time period and interval sessions a week.

Both groups will be required to perform "recovery" runs on the Tuesday and Friday of each week and a medium distance run on a Saturday of each week. After four weeks of training, both groups will once again be required to perform a 40m standing start sprint test and a 3000m all-out time trial run for assessment purposes.

Proposed dates for time trial runs and the training block are as follows:

1st Assessment: 40m sprint and 3000m run test: Thursday, 30th of April 2015

Training Block from Monday the 4th of May – Friday the 29th of May 2015

2nd Assessment: 40m sprint and 3000m run test: Monday, 1st of June 2015

Times for testing can be arranged to suit the group's convenience. There will be time slots allocated for AlterG® groups which suit both parties (runner and Velocity Sports Lab), whilst the Chapmans Peak drive running group will consist of all 15 athletes' running in the early morning.

Runners who meet the participation criteria and are keen to take part can contact the researcher via email at: tim@velocitysportslab.co.za

Please note that you must be willing and able to drive to Velocity Sports Lab in Hout Bay on Mondays and Thursdays over the four week training period and be available for both test dates.

The first week of training will consist of sessions of 20 minutes in total and progress to a maximum of 30 minutes running for each session by the fourth week. Participants will be required to only run the five prescribed running sessions a week (two x interval, two x recovery and one medium distance) without any supplemental training.

Upon completion of the study, there will be two pairs of Merrell trail running shoes to the value of R1800 each as lucky draw prizes for participants who complete the study. Training at the Velocity Sports Lab will be for the account of the researcher.

Kind regards

Tim Ellerbeck

RESEARCHER

E-mail researcher: tim@velocitysportslab.co.za

Tel: +27 71 172 7911

APPENDIX C: INFORMED CONSENT

PO Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth 6031
South Africa
www.nmmu.ac.za
April 2015

Dear Participant,

The department of Human Movement Science in the Faculty of Health Sciences at the Nelson Mandela Metropolitan University will be conducting a study to measure certain physiological adaptations in participants who perform two distinctly different methods of supra-maximal speed training for running.

The study will be performed as part of the completion for a three year Masters course in Sports Science. The study has been given Ethical Approval by the Research and Ethics Committee of the Faculty of Health Sciences at the Nelson Mandela Metropolitan University (REC-H REF: H12-HEA-HMS-001)

You will need to report for two testing appointments spaced 30 days apart. Each testing appointment should take approximately 45min in total. During the testing appointment, participants will have their height and weight recorded, then after a standard five minute warm up participants will be required to do a 40m standing start sprint. After a five minute recovery, a 3000m timed trial run will be undertaken. In between each testing appointment, participants will be required to perform a four week interval training intervention. Interval sessions will take place on a Monday and Thursday each week for a total of four weeks. These sessions will vary from a total of 20 minutes (first week) to 30 minutes (fourth week). Additionally participants will be required to perform two recovery sessions on each Tuesday and Friday, totalling no more than 20 minutes as well as a medium distance run each Saturday, totalling no more than 40minutes.

The research project will include the following tests:

1. The initial testing date for all participants is scheduled for 7am on Thursday the 30th of April.
2. The participant will be taken through the testing routine and familiarised with all the equipment that is going to be used during the research process.
3. Anthropometric measurements involving measurements of body composition including weight and height will be taken.
4. The participant will be asked to do a warm-up of five minutes of running at a self-selected speed along the Hout Bay beach front.
5. The participant will be allowed a trial 40m standing start sprint.
6. Testing will take place. This involves a 40m standing start sprint and a 3000m timed trail run subsequent to a five minute rest period post 40m standing start sprint.

Participants will then be paired according to 3000m timed trial run results. One participant from each pair will be randomly selected to take part in either the AlterG® anti-gravity treadmill supra-maximal training or downhill supra-maximal running for the four week training intervention. The training intervention will begin on the 4th of May and conclude on the 29th of May and consist of the following regime:

Monday and Thursday – supra-maximal intervals

Tuesday and Friday – recovery runs

Saturday – medium distance run

Wednesday and Sunday – days off

Post intervention testing will take place on Monday the 1st of June 2015 and will follow the same format as the initial testing done on the 30th of April 2015.

All results of the assessments and outcomes of the research will be forwarded to you as soon as possible.

Potential Risks of participation:

Running tests

Running is associated with a minor risk of sustaining a musculoskeletal injury or falling. In this study, you will undergo a thorough familiarisation process. All due care will be taken to ensure that you are both familiar and confident with running on the testing track, and either the treadmill or downhill portion of road (depending on which training group you are randomly selected for).

You will also be excluded from the study on the basis of medical or surgical history, any musculoskeletal injury, and any medication use or viral infection within the 12 weeks preceding the study. You will be required to warm up before the running tests, and the warm-up will be monitored to reduce the risk of any musculoskeletal injury that may be associated with running.

Potential benefits:

You will not receive any financial compensation for participating in this study. On completion of the study, the summarised results and recommendations will be formally presented to you. On completion of the study, one participant from the downhill running group and one participant from the AlterG® anti-gravity treadmill running group who complete the study will win a pair of Merrell running shoes as a lucky draw prize.

Questions or Concerns:

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

Tim Ellerbeck (researcher) 071 172 7911 tim@velocitysportslab.co.za

Dr. M. Baard (research supervisor) 041 504 4518 maryna.baard@nmmu.ac.za

I confirm that the exact procedures and possible complications of the above tests have been explained to me. I understand that I may ask questions at any time during the testing procedures. I realise that I am free to withdraw from the study without prejudice at any time, should I choose to do so. I have been informed that the personal information required by the researchers will be held in strict confidentiality. In addition, I know that the information derived from the testing procedures will remain confidential and will be revealed only as a number in statistical analyses.

I have carefully read this form. I understand the nature, purpose and procedure of this study. I agree to participate in this research of the Department of Human Movement Science (with endorsement: Sport Science).

____________________ ____________________________

Signature of Volunteer Name (Please Print)

____

Date

____________________ ___________________________

Signature of Witness Name (Please Print)

____

Date

____________________ ___________________________

Signature of Investigator Name (Please Print)

____

Date

APPENDIX D: RUN TRAINING QUESTIONNAIRE

PO Box 77000
Nelson Mandela Metropolitan University
Port Elizabeth 6031
South Africa
www.nmmu.ac.za
April 2015

The Nelson Mandela Metropolitan University Sport Science Study

Instructions:

This questionnaire consists of two pages.

- Read each question carefully as it is important that we obtain accurate information.
- Answer all questions as truthfully as possible. The information gathered will be used in the study, but will remain strictly anonymous.
- Place information in the appropriate text box, for example; Date of Birth: 21/03/1983 Day/Month/Year
- If a question is asked, place an **'x'** in the appropriate text box, for example: Which province do you live in?

Western Province [ ] Free State [x] Kwa-Zulu Natal [ ]

If you have any questions do not hesitate to phone or e-mail any of the individuals below:

Tim Ellerbeck 071 172 7911 tim@velocitysportslab.co.za

Dr. Baard 041 504 4518 maryna.baard@nmmu.ac.za

Name: ______________________________Surname: _____________________

Age: _______________________________Date of Birth: ___/____/_____

Participant contact details: Tel #:_______________________________________

Electronic mail____

Section A: Health and injury history

1. Have you suffered from a lower limb injury in the past 6 months?

   ____

- If yes, what type of injury? (muscle strain, bone fracture, ligament damage or joint injury)

  ____

- Specify where the injury occurred? (left knee, right ankle, left knee cap, right hip joint)

  ____

- Have you received any form of rehabilitation (medical doctor, physiotherapy, chiropractor, biokineticist, sport scientist, personal trainer) program for this or any other injury in the last 6 months?

  ____

  ____

2. Have you been ill in the past 12 weeks? If so, what illness were you diagnosed with? (cold, flu, measles)
3. ____

   ____

- If yes, did you take any medication for the illness? What was it called?

  ____

  ____

4. Is there any medication that you take regularly to manage pain/injuries (paracetamol, anti-inflammatories)?

   □ yes □ no

- If yes, indicate the type of medication taken: ______________________

Section B: Training History

1. How many years have you been running for?

□ Less than 2 years
□ Less than 5 years
□ 5 – 10 years
□ More than 10 years

2. Do you have a training log that you could supply to us showing the type/distance of your training over the past 6 months?

□ Yes
□ No

3. How often do you run each week?

□1 □2 □3 □4 □5 □6 □7 □more

5. Provide a breakdown of workouts during the week (tempo, speed, distance, etc.)

Day	Tempo	Speed	Distance	Hill Repeats
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				
Saturday				
Sunday				

6. What period of training are you currently engaged in? (Pre-, mid-, post-event)?

____

7. What is your average weekly mileage in km's at present?

____

8. What is your average weekly mileage when not training for a specific event?

____

9. At what intensity do you do most of your training?

____

10. Do you have any further comments on your training?

____

11. Give an indication on current running times for the distances as indicated below.

Distance	Personal Best	Current Estimate
5km		
10km		

Participant signature: ______________________Date:_____________

APPENDIX E: DATA COLLECTION SHEET

Research #:

Age:

Height:

Weight:

BMI:

	Pre-Intervention Test	Post-Intervention Test
40m Standing Start Sprint		
3000m Timed Trial Run		

APPENDIX F: BORG SCALE (RATING OF PERCEIVED EXERTION)

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Table 1. The Borg Rating of Perceived Exertion Scale

[http://www.alpfitness.com/training-intensity-zones-for-targeted-training/]

APPENDIX G: ETHICS APPROVAL

Nelson Mandela Metropolitan University
for tomorrow

Copies to:
Supervisor: Dr M Baard
Co-Supervisor: Mr M Kramer

Summerstrand South
Faculty of Health Sciences
Tel. +27 (0)41 504 2956 Fax. +27 (0)41 504 9324
Marilyn.Afrikaner@nmmu.ac.za

Student number: 207056409

Contact person: Ms M Afrikaner

26 May 2015

MR TA ELLERBECK
15 BRIGHTON DRIVE
SUMMERSTRAND
PORT ELIZABETH
6001

RE: OUTCOME OF PROPOSAL SUBMISSION

FINAL RESEARCH/PROJECT PROPOSAL:
SUPRA-MAXIMAL SPEED INTERVAL TRAINING EFFECT ON 40M STANDING START SPRINT AND TIMED 3000M RUNNING PERFORMANCE IN MODERATELY TRAINED FEMALE RUNNERS: ALTERG® ANTI-GRAVITY TREADMILL AND DOWNHILL RUNNING
QUALIFICATION: MA (SPORT SCIENCE) COURSEWORK

Please be advised that your final research project was approved by the Faculty Postgraduate Studies Committee (FPGSC) subject to the following amendments/recommendations being made to the satisfaction of your Supervisors:

COMMENTS/RECOMMENDATIONS:

1. The proposal was well prepared.
2. Title of the study
   A. Consider changing "... standing start sprint ..." to "... standing - start sprint ..."
   B. Consider changing the title to:
      "THE EFFECT OF SUPRA-MAXIMAL SPEED INTERVAL TRAINING ON AN ALTERG® ANTI-GRAVITY TREADMILL AND A NORMAL WEIGHTED DOWNHILL INTERVAL TRAINING PROTOCOL ON A 40 METER STANDING, START, SPRINT AND A TIMED 3000 METER RUN IN MODERATELY TRAINED FEMALE RUNNERS
3. In terms of the above, change the proposal and annexures where needed.
4. First sentence of the Abstract: Change "or" to "and".
5. Point 4.1 Research design
   The candidate referred to quantitative and qualitative in the first sentence?
   Point 4.2 Participants and sampling
   Should they not be paired according to age as well since recovery is one of the objectives? No procedures to be piloted?
6. Item 10 (Budget)
   The budget for research literature (R 3,000.00) was high.

7. REC H Form
   1b) Complete with PRP the office address
   1K) Adapt commencement date of study
   2a) Adapt; there is a risk of harm (physical) and indicate remedial measures if they are injured while on the intervention. The risk of harm has been described in proposal.

Faculty Postgraduate Studies Committee (FPGSC) reference number: **H15-HEA-HMS-002.**

Please be informed that this is a summary of deliberations that you must discuss with your Supervisors and make the necessary amendments.

Please forward a final electronic copy of your appendices, proposal and REC-H form to the Faculty Postgraduate Studies Committee (FPGSC) secretariat.

We wish you well with the project.

Kind regards

Marilyn Afrikaner
FPGSC SECRETARIAT