The Effect of Supplementary Elliptical Training on Running Performance in Trained Runners

by

Anna Rebecca Malan

MLNANN015

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Division of Physiological Sciences

Faculty of Health Sciences

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Supervisor: Assoc. Prof Andrew Bosch, *PhD*

Declaration

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

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Abstract

Recent studies at the University of Cape Town found comparable physiological and metabolic responses between the elliptical trainer, stepper, and treadmill, and a decrease in muscular effort of lower extremity muscles when exercising at similar intensities on the elliptical trainer and stepper in comparison to treadmill running. It was therefore suggested that the elliptical trainer and stepper could be useful substitutes for running when periods of reduced running load are required, such as during rehabilitation from an injury, or as a means to increase running load without the risk for increased injury. It remains unknown whether the elliptical trainer can be used to improve running performance, and thereby maintain cardiovascular fitness, if added to a running training programme. Thus, the purpose of this study is to investigate whether supplementing existing running training with elliptical training enhances running performance in trained runners. The study was conducted at the Sport Science Institute of South Africa (SSISA). Thirteen trained runners were recruited (male/female: N=11/2, age: 32.8 ± 8.3) to complete PRE and POST assessments of peak treadmill running speed (PTRS), 8-km time trial, and body composition, with assessments of PTRS, 8-km time trial, RPE, and HRmax. Between PRE and POST assessments, participants took part in an 8-week intervention of either additional running, or the same additional training load on the elliptical trainer. Results indicate a significant difference between PRE and POST PTRS as runners increased their peak running speed following the training intervention by 0.4km/h [18.5 ± 1.5 and 18.9 ± 1.5 PRE and POST, respectively] for all participants combined. However, no difference was found between the elliptical training and running training groups. Eight-km time trial, RPE, and HRmax were unchanged. These findings support expectations that the elliptical trainer can be used as a useful modality to both increase running performance and maintain fitness levels when unable to run.

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Abbreviations

CHO	Carbohydrates
EMG	Electromyography
GXT	Graded exercise test
HR	Heart rate
HRmax	Maximum heart rate
%HRmax	Percentage of maximum heart rate
PTRS	Peak treadmill running speed
RMS	Root mean squared
SSISA	Sport Science Institute of South Africa
UCT	University of Cape Town
US	United States
$V_E$max	Maximum minute ventilation
VO_2	Oxygen uptake
VO_2max	Maximal oxygen consumption
VO_2peak	Peak oxygen consumption

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1. Introduction

1.1 Background to the Study

While there is anecdotal evidence from runners and running coaches that cross-training on an “elliptical trainer” or “stepper” may improve running performance, a recent study by Bosch et al. (2021) presented scientific data to substantiate that notion; they reported that the physiological and metabolic load on the elliptical trainer and stepper was similar to exercise on a treadmill when exercise is performed at the same heart rate (HR). Eken et al. (2020) established that training on the elliptical trainer and stepper reduced muscular workload of lower extremity muscles by up to 60%. Thus, there is evidence that these two training devices can be used to maintain physiological load whilst, simultaneously, reducing impact forces. The elliptical trainer and stepper may therefore be useful modalities to increase training load without risk of injury in runners.

The current study is a follow-on to the work of Bosch et al. (2021) and Eken et al. (2020) mentioned above. Although it is reported that the physiological and metabolic load is similar between the two modalities, it remains unknown whether exercise on the elliptical trainer and stepper can provide a suitable training stimulus to enhance running performance when added to a running training programme (Bosch et al., 2021). Therefore, the effect of supplementary elliptical training on running performance in trained runners will be investigated in this study.

1.2 Research Problem

The purpose of this study is to investigate the effect of supplementary elliptical training on running performance in trained runners.

1.3 Hypothesis

It is hypothesized that there will be similar changes in running performance in both the elliptical training and running training group as a result of increased weekly training load by additional training on either the elliptical trainer or increased running. Stated differently, it is expected that each group will improve their running performance during the intervention period, but that no group will improve significantly more than the other.

1.4 Aims

The study has two aims.

1. Determine whether training on the elliptical trainer enhances running performance, compared to equivalent increased running training.
2. Determine whether there is a difference in any improvement in running performance between the elliptical training group and running training group, that is, whether one group improves more than the other.

1.5 Objectives

To address the above aims, specific objectives of the study were the following:

1. Compare any changes in peak treadmill running speed (PTRS) of participants after the 8-week training intervention.
2. Compare any changes in the performance of participants in an 8-km time trial after the 8-week training intervention.
3. Compare any changes in the rating of perceived exertion (RPE) of participants after the 8-week training intervention during testing of the PTRS and 8-km time trial tests.
4. Compare any changes in maximum heart rate (HRmax) of participants after the 8-week training intervention during testing of the 8-km time trial.

1.6 Study Overview

The purpose of this study is to investigate whether supplementing an existing running training programme with elliptical training enhances running performance in trained runners. In this randomized controlled trial, 13 healthy trained runners were recruited to investigate the effect of an 8-week elliptical training intervention on running performance. The study was conducted at the Sport Science Institute of South Africa (SSISA). Data collection was over two visits by the participants at SSISA, followed by an 8-week training intervention, and subsequent post-intervention measurements to compare to baseline. The information collected was used to elucidate the relationship between additional training on the elliptical trainer and running performance.

1.7 Outline of Dissertation

This dissertation investigates the effect of supplementary elliptical training on running performance in trained runners. In the following chapter, a review of the literature is presented. A summary of the epidemiology of running and running injuries, a brief history of the elliptical trainer, and studies that have investigated the impact of exercise training on the elliptical trainer and stepper provides background information for the dissertation. This will be followed by the rationale for the study, presenting findings from two important research studies (Bosch et al., 2021; Eken et al., 2020) on the elliptical trainer and stepper upon which this study is based. The remaining chapters focus on the research design and methodology used in the study, a presentation of the results of the intervention and discussion thereof. The final chapter presents the conclusions and recommendations for future research.

2. Literature Review

There is limited research available on the topic of training on the elliptical trainer and/or stepper and the effect on running performance. There are two important research studies conducted at the University of Cape Town (UCT) (Bosch et al., 2021; Eken et al., 2020) upon which this study is based. Further available literature that is closely associated with the topic is also reviewed. The findings of the studies reviewed indicate that further research is necessary to assess the implications of exercise training on two cross-training devices, the elliptical trainer and stepper, on running performance.

Specifically, we wish to determine whether supplementary training on the elliptical trainer can improve running performance. A subsequent study will investigate training on the stepper. While improvement in performance, without associated risk of increased injury, is the prime focus of the proposed study, an associated goal is to determine whether the elliptical trainer is a useful alternative training modality for runners who want to increase training load without risk of a running injury. Should it be found that the addition of training on the elliptical trainer improves performance, then, by inference, it can be concluded that an injured runner who is unable to run, or who can only run a reduced training distance, will at least maintain running fitness by training on the elliptical trainer whilst injured (most running injuries are such that training is possible on the elliptical trainer).

With reference to the above, this literature review will provide a context for the proposed study, its position in the broader realm of research, and its practical implications in the sport of running, including injury management.

2.1 Epidemiology of Running and Running Injuries

Over the years, running participation has increased substantially (Novacheck, 1998). According to Novacheck (1998), in a review paper on the biomechanics of running, there has been a vast growth in running participation in the United States (US) since the late 1960s and early 1970s—at the time of writing, it was estimated that 30 million Americans run. According to Videbæk et al. (2015), 17 years later, in a systematic review of the incidence of running-related injuries, running participation in the US had increased to 40 million. It is also evident that 2.5 – 12.5% of Denmark's population run on a regular basis. This is confirmed by van der Worp et al. (2015), who conducted a systematic review of injuries in runners. They report that running has been popular since the 1970s but that there has been a persistent increase in runners and running events since the 2000s. Similarly, Doherty et al. (2020) found that running participation in long-distance running is steadily increasing—in 2016, there were more than 5000 marathons taking place, worldwide, attracting more than 1.8 million runners.

According to (Van Wyk, 2022), South Africa has an enduring, rich history with road running and ultra-distance running events. The Comrades Marathon, which has been hosted since 1921 in the KwaZulu-Natal province, hosts the highest number of participants for an ultramarathon globally. The popularity of running, and more recently trail running, has been steadily increasing in South Africa over the past decade, with a threefold increase in trail running events between 2011 – 2016 alone (Van Wyk, 2022).

Worldwide, running is one of the most popular and accessible activities (Videbæk et al., 2015). It is also one of the easiest ways to improve physical fitness and health. According to van der Worp et al. (2015), worldwide, running is the most popular and efficient physical activity to increase physical fitness. Anecdotally, it is often heard that it is more convenient, and more affordable, to put on a pair of running shoes and go for a run, than any other sports participation. Unique to running, and perhaps other team sports such as football or soccer (as it is known in South Africa), is that participation and excellence is not confined by the limitations of affordability.

The greatest barrier to continued running participation is musculoskeletal injury (Bertelsen et al., 2017). In a review article on the etiology of running injuries, Bertelsen et al. (2017) state that injuries occur when runners increase their participation to the point at which interaction with an existing risk factor becomes significant enough to cause injury. Unique to this article is that a framework was developed for how injuries occur in runners. This framework looked at both intrinsic and extrinsic factors, and the interaction between them—it considers running-related injury a multifactorial process. Importantly, they do state that the dose–response relationship between running participation and injury remains largely unknown. What is known is the incidence rate of running-related injuries. In their systematic review, Videbæk et al. (2015) found that 7.7 and 17.8 injuries occur per 1000 hr running in recreational and novice runners, respectively. Simply put, novice runners experience more injuries per number of hours run than runners who are more experienced. This was confirmed by van der Worp et al. (2015); they found a high incidence of running injuries in runners, ranging from 19% – 79%, of which 80% of injuries were overuse injuries.

With a high incidence rate of running-related injuries in a sport that is popular the world over, and with its participation continually increasing, additional means for enabling continued running participation have been developed over the years. One of these means became available after the emergence of the elliptical trainer and stepper machines. In the next section, a brief history of these two modalities will be presented.

2.2 History of Elliptical Trainers and Steppers

The elliptical trainer and stepper are upright, non-impact, weight-bearing exercise machines that train the aerobic energy systems of the body, similar to running (Joubert et al., 2011). They involve inter-limb coordination in a reciprocal motion that sees the feet travelling in a cyclical pattern during use, with a person's body weight supported by their lower body and their upper body by the handlebars for balance support (Mercer et al., 2001; Prosser et al., 2011). The elliptical trainer and stepper appeared on the market in the mid- to late 1990s as new exercise machines developed to simulate running kinematics (Mercer et al., 2001). See *Figure 1* for an example of the elliptical trainer and *Figure 2* of stepper machines, made by Life Fitness, Precor, and Matrix (Photos courtesy of their websites).

Figure 1 - Example of elliptical trainer machines made by Life Fitness, Precor, and Matrix

Figure 2 - Example of stepper machines made by Life Fitness, Precor, and Matrix

Elliptical trainer and stepper machines have become popular exercise modalities and are now commonly found in health and fitness facilities (Mays et al., 2010). Their advantage, in addition to simulating running motion, is that less strain is placed on the body due to decreased ground reaction force (Joubert et al., 2011; Mercer et al., 2001). According to Mays et al. (2010), the elliptical trainer and stepper place less than half of the ground reaction force on the body compared to treadmill running. This was confirmed by Joubert et al. (2011), who stated that the impact force of the elliptical trainer and stepper force is the same as walking, and half that of running. Likewise, in the recent study by Eken et al. (2020), it was determined that muscular activation of the lower extremities, as measured by electromyography (EMG) analysis, is reduced by up to 60% on the elliptical trainer and stepper compared to treadmill running, with the exception of the quadriceps. The quadriceps (vastus medialis and rectus femoris) showed similar values of muscular effort between the three different modalities, ranging from 85% to 110% effort. Mays et al. (2010) conclude by suggesting that the elliptical trainer and stepper can safely be used as alternatives to the treadmill and are therefore appropriate for both clinical and health/fitness settings.

The elliptical trainer and stepper are used by runners to augment or replace their running training with aerobic cross-training, to increase their total training volume or maintain fitness levels during rehabilitation from an injury (Eken et al., 2020). Besides the anecdotal and evidential benefits of the elliptical trainer and stepper, there is a scarcity of research investigating the impact of these modalities as part of a training programme (Joubert et al., 2011).

2.3 Exercise Training on Elliptical Trainers and Steppers

Only a few studies have investigated the impact of exercise training on the elliptical trainer and stepper—very few have looked at the impact of training on running performance. One example of such a study is that of Egaña & Donne (2004)—they measured the physiological changes following a 12-week gym-based stair climbing (terminology as used in the source literature—where the stair climber is similar to the term 'stepper', as we generally use in our study), elliptical trainer, and treadmill running programme in females. The aim of the study was to compare the physiological and metabolic improvements following a (heart rate) HR-controlled aerobic training programme using the three modalities. Twenty-four young to middle-aged moderately trained women participated in the study. Inclusion in the study required a maximal oxygen consumption (VO_2max) of between 30 and 45 ml/kg/min (considered moderately active). Participants were randomly assigned to three groups and exposed to a 12-week, moderate/high intensity stair climber, elliptical trainer, or treadmill running protocol, to investigate the effect on physiological and metabolic variables and training intensity, based on a graded exercise test (GXT) on a cycle ergometer. Participants performed three supervised exercise sessions weekly: initially for 4 weeks at 70-75% maximum heart rate (HRmax) for 30 min, progressing to 75-80% HRmax for 40 min for a further 4 weeks, then progressing to 80-90% HRmax for 40 min for the final 4 weeks. The main findings of the study, in these very modestly trained participants, were that similar physiological (VO_2max and maximum minute ventilation) and body composition benefits were observed between the stair climber and elliptical trainer, in comparison to treadmill running, when the training volume, frequency and intensity were similar. It was also found that the stair climber and elliptical trainer had a similar training stimulus to treadmill running as VO_2max improvements observed were similar. Notably, the improvements in VO_2max observed were 4.4 ± 1.3% for stair climbing, 6.8 ± 2.8% for the elliptical trainer, and 5.7 ± 1.8% for treadmill running (Egaña & Donne, 2004).

Limitations of their study were that the training intensity for the intervention was derived from a cycle ergometer GXT as opposed to a treadmill GXT. This could have impacted the results and may have limited the overall study findings by causing a measurement bias. Interestingly, it was mentioned that future studies on the elliptical trainer and stepper should utilize ergometer-specific maximal exercise tests for pre- and post-tests to limit any possible bias (Egaña & Donne, 2004). The practical implication of the findings, however, is that the stair climber and elliptical trainer provide sufficient training stimulus compared to treadmill running to develop cardiovascular fitness in females, at least among the participants in this particular study, who, as stated, were not well trained.

In an earlier study, Loy et al. (1993) investigated the effects of stair climbing versus run training on a treadmill and track running performance. The aim of their study was to compare the effects of stair climbing versus run training of similar exercise intensity on physiological parameters, during sub-maximal and maximal treadmill running, and to compare running performance on an outdoor track. Twenty-three active university-going women participated in this study. Participants were randomly assigned to a stair climbing or run training group after completion of baseline assessments, VO_2max evaluation, a sub-maximal treadmill running test, a body composition assessment, and a 2.4-km time trial outdoor track assessment. This was followed by 9-weeks of training at moderate/high intensity, initially for 30 min at 70-80% HRmax then progressing to 45 min at 85-90% HRmax for 4 days per week, and subsequent post-intervention testing. The main findings of the study were that, with increased training, both groups significantly increased their VO_2max and improved their run times—no significant difference in VO_2max, time trial performance or body composition between groups was found.

There was, however, a limitation to this study, specifically, a difference in the control of ambient conditions between groups: the run training group completed training outdoors on a track, whereas the stair climbing group completed training indoors in laboratory-controlled conditions. This may have impacted on the HR response and training intensity of the run training group. The authors suggested that further investigations should control for ambient conditions if relying on the percentage of maximum heart rate (%HRmax) for training intensity (Loy et al., 1993). Nonetheless, the practical implication of the study is that stair climbing can be used as a viable alternative to running training, with similar treadmill and field running performance results (Loy et al., 1993).

In a more recent study, Joubert et al. (2011) examined the effects of elliptical cross-training on VO_2max in recently trained runners. Recently trained runners, referring to runners who started running shortly before the intervention, underwent their initial training at the beginning of the study, which was then followed by the intervention period. The aim of the study was to determine the effectiveness of an elliptical trainer exercise program on the maintenance of cardiorespiratory fitness. Twenty university-going men and women participated in this study. The study comprised the initial 4 weeks of moderate/high intensity running training for all participants, whereby participants ran on a treadmill, 4 days per week for 30 min at 80% HRmax. This was done to eliminate the expected increase in VO_2max with increased training, regardless of the modality. Participants were then randomly allocated into one of three groups: a run training group, an elliptical trainer group, and a detraining group (the latter participants volunteered to be a part of the detraining group), which also served as the control group. The running training and elliptical trainer groups then participated in a further 3 weeks of moderate/high intensity training at the same exercise prescription, 4 days per week for 30 min at 80% HRmax, and the detraining group participated in no exercise. Results of the study revealed no significant differences between groups following the 3-week phase of ergometer-specific training, although the detraining group's VO_2max decreased more and revealed an inclination towards significance, as would be expected with no exercise. In addition, all runners increased their VO_2max in the initial 4 weeks of running training. The main finding of the study was that the elliptical trainer is a viable cross-training option for recently trained runners to maintain their VO_2max in the short term (Joubert et al., 2011).

A limitation of the above study was time constraints (due to an inability to recruit students for longer periods due to the university holidays), which restricted the length of the second training phase. Nonetheless, the findings of the study added valuable insight into how the elliptical trainer can sustain or improve VO_2max in recently trained runners (Joubert et al., 2011). The value that elliptical training offers to runners to maintain or improve cardiovascular fitness, due to its simulation of running kinematics, as opposed to cycling, was also recognized. Joubert et al. (2011) suggest that further studies are required to measure the impact of elliptical trainers on “more measures than just VO_2max, but also need to look at other performance variables such as lactate threshold, running economy, and peak treadmill running velocity."

From the studies cited above, it is apparent that the elliptical trainer and stepper offer viable cross-training alternatives to maintain, and possibly improve, cardiovascular fitness (VO_2max) in runners. Cross-training, defined as the participation in an alternative training mode to the one normally used (Mujika & Padilla, 2000), is used by athletes for a number of reasons, but, specifically, to derive a physiological and performance benefit similar to, or better than exclusive sport-specific training (Loy et al., 1995). To understand the potential impact of elliptical trainers and steppers on running performance, it is important to understand the factors that determine running performance.

In a study in the 1990s, Noakes et al. (1990) looked at the physiological variables that predict running performance at distances of 10-90 km among a large group of trained runners who specialized in marathon or ultra-marathon distances. The physiological variables assessed were VO_2max (for many years believed to be the best predictor of performance), peak treadmill running velocity, running economy, and running velocity at the blood lactate turnpoint. The ventilatory threshold, although not documented in this study, is also believed to be an important predictor of performance (Hoffmann et al., 1993). The main findings of the study were that peak treadmill running velocity is the best laboratory-based predictor of running performance, while VO_2max is the poorest (among a group of runners who were fairly homogenous in terms of running performance). The best field-based predictor was found to be running times in other, shorter races. Another important finding of the study was that the physiological variables that determine success at distances of 10-90 km are not different. This implies that the fastest 10-km runners will also be the fastest marathon and ultra-marathon runners, provided that they have done the required training for an ultra-marathon, such as high weekly training distance, training runs over long distance, etc. To the best of our knowledge, no studies other than that of Loy et al. (1993), which explored the effect of the stair climbing protocol on track running performance, have investigated the impact of the use of the elliptical trainer and stepper on running performance. Considering that a key motivation for cross-training is to derive a physiological and performance benefit (Loy et al., 1995), together with the knowledge established by Noakes et al. (1990) of the importance of peak treadmill running velocity and running time in other races on running performance, it then remains to be investigated whether use of the elliptical trainer and stepper can result in improvements in these variables, as a means to improve running performance.

2.4 Two Important Research Studies

The study of Eken et al. (2020) compared the lower extremity muscular effort between the treadmill, stepper and elliptical trainer while exercising at a number of sub-maximal workloads. Seventeen moderately trained to well-trained runners, aged 18-29 years, participated in the study. Entry into the study required the ability to run 10 km in under 60 min, a training load of at least 2 hr of aerobic exercise weekly and familiarity with training on the treadmill, stepper, and elliptical trainer. Muscular effort was derived from the root mean squared (RMS) value, based on EMG analysis of lower extremity muscles. RMS was analysed at 60%, 70% and 80% of peak workload on the treadmill, stepper, and elliptical trainer—it was determined following peak workload tests on separate days on all three modalities. The main finding of the study was the significant reduction in muscular effort of the lower extremity muscles while exercising on the stepper and elliptical trainer compared to treadmill running. Similar reductions were found for all sub-maximal intensities. RMS values of the lower extremities decreased by up to 60%, except for the quadriceps. Similar RMS values were found for exercise on both the stepper and elliptical trainer (Eken et al., 2020). These findings support the use of the stepper and elliptical trainer for rehabilitation (reduced muscle activity) because muscular effort and impact on the lower extremities is reduced. Furthermore, indications are that the stepper and elliptical trainer could potentially be used to add additional training load to a running programme, with no significant increase in injury risk.

Whereas the study of Eken et al. (2020) concentrated on EMG activity (described above), the study of Bosch et al. (2021) compared the physiological and metabolic responses to exercise on the three exercise modalities under consideration (treadmill, elliptical trainer, and stepper). Physiological and metabolic responses were compared between the three modalities while exercising at 60%, 70% and 80% of peak workload on each modality. Specifically, maximal, and sub-maximal oxygen consumption tests were conducted on all three modalities. Associated HR data and peak workload were also recorded. The relationship between workloads was assessed, and any difference between results of males and females noted. The study utilized 18 trained runners of similar age in a cross-sectional study design. Entry into the study required the ability to run 10 km in under 60 min, familiarity with exercise on the treadmill, the elliptical trainer and the stepper, and regular use of all three modalities in the subjects' training routines. The main finding of the study was that the oxygen uptake (VO_2)/HR relationship remained the same while exercising on the treadmill, elliptical trainer, and stepper at sub-maximal workloads of 60%, 70% and 80%, and there was no difference in VO_2max between the three modalities, with a similar response between males and females. In other words, if the VO_2 was "x" on the treadmill with a corresponding HR of "y", at a VO_2 of "x" on the elliptical trainer and stepper, the corresponding HR was also "y". Given that there were no differences in VO_2max, this means that physiological work intensities across modalities can be set based on HR, which would then yield similar VO_2 values and %HRmax between the three different modalities. This indicates that training on the elliptical trainer and/or stepper could be set based on HR—and match the physiological response of running. There was also no difference in energy expenditure between the three modalities: carbohydrate (CHO) and fat oxidation were similar.

The practical implications of the study are that a runner can exercise on an elliptical trainer or stepper at the same HR as they would when running, with knowledge that their physiological (VO_2 and HR) and metabolic (CHO and fat oxidation) loads will be similar between the three modalities. This suggests that runners can potentially use the elliptical trainer or stepper as a cross-training alternative to maintain their fitness levels when they are unable to run due to a running injury, but at a reduced impact on the lower extremities (Bosch et al., 2021; Eken et al., 2020). This also provides a way to potentially increase training load of a runner without increased risk of injury, perhaps enhancing running performance.

The above lays the foundation for the elliptical trainer or stepper, or both, to potentially be used to enhance running performance. Although, it is important to note that Bosch et al. (2021) advise that while the elliptical trainer and stepper generate similar physiological and metabolic responses to running, it does not mean that they will produce a similar training stimulus to running since the impact on leg muscles is reduced (referring to the study of Eken et al. (2020)).

Thus, the question is whether the (lower) impact of training on the muscles when exercising on the elliptical trainer or stepper would be sufficient stimulus to potentially result in an improvement in running performance when added as additional training to an existing training programme, as would additional running. If it does, the advantage would be that the training load of a runner can be increased without the additional impact that comes with additional running training, but perhaps with an equivalent performance improvement. The only way to determine this is by studying the effect of additional training on the elliptical trainer and stepper on running performance, as per the aims of the current study on the elliptical trainer. As recently stated by Bosch et al. (2021): “future research is recommended to evaluate the effect on running performance.”

3. Research Design and Methodology

3.1 Introduction

The hypothesis of the study, as presented in section 1.3, is that there will be an equal improvement in running performance in both groups (the elliptical trainer and running training group) as a result of increased weekly training load. It is expected that each group will improve their running performance but that neither group will improve significantly more than the other. The hypothesis was derived based on knowledge of the similarity in physiological and metabolic responses between the elliptical trainer and treadmill (Bosch et al., 2021), and the findings of three previous studies that there were equal improvements in the elliptical trainer, stair climber and running groups (Egaña & Donne, 2004; Joubert et al., 2011; Loy et al., 1993). To ascertain the effect of the elliptical trainer on running performance, the effect on peak treadmill running velocity and performance in a running time trial test, based on the findings of Noakes et al. (1990) was determined. As suggested by Noakes et al. (1990), "peak treadmill running velocity must, in future, always be reported in similar studies or in studies in which the effects of training on physiological variables are reported."

This chapter provides an overview of the participants used in the present study and how they were recruited, the study design, a detailed presentation of the testing procedures and intervention followed, an explanation of how the sample size was estimated, and the ethical considerations of the study. This will be followed by an explanation of how data were collected and analysed, and any shortcomings and sources of error that were encountered.

3.2 Methodology

3.2.1 Participant Recruitment

Participants were recruited via local running clubs and via social media pages of local running groups. Posters marketing the research study were placed at appropriate locations. Participants were included in the study if they were between the ages of 18 and 50, trained at least 60 km weekly, and were able to run 10 km in under 50 min. Participants were excluded from the study if they presented with an injury in the past

3 months. If participants were unfamiliar with exercise on the treadmill, they were given time to familiarize themselves with treadmill running prior to testing.

The decision to include faster runners in this study, compared to those in the studies of Bosch et al. (2021) and Eken et al. (2020), was made to acquire runners of higher aerobic fitness to better assess the effect of the intervention on running performance. By implication, one would expect to find a larger increase in aerobic fitness and subsequently performance in runners with a lower aerobic fitness level than in those who are fitter, due to their higher training load and level of performance. Furthermore, as noted by Loy et al. (1995) on the benefits and practical use of cross-training in sports, there is a need for studies to assess the impact of cross-training in well-conditioned elite athletes, to determine its efficacy for increasing, or maintaining, VO_2max and performance. Although the participants in this study were not well-conditioned elite athletes, but competent runners, the same principle regarding the evaluation of athletes with a higher fitness level to assess the impact of cross-training on sports performance, applies.

Seventeen trained runners met the inclusion criteria and were recruited for the study. All benefits and risks were explained to the participants. The participants were informed that participation in the study was voluntary, and that they were allowed to leave the study at any stage at their own discretion.

3.2.2 Sample size estimation

Sample size calculations were carried out according to Hopkins et al. (2009) based on the following: effect size 0.5, power 80%, alpha level 0.05. Results indicated that 16 participants were required. To make provision for possible dropouts during the study, we attempted to recruit more participants than required. Once recruitment was complete, we had 17 participants who met the inclusion criteria (13 male, 4 female) for the study, which were distributed between the two groups.

3.2.3 Study Design

In this empirical study, an 8-week, randomized controlled trial was utilized to assess the effect of supplementary elliptical training on running performance in trained runners. The participants were asked to visit SSISA on two occasions: first, for baseline testing to assess body composition, for testing of running performance with PTRS test, as utilized in Siegl et al. (2017), and an 8-km time trial test. Following testing, participants were randomly assigned via a simple randomization technique, initially by alternating the allocation of participants between two groups: (1) an elliptical training group and (2) a running training group, serving as the control group. It was later found that we were short of participants in the running training group due to the drop-out participants, therefore, the remaining participants were allocated to the running training group. Participants were then asked to add additional training on the selected exercise modality, as prescribed, based on their intervention group, to supplement their current running regimens. This was determined as a percentage time of their current training; thus, each group was exposed to the same additional training load. Following the intervention, participants visited SSISA on a second occasion, to retest PTRS and the 8-km time trial to determine the effect of the intervention on running performance.

3.2.4 Testing

3.2.4.1 Testing Procedures

All tests were performed at SSISA under stable environmental conditions (17 °C and 60% humidity). During the *first visit*, the participant information sheet (Appendix 1) and informed consent (Appendix 2) were completed, and participants filled in the physical activity readiness questionnaire (Appendix 3). The latter was used to determine a participant's readiness and safety for participation in exercise testing. A standard research unit questionnaire (Appendix 5) was used to gather a participant's information concerning personal details, running training, and running experience. Participants then completed three assessments: firstly, a body composition assessment; secondly, the PTRS test; thirdly, the 8-km time trial test.

3.2.4.2 Body Composition Assessment

Height and weight were recorded, using a Seca Stadiometer and Floor Scale (Seca; Hamburg, Germany), respectively, and body fat percentage was determined using the sum of seven skinfolds (biceps, triceps, subscapular, supra-iliac, calf, thigh and abdomen) (Ross & Marfell-Jones, 1991) using calipers (Harpenden; Baty International, Sussex, United Kingdom) and the Durnin & Womersley (1974) to calculate percentage fat.

3.2.4.3 Peak Treadmill Running Speed Test

Participants completed a PTRS test, in accordance with the protocol as described by Siegl et al. (2017), on a motorized treadmill. Prior to the test, participants were fitted with a HR monitor (specifically, prior to completing a 5-min self-paced warm-up), followed by any stretching or other procedures that they would normally do before a hard run. The PTRS test was initiated at a speed 1 km/hr slower than the standard training speed of the runner and was increased by 0.5 km/hr after the first minute. Thereafter, running speed was increased by 0.5 km/hr every 30 sec. This continued until volitional fatigue was reached and the runner stopped the test. Participants were encouraged to perform to their maximum effort during the test (Eken et al., 2020). HR was recorded, with HRmax determined as the highest 2 sec HR measured in accordance with the protocol utilized by Bosch et al. (2021). On completion of the PTRS test, all participants were asked their RPE on a modified Borg RPE 0 - 10 scale (Borg, 1962). Maximum workload was recorded as the PTRS attained for the treadmill test. Participants were then given 10 min to rest before commencement of the 8-km time trial test. Although they thus commenced the time trial in a slightly fatigued condition from the PTRS, this was done to make any differences in time trial performance as a result of the training intervention, more pronounced.

3.2.4.4 Eight-km Time Trial Test

Participants completed an 8-km time trial on the treadmill in the same way as they would on the road. When they wanted to speed up or slow down they could do so by using a remote-control switch that they held in their hand, or on the treadmill console. The remote-control switch was a standard garage door device that had been modified to control treadmill speed. As with a time trial on the road, where the runner is aware of distance and speed, this information was provided. However, the final time achieved was withheld so as not to influence the outcome of the test. Participants were encouraged to perform to their maximum effort during the test. On completion of the test, time to complete the 8-km distance was recorded, HRmax was determined as the highest 2 sec HR measured, and participants' RPE was recorded. *Figure 3* shows an example of the testing of participants. (The images are used with permission of the participants.)

Figure 3 – Participants during testing of the PTRS and 8-km time trial tests

3.2.5 Intervention

Following completion of the baseline assessments during the *first visit*, participants were asked to fill in an Excel spreadsheet (see Appendix 6.2) of their running training over the past 8 weeks. The excel spreadsheet was used to confirm sufficient running mileage for inclusion in the study, and to prescribe the additional exercise training for the 8-week intervention, depending on the group to which they were assigned, to supplement their normal running training. Participants were randomly divided into two groups: the elliptical training group and the running training group.

3.2.5.1 Elliptical Training Group

The elliptical training group was required to continue their normal running training, but to supplement it with two additional exercise sessions per week of elliptical training for 8 weeks. These supplementary sessions were done either at SSISA or at the participant's exercise facility of choice. The first exercise session was completed in the presence of the researcher, but subsequent exercise sessions were done by the participants individually. The exercise intensity for the elliptical training sessions was based on the individual participant's average running training pace. This was done by setting the resistance on the elliptical trainer to the same corresponding running speed. The resistance set was determined based on the Bosch and Lamberts comparative intensity chart, as utilized by Bosch et al. (2021). *Table 1* shows the Bosch and Lamberts comparative intensity chart for the Technogym treadmill, elliptical trainer, and stepper (Bosch et al., 2021))— stepper data is not included. The comparative intensity chart would ensure that the prescribed exercise dose was the same for all participants. Thus, all supplemented training loads, whether on the elliptical trainer or running training, were equivalent.

The duration of the exercise sessions on the elliptical trainers commenced with 10-min sessions twice a week, in week one, which progressively increased by 5 min each week until week seven, at which time exercise sessions were 40 min. Participants then completed their final week of training, week eight, with 40 min on the elliptical trainers, twice a week. See *Table 2* for a summary of the progression of the duration of elliptical trainer exercise sessions for the 8-week intervention and Appendix 6.1 for the elliptical trainer group programme that the participants received. Participants were required to hold onto the static handlebars during exercise sessions and were encouraged to "run" on the elliptical trainers as they would normally run on the road. See *Figure 4* for an example of two participants running on the elliptical trainer. (The images are used with permission of the participants.)

Monitoring of the exercise training sessions was done via self-report by participants on an exercise training log, and weekly correspondence between participants and the researcher via mobile phone and email.

Table 1: Bosch and Lamberts Comparative Intensity Chart for the Technogym treadmill, elliptical trainer and stepper

Treadmill (km/hr)	Elliptical (level)
6	5
7	6
8	8
9	9
10	10
11	12
12	13
13	15
14	16
15	17
16	19
17	20
18	22
19	23
20	24

Table 2: Elliptical trainer weekly exercise progression for the elliptical training group

Week	Exercise Session 1	Exercise Session 2
Week 1	10 min	10 min
Week 2	15 min	15 min
Week 3	20 min	20 min
Week 4	25 min	25 min
Week 5	30 min	30 min
Week 6	35 min	35 min
Week 7	40 min	40 min
Week 8	40 min	40 min

Figure 4 – Participants of the elliptical training group exercising on the elliptical trainer

3.2.5.2 Running Training Group

For the running training group, the prescribed exercise dose of running training for the 8-week intervention was determined using the running training history of the previous eight weeks of each participant. To correctly compare the effects of elliptical training versus running training after the 8-week intervention, the running training group load increase matched that of the elliptical training group, i.e., the running training group added the same load as the elliptical training group.

The exercise intensity for the supplementary running training sessions was based on the average running pace of the participant, and to match the increase in training time of the elliptical training group. Thus, since the elliptical training initially had 20 mins of elliptical training added to their running programme in total in the first week, a runner who trained at 5 mins/km would have 20mins / 5mins/km = 4km of training added to their programme. The training was designed so that the training schedule of participants of the running training group continued with their normal running training i.e., if they normally included an interval session in their programme, this was maintained, it was not changed. The participants' other running training sessions were also maintained, whether speed training, interval training or hill training. The increased weekly distance was written into the schedule in the most appropriate way for each participant, based on standard training principles, by the principal investigator, who is an Olympic level coach. All additional kilometres that were added to the participant's running training for the week were run at the average running pace of the participant. By training at the participant's average running pace, it could be ensured that the supplementary running training sessions were the same as the supplementary elliptical training sessions in terms of added durational load. Upon completion of the 8-week training intervention, the running training group had increased their weekly distance by approximately 20km. All additional running training was done on the road.

After the completion of the 8-week intervention, during the *second visit* for post-intervention assessments, the PTRS test and 8-km time trial were reassessed, and results were compared to baseline measurements. This was done to elucidate the relationship between supplementary training on the elliptical trainer versus additional running training distance on running performance.

3.2.6 Ethical Considerations and Data Collection

The study was conducted in accordance with the principles of the Declaration of Helsinki (2013, Fortaleza, Brazil), the International Conference on Harmonization (June, 1996), the South African Good Clinical Practice (GCP) guidelines (Third Edition, 2020) and the laws of South Africa. All consent was obtained by the researcher during a participant's first visit, before baseline assessments commenced. Data were collected by the researcher at two time points: (1) baseline, at the start of the intervention, and (2) post-intervention, once the 8-week intervention was complete.

3.3 Statistical Analysis

Participant demographics are summarised as descriptive statistics, and performance during the PRE and POST assessments are summarised as performance parameters. Normality of data was assessed using the Shapiro–Wilk test for normality, and, if normally distributed, expressed as the mean ± standard deviations. If not normally distributed, data were expressed as the median and interquartile range. A mixed ANOVA with repeated measures statistical test was used to compare change in PTRS, 8-km time trial, RPE, and HRmax in the two groups at PRE and POST and to determine if this changes differently in the elliptical training and running training groups. This was selected due to the need for an assessment of the impact of the intervention on running performance, and if whether there is an interaction between the intervention and mode of exercise on running performance. All data were analyzed using IBM SPSS Statistical Software (Chicago, Illinois, USA), version 28.0.1.1. All figures were completed using GraphPad Prism, version 8.0.0 for Windows, GraphPad Software (San Diego, California, USA). Significance was accepted at $p<0.05$.

3.4 Shortcomings and Sources of Error

Shortcomings noted during the study included the absence of supervised exercise training sessions during the 8-week intervention which could have impacted the adherence to the study protocol. Due to time constraints of the researcher, exercise training sessions during the 8-week intervention were not supervised. Although this did not impact the adherence to exercise training sessions in the elliptical training group, this may have impacted adherence in the running training group where there was a dropout of four participants. By using supervised exercise training sessions, adherence could be better controlled with the added benefit of a higher perception of external reward through weekly face-to-face visits with the researchers. Some participants were also from outlying areas, where transport and safety during running training were a concern. For participants in the running training group, one participant found it difficult to increase his running training in the week as his running training needed to be done in a group for safety reasons. By having supervised running training sessions, participants could safely increase their running training which would subsequently increase adherence to the study protocol. The study design also required weekly communication and engagement with participants over email and cell phone for the researchers to get feedback on the training completed during the week. This presented a problem for some participants who did not have frequent access to emails or to a laptop computer or did not always have airtime or data available on their mobile phones. There was also a variation in the socio-economical position of participants. For example, some participants had running training (GPS) watches, others did not. This negatively influenced traceability of some exercise sessions while gathering running training history in the study.

4. Results and Discussion

4.1 Results

4.1.1 Descriptive Statistics

Of the 17 runners included in the study, four were not able to complete the study (travelling commitments, communication difficulties and alternative training commitments) and were excluded. Thus, 11 male participants and two female participants completed all testing and intervention requirements (the two remaining female participants were part of the elliptical training group, and, although no female participants remained in the running training group, this did not negatively impact the results). The descriptive statistics of participants is shown in *Table 3* according to the elliptical training and running training groups, and all participants combined. Shapiro-Wilk tests for normality revealed that all data were normally distributed ($p > 0.05$); data are presented as mean ± SD. There were no significant differences between groups ($p > 0.05$).

Table 3: Descriptive Statistics of the Participants

Parameter	Elliptical training (n = 8)	Running training (n = 5)	All participants (n = 13)
Age (years)	33.0 ± 9.4	32.4 ± 7.3	32.8 ± 8.3
Height (cm)	165.4 ± 6.5	171.2 ± 2.8	167.7 ± 6.0
Weight (kg)	61.3 ± 10.5	65.1 ± 8.1	62.7 ± 9.5
Body fat percentage (%)	18.3 ± 5.7	14.4 ± 6.3	16.8 ± 6.0

Note: Values are expressed at mean ± SD. BMI = body mass index

The characteristics of the sample indicate an equitable representation of results, with exception of the smaller sample size of the running training group compared to the elliptical training group due to the dropout of the four participants mentioned above.

4.1.2 Performance Parameters

A summary of the performance characteristics of participants is shown separately in *Table 4* for the elliptical training and running training groups. A comparison between the variables for PRE and POST assessments is provided. Shapiro-Wilk tests for normality revealed that all data were normally distributed ($p > 0.05$), except for RPE for the running training group. Data that is normally distributed is presented as mean

± SD, and data that is not normally distributed is presented as median and interquartile range. There were no significant differences between groups ($p > 0.05$).

Table 4: Performance parameters (PRE and POST intervention) of the participants

	PRE			POST		
Parameter	**Elliptical training (n = 8)**	**Running training (n = 5)**	**All participants (n =13)**	**Elliptical training (n = 8)**	**Running training (n = 5)**	**All participants (n =13)**
PTRS						
PTRS (km/hr)	18.6 ± 1.5	18.4 ± 1.5	18.5 ± 1.5	18.8 ± 1.6	19.0 ± 1.3	18.9 ± 1.5
RPE at max	7.3 ± 1.8	9.0 ± 3.0*	7.5 ± 1.7	7.1 ± 2.4	8.4 ± 1.1	7.6 ± 2.0
8-km time trial						
Time (min)	34.1 ± 3.0	34.7 ± 3.4	34.3 ± 3.1	33.5 ± 2.6	34.4 ± 4.1	33.9 ± 3.1
HRmax (bpm)	185.5 ± 9.1	187.4 ± 9.8	186.2 ± 9.0	181.8 ± 8.5	186.2 ± 4.9	183.5 ± 7.5
RPE at max	8.8 ± 0.9	8.8 ± 1.3	8.8 ± 1.0	8.9 ± 1.0	9.0 ± 1.2	8.9 ± 1.0

Note: Values are expressed as mean ± SD. PTRS = peak treadmill running speed; HRmax = maximum heart rate; bpm = beats per minute; RPE at maximum = rating of perceived exertion at maximum; * = non-parametric distribution of data $p<0.05$), represented as median and interquartile range

Adherence to training sessions was 100% for the running training group (any running training sessions that were missed were adjusted to the training of subsequent training sessions). Adherence to the training sessions for the elliptical group was 99.21%, with one participant missing one of the 16 elliptical training sessions during the 8-week intervention.

A mixed ANOVA with repeated measures was used to compare the change in means of PTRS, 8-km time trial, RPE (PTRS and 8-km time trial tests), and HRmax (8-km time trial test), and in the two groups at PRE and POST assessments, and to determine if this changed differently in the elliptical training and running training groups. Therefore, the means of the PRE test PTRS, 8-km time trial, RPE (PTRS and 8-km time trial tests), and HRmax (8-km time trial test) were compared to the means of the POST test PTRS, 8-km time trial, RPE (PTRS and 8-km time trial tests), and HRmax (8-km time trial test), and were used as the within-group factor. Mode of exercise, which was the elliptical training compared to running training groups, was the between-group factor.

When comparing the change in PTRS, 8-km time trial, RPE, and HRmax between the PRE and POST assessments for all participants combined, a significant increase in PTRS of 0.4km/h [18.5 ± 1.5 and 18.9 ± 1.5, respectively] was found. The 8-km time trial revealed a trend towards small improvement in run times of 0.4 minutes, or 30 seconds [34.3 ± 3.1 and 33.9 ± 3.1], but this was not significant. RPE for the PTRS showed a slight increase of 0.1 units [7.4 ± 1.7 and 7.6 ± 2.0], and for the 8km time trial, likewise, an increase of 0.2 units [8.8 ± 1.0 and 8.9 ± 1.0], although both not significant. Lastly, HRmax decreased by 2.8 bpm [186.2 ± 9.0 and 183.5 ± 7.5] but was not significant. The 8-km time trial, RPE and HRmax remained relatively unchanged, although PTRS improved. No significant difference was found between the elliptical training and running training groups for all variables, PTRS, 8-km time trial, RPE and HRmax.

[Within-Subject Effects]

PTRS

There was a significant difference ($p = 0.007$) in PTRS between the PRE and POST assessments of 0.4km/h [18.5 ± 1.5 and 18.9 ± 1.5] for all participants combined. There was no significant difference found between the elliptical training and running training groups ($p=0.197$) when looking at the time * group interaction effect on PTRS. *Figure 5* shows a similar increase in PTRS—both groups showed a similar trend in improvement in running performance, which is statistically significant.

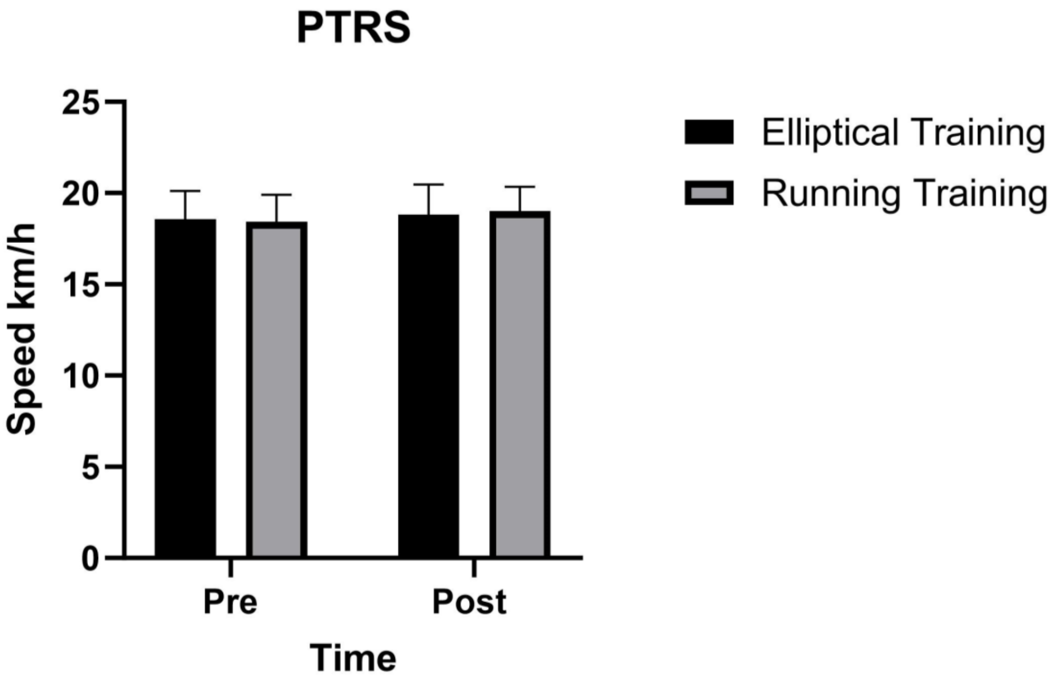

Figure 5 - Peak treadmill running speed (PTRS) PRE and POST for Within-Subject Effects. Significant difference for all participants combined (p = 0.007) between PRE and POST assessments. No significant difference found between groups (p = 0.97).

8-km Time Trial

There was no significant difference (p = 0.261) in 8-km time trial between the PRE and POST assessments, although a slight improvement in run times of 0.5 min, or 30 seconds, [34.3 ± 3.1 and 33.9 ± 3.1] was found for all participants combined. There was also no significant difference found between the elliptical training and running training groups (p=0.689). *Figure 6* below reveals no interaction between time and group in the 8-km trial.

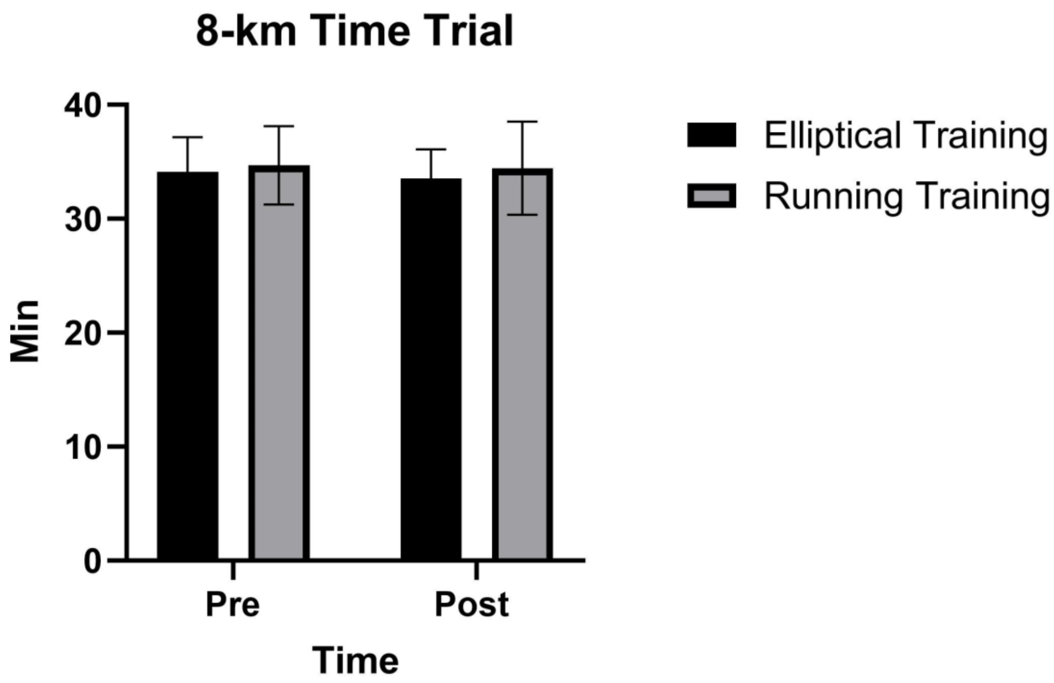

Figure 6 - Eight-km time trial PRE and POST for Within-Subject Effects. No significant difference for all participants combined (p = 0.261) between PRE and POST assessments. No significant difference found between groups (p = 0.689).

RPE

There was no significant change in RPE between the PRE and POST assessments for PTRS ($p = 0.783$) with a slight increase 0.1 units [7.4 ± 1.7 and 7.6 ± 2.0], and 8-km time trial ($p = 0.692$) an increase of 0.2 units [8.8 ± 1.0 and 8.9 ± 1.0], for all participants combined. There was no difference in change in RPE for the elliptical training and running training groups after the 8-week intervention. This is seen in the time*group interaction effect for PTRS ($p = 0.600$) and 8-km time trial ($p = 0.927$) indicating no significance. See *Figure 7* below for RPE for the PTRS, and *Figure 8* for the 8-km time trial.

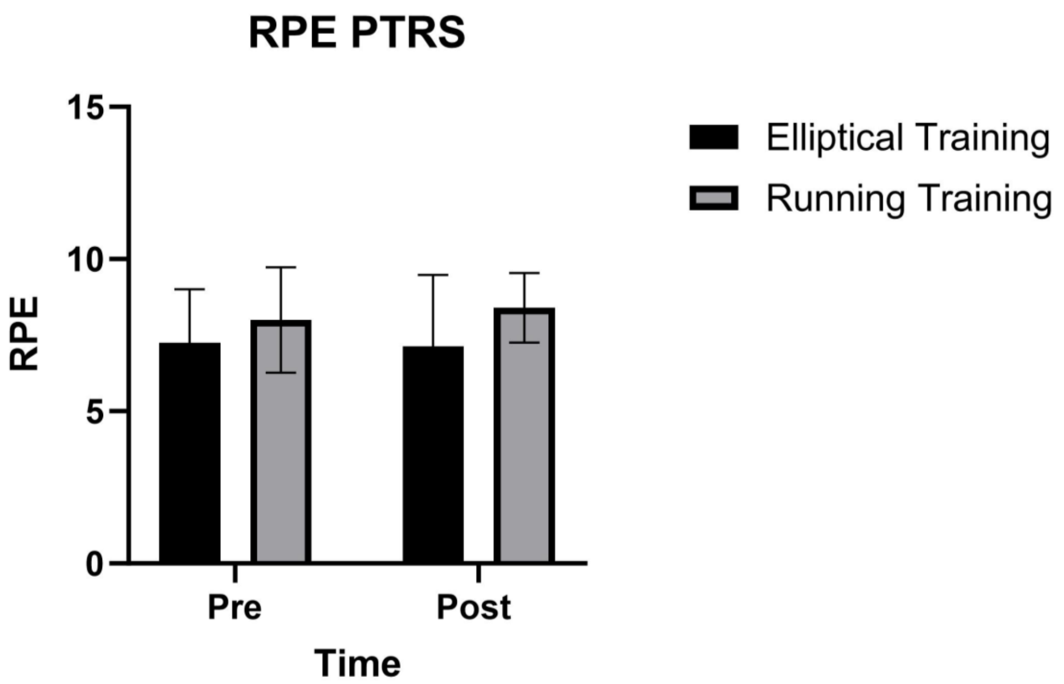

Figure 7 - Rating of perceived exertion (RPE) PRE and POST for PTRS Within-Subject Effects. No significant difference for all participants combined (p = 0.783) between PRE and POST assessments. No significant difference found between groups (p = 0.600).

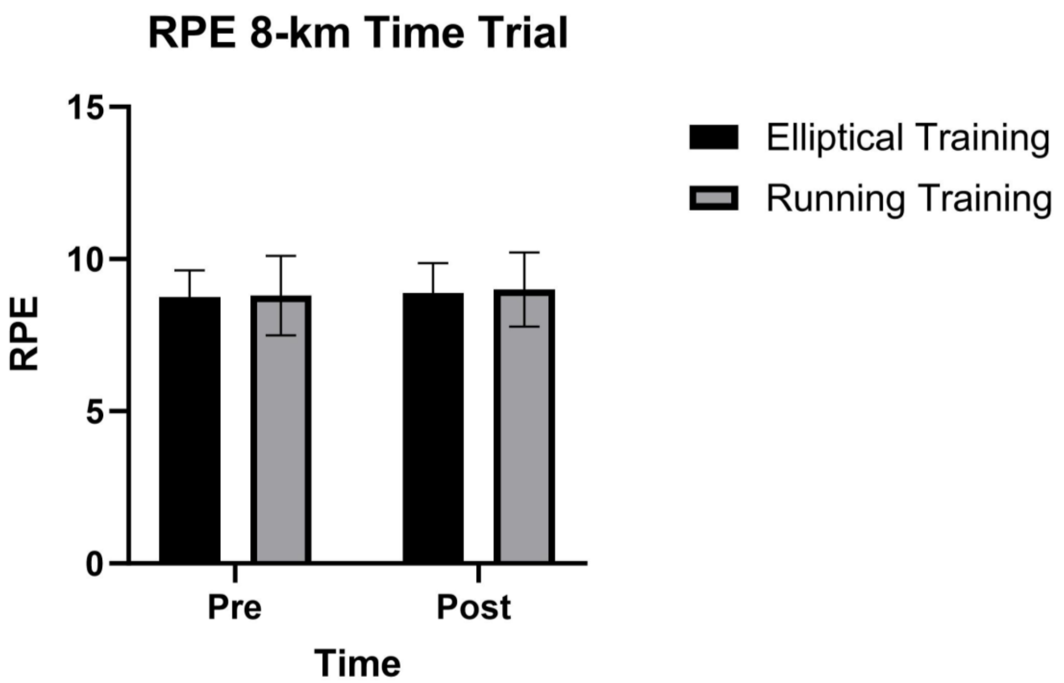

Figure 8 - Rating of perceived exertion (RPE) PRE and POST for 8-km time trial for Within-Subject Effects. No significant difference for all participants combined (p = 0.692) between PRE and POST assessments. No significant difference found between groups (p = 0.927).

HRmax

There was no significant change in HRmax between the PRE and POST assessments for the 8-km time trial (p = 0.241), although a decrease of 2.8 bpm [186.2 ± 9.0 and 183.5 ± 7.5] was found for all participants combined. There was no difference in change in HRmax between the elliptical training and running training groups after the 8-week intervention. This is seen in the time*group interaction effect (p=0.536) indicating no significance. See *Figure 9* below for HRmax.

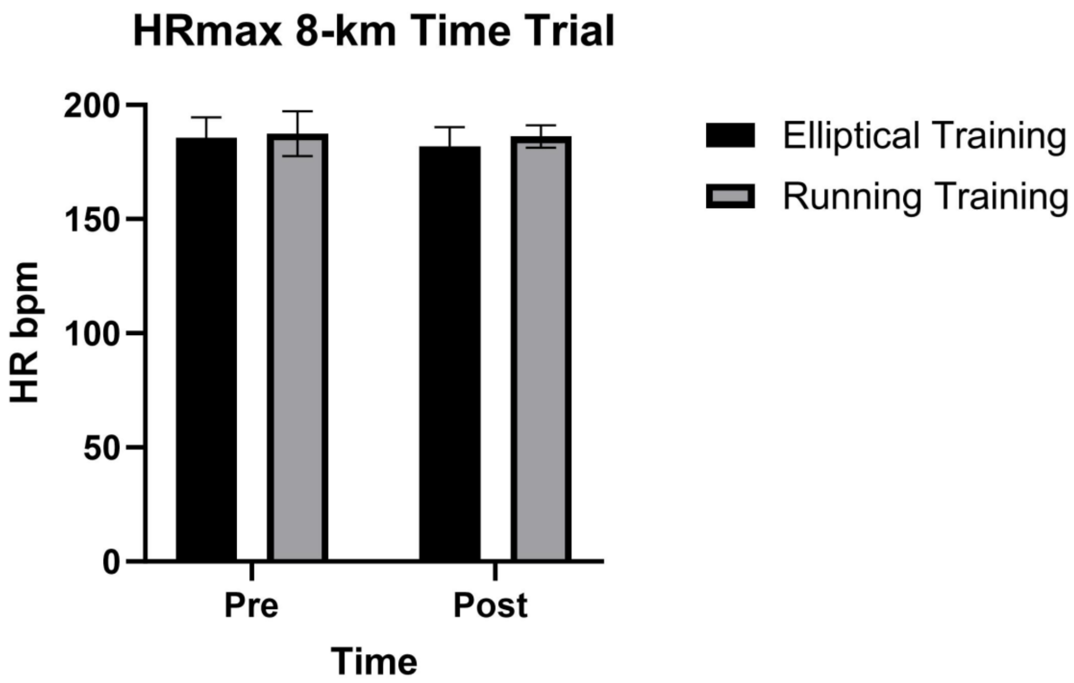

Figure 9 - Maximum heart rate (HRmax) PRE and POST for Within-Subject Effects. No significant difference for all participants combined (p = 0.241) between PRE and POST assessments. No significant difference found between groups (p = 0.536).

[Between-Subject Effects]

To compare the effects of the intervention on the elliptical training and running training groups (between-subject factors), each within-subject factor for the PRE and POST assessments is combined. Below, the PRE and POST assessment result for each factor is expressed together to compare the effect of the intervention on each group.

Elliptical Training versus Running Training

There was no statistical significance for the PTRS for the between-subject effects. This is reflected in the 'group' p-value for PTRS of $p = 0.982$ indicating that the elliptical training and running training groups improved similarly when exposed to the intervention. The 8-km time trial for the elliptical training group was similar to that of the running training group and is reflected in the 'group' p-value of $p = 0.687$, which indicates a comparable result. RPE for the PTRS for the elliptical training group was similar to that of the running training group, with a p-value of $p = 0.311$; RPE for the 8-km time trial also indicates a similar result, with a p-value of $p = 0.853$. Lastly, HRmax for the elliptical training group was similar to that of the running training group and is reflected in the 'group' p-value of $p = 0.484$, indicating a similar result

Running performance significantly improved for all participants, that is, for both the elliptical training and running training groups, with respect to PTRS, when exposed to the 8-week intervention. Running performance, however, was similar between the elliptical training and running training groups after the intervention. Additionally, running performance was the same between the elliptical training and running training groups when exposed to the intervention. Lastly, there was no significant change in the 8-km time trial, RPE and HRmax after the intervention, with no difference found between the elliptical training and running training groups.

4.2 Discussion

This is the first study to compare the effect of additional running training added to an existing running programme with a similar volume of elliptical training added to a running programme, on running performance in trained runners. The results of this study showed that running performance significantly improved in both groups after the 8-week intervention, with respect to the PTRS which improved for all participants after both training interventions. There was, however, no difference found between the improvements in the elliptical training and running training groups. These results confirmed the hypothesis that that there will be a similar improvement in running performance in both the elliptical training and running training group when exposed to the intervention.

With reference to the comparable increase in running performance that was found, this is similar to the findings of Egaña & Donne (2004) who found similar improvements in VO_2max between groups training on the elliptical trainer, stair-climber, and treadmill. They suggested that the elliptical trainer and stair-climber provide sufficient training stimulus compared to treadmill running to develop cardiovascular fitness in moderately active females. These findings were expanded upon by Joubert et al. (2011), who also found that the elliptical trainer is a viable cross-training option for recently trained runners to maintain their VO_2max in the short term. Loy et al. (1993), although investigating the impact of stair-climbing on running performance and not the elliptical trainer, found similar results. Their main findings were that with increased training, the stair-climbing and run training groups had equal improvements in VO_2max and also improved their run times in moderately active females. Thus, the findings of the current study of similar improvement with additional running training or elliptical training show that habitual runners who are fairly well trained, also respond to addition of elliptical training to their training programme. The previous studies included runners who were not well trained, or recently trained.

As proposed by Joubert et al. (2011), who indicated that studies are required to measure the impact of elliptical trainers on more performance variables than just VO_2max, such as lactate threshold, running economy, and peak treadmill running velocity, this study investigated the impact on peak treadmill running velocity, or PTRS, and the performance of an 8-km time trial.

The findings of the present study add to the results of previous studies pertaining to the impact of elliptical training and stepper training on VO_2max (Egaña and Donne, 2004; Joubert et al., 2011; Loy et al., 1993). In this current study, interestingly, a similar impact of the training intervention was found on running performance as have previous studies on VO_2max. These studies, listed above, found that elliptical training is a viable cross-training alternative to maintain cardiovascular fitness. Similarly, this study suggests that elliptical training is a viable cross-training alternative to improve PTRS, and thereby, running performance. Although the current study did not find an associated improvement in running performance of the 8-km time trial, this is surprising given previous studies have found a comparable improvement in PTRS and running performance in time trials (Noakes et al., 1990). In the present study, this is somewhat unexpected, given the improvement in PTRS. The 8-km time trial remained unchanged for all participants, with both groups having similar results after the training intervention. This is contrary to expectation and may have occurred due to two reasons: firstly, the 8-km time trial were conducted shortly after the PTRS; in planning the study, it was envisaged that the PTRS would act as a pre-load prior to the time trial, but it’s conceivable that the lack of sufficient recovery between tests resulted in participants not being able to perform to their maximum ability in the time trial. Secondly, it is possible that the time trial method of testing on the treadmill did not sufficiently replicate the experience of running a time trial on the road. During the course of the study, unfortunately, due to technical difficulties encountered with the treadmill’s remote control which handled treadmill speed independently by the runner during testing, the remote control was no longer able to be used. This affected the elliptical training and the running training groups equally. An adjustment was made that allowed runners to adjust the treadmill speed themselves on the treadmill console during testing. It is possible that having to adjust treadmill speed on the treadmill console meant that runners varied their running speed less due to the inconvenience of reaching to the console while running, and this may have impacted the fluidity of the runner during running and the true time trial-like experience during testing.

RPE was unaffected during the PTRS and 8-km time trial tests after the training intervention, with a similar result found between groups. Likewise, HRmax was also unaffected during the 8-km time trial test after the training intervention, with a similar response found between groups. This indicates that the runners performed at the same maximal intensity of effort during the PRE and POST assessments. As the intensity (RPE and HRmax) during both assessments remained the same, yet PTRS improved, this aspect of running performance increased in the runners following the training interventions.

The observations in our study, with respect to PTRS, nonetheless confirm the hypothesis that there would be an equal improvement in running performance following either additional running or elliptical training intervention. Thus, the elliptical trainer could be used interchangeably with additional running training to improve running performance, or as a cross-training alternative to maintain running fitness when unable to run. Interestingly, the question posed by Bosch et al. (2021), even though the elliptical trainer and stepper generate similar physiological and metabolic responses to running, caution should be given to assuming whether they produce a similar training stimulus to running due to the impact on leg muscles being reduced. Specifically, the current study suggests that elliptical training does produce a similar training stimulus to running, despite the reduced impact on the leg muscles. Nonetheless, further studies are required to investigate the impact of elliptical training on running performance over a longer duration.

A limitation in this study is the length of the training intervention. By comparing the impact of elliptical training to running training over a longer duration, a more conclusive understanding of the impact on running performance will be possible. A longer intervention would allow a greater increase in training load, both by additional running and elliptical training. In running training terms, because of the duration of the intervention, the total increase in running training load was very modest. Nevertheless, the indications from the results of this study on the impact on running performance are positive and should be investigated further. The drop-out and non-compliance experienced in the study was also a limiting factor, which led to the drop-out of four participants. As the study unfolded, it was realized that recruiting well-trained runners, many of whom were already coached by running coaches, introduced compliance problems, as many were in structured running programs, or were preparing for running championships. As a result, they were hesitant to adapt their running training as the study required. Although including well-trained runners is better for the study outcome measures, the downside thereof is that the runner’s training may be less modifiable for participation in a research study. The drop-out impacted the sample size, a limitation of this study that needs to be taken into consideration when interpreting the results. The sample size was small and is a limiting factor. Specifically, the reduced sample size of the running training group was unfortunate (due to drop out and non-compliance) and future studies should implement ways to improve the running training group’s adherence, for example, with the use of supervised training sessions. The results of this study can be used as a pilot study for future research. Finally, while every attempt was made to recruit runners who were of reasonable standard, the personal best times of the runner who enrolled in the study were relatively slow; it would be of particular interest to repeat the study with runners who were performing at a higher level.

5. Conclusions and Recommendations

The results of this study indicate that training on the elliptical trainer enhances PTRS, a predictor of running performance, and the enhancement is similar/equivalent to that achieved with equivalent increased running training (Noakes et al., 1990). Additionally, indications are that there is no difference in the effect of training on the elliptical trainer and running training with respect to improving running performance. Stated differently, running performance increased similarly to normal supplementary running training when the training load is by training on the elliptical trainer. Specifically, the PTRS of participants increased in both groups after the 8-week intervention, and there was no difference between groups. Finally, there was no observable effect in the performance of participants of the 8-km time trial after the 8-week training intervention.

These findings suggest that elliptical training can be used to supplement running training as a means to improve running performance. With such equal improvements in running performance, the elliptical trainer could then be used as a viable cross-training method to potentially improve running performance in trained runners, by increasing the training load of a runner with minimal risk of increasing likelihood of injury (the elliptical trainer offers reduced impact forces), or when unable to run due to injury.

During the course of this study, several limitations emerged. Due to these limitations, it is recommended that these results be used as a pilot study for future research and be viewed as exploratory in nature. Recommended for further research include continuing to investigate the impact of elliptical training on running performance, specifically considering the positive effects observed on PTRS, so as to improve the strength of eventual conclusions. Future research should also compare the effects of supplementary elliptical training and running training on running economy, and to continue with the recommendations of Joubert et al. (2011) on lactate threshold. Finally, although the results of this study could suggest a similar anticipated result with stepper training, future research should specifically include assessment of stepper training on running performance in trained runners.

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Appendix 1: Participation Information Sheet

The effect of supplementary elliptical training on running performance in trained runners

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PARTICIPANT INFORMATION SHEET

Why am I receiving this letter?

The University of Cape Town is conducting a research study to assess the effect of supplementary elliptical training on running performance in trained runners. This study forms part of the research thesis component of MPhil Biokinetics student, Anna Malan. If you are interested in taking part in this study, please read further.

Why are we doing this study?

Recent studies conducted at the University of Cape Town found that training on the elliptical trainer and stepper can be used effectively as a substitute to running to maintain cardiovascular fitness. These studies found that training on the elliptical trainer and stepper reduces workload in the muscles of the lower body by up to 60% compared to running but provides a similar training stimulus to running on a treadmill. Training on an elliptical trainer and stepper, when performed at the same intensity, can therefore be used to maintain cardiovascular fitness, and as hypothesized in this study, running fitness.

This research study is a follow-on to the previous studies conducted at the University of Cape Town. The aim of the study is to determine whether training on the elliptical trainer enhances running performance compared to equivalent increased running training.

Who is responsible for the information contained in this letter?

The persons responsible for this research study are Professor Andrew Bosch (University of Cape Town; contact details below), and the student researcher, Anna Malan.

Who can take part in this research study?

We are looking for runners between the ages of 18-50 years old, who train at least 60km weekly and can run 10km in under 50 minutes. Runners should be injury-free for three months prior to starting the study and be willing to participate in the extra training that will be required.

Principles concerning research: your rights

It is important that you read and understand the principles that apply to **all persons** who agree to participate in the research study described below:

1. Taking part is **entirely voluntary.**
2. You are **free to withdraw** from the study **at any time** without anyone objecting and without penalty or loss of any benefits to which you are otherwise entitled.
3. You **will not directly benefit** from taking part in the study.
4. You will **receive feedback on training and running performance** on completion of the study.
5. Your **privacy** and **anonymity** will be maintained at all times. Your name, surname, identification number and any personal identifying characteristics will remain entirely confidential.

If I choose to take part, what is expected of me?
You will be required to visit the Sport Science Institute of South Africa (SSISA) on two occasions for testing. Please find a summary below:

Visit 1
During the *first visit*, informed consent will be obtained, and you will be asked to fill in two questionnaires: a physical activity readiness questionnaire (PAR-Q), and a standard research questionnaire containing personal details, injury history, sporting details and running history. Body composition measurements will be obtained using a seven-site skinfold assessment to determine percentage body fat. After familiarization, you will then be asked to complete an 8km time trial test on the treadmill followed by a peak treadmill running speed (PTRS) test. This will be used to determine your running fitness.

Following these tests, you will be randomly divided into one of two groups: an elliptical trainer group or a running training group, and be required to supplement your normal running routine with the additional exercise training for 8-weeks on the exercise modality to which you are assigned. Appropriate exercise intensity and exercise load (time) for the 8-week intervention will be provided to you, and you will be asked to log your sessions in a training diary.

Visit 2
During the *second visit,* eight weeks later, we will redo the 8km time trial and PTRS tests. These will be compared to baseline measurements and used to determine whether training on the elliptical trainer enhanced running performance compared to the addition of normal running.

What about ethical considerations?
This research study is classified as minimal risk. This means that possibility for harm anticipated in the research study is no greater than those ordinarily encountered in daily training.

Are there any risks to me if I decide to take part?
There is no risk associated with completion of the questionnaires. Normal COVID-19 protocol will be taken with regards to baseline and post-intervention testing at SSISA. This includes screening and sanitizing upon entry into the building, and care will be taken to sanitize all testing equipment between each use. There is minimal risk for discomfort, as is the likelihood of sustaining an injury in the 8-week exercise intervention.

Are there any benefits to me if I decide to take part?
There are no direct benefits to you should you take part in this research study, except for the knowledge to be gained regarding elliptical training and its effect on running performance. Feedback will be provided to you at completion of the study.

What will happen to the information we collect?
The information collected will be used to gain more understanding about the relationship between the elliptical training and running performance. Only the research team involved in the study will have access to the data, with personal information stored safely and securely. Information collected will be stored for up to 5 years and will only be used for the purposes of this study. Data will be kept anonymous if the study is published.

What if something goes wrong?
Should any injury or medical emergency occur during testing at SSISA, the research team and medical personnel will provide on-site emergency medical care. Participation in the training regimens will be done at your own risk.

Freedom to withdraw and confidentiality:
Your participation in the study is entirely voluntary, and you can withdraw from the study at any time without having to explain your reasons for doing so. All personal information will be kept confidential and will be stored securely, and only be available to the research team.

What must I do if I have any questions?
If you have any questions about your participation in the study, you are welcome to contact the student researcher (Anna Malan) or the Principal Investigator (Professor Andrew Bosch). You may also contact the Chairperson of the UCT Human Research Ethics Committee, Prof Marc Blockman, for any ethical concerns or queries regarding participation in this study (contact details below).

- Ms Anna Malan, MPhil Biokinetics student. Division of Physiological Sciences, Department of Human Biology, Faculty of Health Sciences, University of Cape Town. Phone: 084 506 5480. Email: MLNANN015@myuct.ac.za

- Professor Andrew Bosch. Division of Physiological Sciences, Department of Human Biology, Faculty of Health Sciences, University of Cape Town. Phone: 021 650 4578. Email: Andrew.Bosch@uct.ac.za
- Professor Marc Blockman, Chairperson of University of Cape Town's Human Research Ethics Committee, Faculty of Health Sciences, Room E52-24 Groote Schuur Hospital Old Main Building, Observatory 7925. Phone: 021 406 6338.

I am interested in being a participant, now what?

Thank you for your interest to participate in the research study. Please read and sign the informed consent form below. Questionnaires will be sent to you via email.

Appendix 2: Informed Consent Form

The effect of supplementary elliptical training on running performance in trained runners

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CONSENT FORM

Participant ID: __________

I, the undersigned, have been fully informed about the study entitled “The effect of supplementary elliptical training on running performance in trained runners” to be conducted by researchers from the Division of Physiological Sciences within the Department of Human Biology, Faculty of Health Sciences at the University of Cape Town. I understand what is involved, including the risks and benefits of taking part. I have had the opportunity to ask all the questions that I have relating to the study.

I understand that:

- Taking part is **entirely voluntary.**
- I am **free to withdraw** from the study **at any time** without anyone objecting and without penalty or loss of any benefits to which I am otherwise entitled.
- I **will not directly benefit** from taking part in the study.
- I **will receive feedback on my training and running performance** on completion of the study.
- My **privacy** and **anonymity** will be maintained at all times. My name, surname, identification number and any personal identifying characteristics will remain entirely confidential.
- I understand that my consent here indicates that I am willing to participate in this research study as described above.
- I will receive a signed copy of this informed consent document.

Please tick the appropriate box:

☐ I agree to participate in this study.

☐ I do not agree to participate in this study.

____ Date:____________

(Signature: Participant)

____ Date:____________

(Signature: Witness)

Appendix 3: Physical Activity Readiness Questionnaire (PAR-Q)

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

01-11-2019

Appendix 3: Physical Activity Readiness Questionnaire (PAR-Q)

2020 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1.	**Do you have Arthritis, Osteoporosis, or Back Problems?** If the above condition(s) is/are present, answer questions 1a-1c If **NO** ☐ go to question 2	
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐
2.	**Do you currently have Cancer of any kind?** If the above condition(s) is/are present, answer questions 2a-2b If **NO** ☐ go to question 3	
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐
3.	**Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm** If the above condition(s) is/are present, answer questions 3a-3d If **NO** ☐ go to question 4	
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐
4.	**Do you currently have High Blood Pressure?** If the above condition(s) is/are present, answer questions 4a-4b If **NO** ☐ go to question 5	
4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐
5.	**Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes** If the above condition(s) is/are present, answer questions 5a-5e If **NO** ☐ go to question 6	
5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

 2 / 4
11-01-2019

Appendix 3: Physical Activity Readiness Questionnaire (PAR-Q)

2020 PAR-Q+

6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

Appendix 3: Physical Activity Readiness Questionnaire (PAR-Q)

2020 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

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11-01-2019

Appendix 4: Recruitment Material

Appendix 4: Recruitment Material

WHEN?

June - August 2023

WHERE?

Testing at SSISA, training at your own exercise facility of choice

INTERESTED?

Contact me at:

Anna Malan

MLNAN-N015@myuct.ac.za

Appendix 5: Questionnaires

5.1 Personal Details

Surname			
First Name			
Postal Address			
		Postal/ Zip Code	
E-mail address			
Alternate E-mail address		Phone (day-time)	
Date of birth		Cell (mobile)	
Height	cm	Sex	Male ☐ Female ☐
Weight	kg	Age	yrs
Country of Birth			
Dominant Hand	Left ☐ Right ☐ Both ☐	Dominant Leg Left ☐ Right ☐	
Current Occupation			
What **percentage** of your **working** day is spent in the following activities?	Sitting: ______ % Standing: ______ % Walking (lower body activity) ______ % Manual Labour (upper and body activity) ______ %		

5.2 Sporting Details

Please record your sporting activities in order of importance Use an additional form if you participate(d) in more than 6 sports			
Type of sport(s) you have participated in (please name)	**Main sport 1**	**Other sport 2**	**Other sport 3**
Current or past participation	Current ■ Past ■	Current ■ Past ■	Current ■ Past ■
Year started participation			
Number of years involved in the sport			
Position played prior to injury (if appropriate)			
Playing level prior to injury (if appropriate)			
Number of years played prior to the injury.			

Type of sport(s) you have participated in (please name)	**Other sport 4**	**Other sport 5**	**Other sport 6**
Current or past participation	Current ■ Past ■	Current ■ Past ■	Current ■ Past ■
Year started participation			
Number of years involved in the sport			
Position played prior to injury (if appropriate)			
Playing level prior to injury (if appropriate)			
Number of years played prior to the injury.			

5.3 Running Training and Performance

Please record your current training programme details alongside your best running performances		
Running experience (years)	<6 yrs O >6 yrs O	
Do you follow a specialised training program?		
Typical training week	**Type** (speed, hill work, long run, rest)	**Time** (duration)
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		
Total training time per week (minutes)		
Performance Times	**Venue/Race**	**Time**
5km		
10km		
21.1km (Half-Marathon)		
42.2km (Marathon)		
> 42.2km (Ultra Marathon)		

Appendix 6: Questionnaires

6.1 Elliptical Trainer Group Program

Name:				
Elliptical Trainer group: Train at level …				
Please record weekly the dates of your supplementary exercise sessions and whether they have been completed or not				
Weeks (1 – 8)	**Session 1**		**Session 2**	
	Date	**Complete (√ / x)**	**Date**	**Complete (√ / x)**
Week 1: *10 minutes, 2 x / week*				
Week 2: *15 minutes, 2 x / week*				
Week 3: *20 minutes, 2 x / week*				
Week 4: *25 minutes, 2 x / week*				
Week 5: *30 minutes, 2 x / week*				
Week 6: *35 minutes 2 x / week*				
Week 7: *40 minutes, 2 x / week*				
Week 8: *40 minutes, 2 x / week*				

6.1 Excel Spreadsheet Summarizing Running Training History

NAME:

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Example	8 weeks ago	7 weeks ago	6 weeks ago	5 weeks	4 weeks	3 weeks	2 weeks	last week
Mon AM	10 easy								
PM	(5:00/k)								
Tues AM	0								
PM									
Wed AM	12 incl 8x 800 in 2:45 average; 2:30 jog recovery								
PM									
Thurs AM	8 easy								
PM									
Fri AM	12 incl 5 at 4:30								
PM									
Sat AM	0								
PM									
Sun AM	30 in 2:30 (5:00/k)								
PM									
Total	72	0	0	0	0	0	0	0	