



## The Effects of Minimalist Shoes on the General Endurance in Long-Distance Recreational Runners

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### Abstract

**Background:** The difference in general endurance between running with a minimalist shoe versus structured footwear is a topic of debate amongst both runners and researchers. Studies investigating the effect of structured and minimalist footwear on general endurance are still lacking. Therefore, the purpose of this study was to explore the difference between running in minimal versus structured footwear on endurance amongst long distance recreational runners.

**Methods:** Thirty healthy long distance recreational runners were recruited for this study. Treadmill running in two different shod conditions: 'Trial 1' with structured footwear and 'Trial 2' with minimalist footwear was conducted. The Bruce Treadmill Protocol was used to estimate the  $VO_2$  max of each athlete were the time taken to reach volitional exhaustion was recorded and interpreted via two equations depending on whether the participant was male or female. The results of the equations estimating the participants'  $VO_2$  max were compared between the two types of footwear.

**Results:** The results of this study found a significant difference in general endurance when wearing minimalist footwear versus structured footwear ( $p = 0.038$ ), indicating a higher efficiency when running with minimalist footwear. No significant difference was found in the mean Borg 6-20 RPE (Rate of Perceived Exertion rating scores) between structured and minimalist footwear ( $p = 0.32$ ). However, although no significant difference was found, it is important to note that whilst all the participants wearing both structured and minimalist footwear reached stage 7 on the BTP protocol, in stages 8 and 9 the number of participants in minimalist footwear exceeded those in structured footwear implying better endurance when using minimalist footwear.

**Conclusion:** This finding provides important information to the running community, clinicians and researchers alike with regards to the efficacy when using minimalist shoes in long distance running. Since physical exercise and sports are today being advocated as important elements to improve general health status and weight loss, with recreational running being picked up by many individuals, it is of utmost importance to provide recreational runners and their coaches with evidence-based information regarding potential implications when choosing the appropriate footwear for distance running.

**Keywords:** General Endurance; Minimalist Shoes; Structured Footwear; Long Distance Running

### Introduction

Minimalist versus structured footwear has been a remarkably interesting topic of study [1]. There is an on-going controversy over the efficacy of minimalist versus structured running shoes, however there is still insufficient evidence regarding this matter

[2]. It was previously believed that human feet were not evolutionary successful enough, as footwear experts and health professionals thought that they needed support, motion control and cushioning as they were frail, so that they could bare the roughness of running [3,4]. However, today it seems that this theory is being questioned.

Features of structured footwear include elevated heavily cushioned heels with characteristics that control subtalar joint motion and arch supports [5,6]. Structured footwear are advertised on the basis that they reduce the risk of injuries and improve performance, however research has shown that this may be misleading [7]. Currently, the minimalist running shoe movement has invaded the endurance running community [2]. The thin and less structured minimalist footwear include features such as, lower heels, more flexible mid soles and lack arch supports [8,9].

One of the determinants of successful and effective distance running performance of an athlete is maximal oxygen uptake ( $VO_2$  max) [10] which is a vital component when defining 'general endurance' [11].  $VO_2$  max refers to maximal amount of oxygen uptake achieved when an individual is working at maximal capacity and is measured via a direct or indirect, sub-maximal or maximal graded exercise test [12].  $VO_2$  max is an important determinant of the endurance capacity during prolonged exercise.

Even though, running barefoot or in minimalist footwear has gained popularity over the last few years and is said to potentially revolutionize distance running, there still is little evidence to support these claims [13]. Evidence related to the physiological response to minimalist footwear or barefoot running compared to shod running is still lacking. Paulson and Braun [14] stated that barefoot running is more economical than running shod, while other studies found that running with a minimal running shoe is more economical than shod running [15,16]. Therefore, the purpose of this study was to assess the effect on general endurance when using both minimalist and structured footwear, by estimating any difference in maximal oxygen uptake ( $VO_2$  max) between the two types of footwear utilizing the Bruce Protocol Formula. The alternative hypothesis stated that minimalist footwear is more effective in improving general endurance over structured footwear, in long distance recreational runners.

## Material and Methods

### Methodological rigor

To test our hypothesis, a quantitative, quasi-experimental, within subject design study was employed. The clinical tools used during this research were based on validated and previously published methods following a thorough review of the literature on international guidelines and recommendations. A database was constructed to record all the information.

### Participants

Thirty recreational long distance runners (20 males and 10 females), who consistently trained for the past six months and ran at least 12km per week, were recruited. All participants had no previous experience with minimalist running shoes and/or barefoot running. Participants were included in the study if they were confirmed fit/healthy using the Physical Activity Questionnaire (PAR-Q). Participants were excluded from the study if they were utilising foot orthoses, if they had any reported illnesses, lower limb injuries, history of cardiovascular conditions and no previous experience with treadmill running.

This study was approved by the University Research Ethics Committee and all participants provided informed consent. All investigations were carried out in accordance with the principles of the Declaration of Helsinki as revised in 2017 [17].

### Shoe Characteristics

Participants ran in two shoe conditions during this study: structured footwear – consisting of the running shoe in which they were currently using during their training and minimalist footwear – using Saucony Kinvara 5. The Saucony Kinvara 5 fits the category of a minimalist shoe as it is highly flexible, lightweight, has decreased padding, has a low heel, little support, lacks motion control and stability and it has a 4mm heel to toe drop. The Saucony Kinvara 5 has an average weight of 7.5oz, and this type of shoe is suggested to mimic barefoot running as it promotes a midfoot or forefoot strike. Structured footwear has diverse characteristics such as heavy cushioning, elevated heels, stiff arch supports, stiff soles and toe springs, with an average weight of 10oz.

### Instrumentation

#### Physical activity readiness questionnaire (PAR-Q)

For the purpose of this study, the Physical Activity Readiness Questionnaire (PAR-Q) was utilised to determine whether subjects were eligible to participate, as they had to be clear from any at-risk medical conditions. The Physical Activity Questionnaire is a health screening tool that determines an individual's readiness for physical activity [12]. To carry out cardiorespiratory fitness testing, the PAR-Q is strongly recommended and it is part of general procedures when performing such assessments [18]. This questionnaire was administered prior to the commencement of the Bruce Treadmill Protocol, to determine the safety and confirmed

the eligibility of each individual to partake in the study [19]. The PAR-Q questionnaire is composed of seven questions. Any of the potential participants who answered “yes” to any of the questions in this questionnaire, were automatically excluded from the study.

### Bruce treadmill protocol and the Borg 6-20 RPE scale®

The Bruce Treadmill Protocol (maximal graded exercise test) was utilized to measure the indirect (estimated) maximal oxygen consumption ( $\text{VO}_2 \text{ max}$ ) of the athletes when running with both structured and minimalist footwear. Maximal oxygen uptake ( $\text{VO}_2 \text{ max}$ ) refers to the maximal amount of oxygen that can be utilized by an individual during maximal exertion or exhausting exercise [20]. It is also known as aerobic power, maximal oxygen consumption, and cardiorespiratory endurance capacity.

The Bruce Protocol is comprised of ten progressive stages, where speed (km/hr) and inclination (percent grade - %) increases every three minutes [21]. In the first stage (1-3 minutes), the athlete walks at a pace of 2.74km/hr at 10% grade, after which the second stage commences (4–6 minutes), where the speed increases to 4.02km/hr and the percent grade increases to 12% (2% increase). The percent grade increases by 2% and the speed by 1.29 or 1.45km/hr, in each subsequent stage until the individual is exhausted [12]. The duration of time spent on the treadmill will reflect the test score that the athlete obtained and it is then used to determine the estimated  $\text{VO}_2 \text{ max}$  value [22]. The  $\text{VO}_2 \text{ max}$  value is then determined The Bruce Protocol Formula for Estimating  $\text{VO}_2 \text{ Max}$  is shown below with a specific equation used according to gender difference.

The Bruce Protocol Formula for Estimating  $\text{VO}_2 \text{ Max}$

- For Men  $\text{VO}_2 \text{ max} = 14.8 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$
- For Women  $\text{VO}_2 \text{ max} = 4.38 \times T - 3.9$

T = Total time on the treadmill measured as a fraction of a minute (i.e.: A test time of 9 minutes 30 seconds would be written as T = 9.5).

The overall perceived exertion at every stage in the graded exercise was determined by the Borg 6-20 RPE Scale. The Borg 6-20 RPE Scale [23] allows athletes to subjectively rate their feelings during incremental exercise, while taking into consideration each

individual’s physical fitness, general fatigue levels and overall exertion [24]. The Borg 6-20 RPE Scale consists of a scale from 6 to 20, with a rating of 6 indicating “no exertion at all” (rest) whilst a rating of 20 would mean that the participant reached their maximal exertion (most strenuous exercise experienced).

A strong relationship between Borg 6-20 RPE scale and maximal oxygen uptake ( $\text{VO}_2 \text{ max}$ ) in endurance trained athletes was recorded in previous studies [25]. For the purpose of this research the Borg 6-20 RPE Scale was placed in front of each participant towards the end of every stage in of the maximal graded exercise test (Bruce Treadmill Protocol) during both trials in order to assess each participant’s overall perceived exertion, so that an indication on which type of footwear requires most perceptual exertion was obtained.

### Study Protocol

A clinical Biomechanics Laboratory situated inside a general hospital was used to conduct the trials. The participants completed two different trials using the Bruce Treadmill Protocol in each setting: ‘Trial 1’ with structured foot and ‘Trial 2’ with minimalist footwear. Each trial was segregated by a recovery period of forty-eight hours [25]. The sequence of the type of shoe was alternated between participants. Fifty per cent of the participants started the trial with structured footwear, while fifty per cent of the participants started with minimalist footwear. Stretching was encouraged before each trial, followed by a 10-minutes warm-up on the treadmill at a selected speed between 0.8km/hr to 2.4km/hr, depending on the athletes’ preference as proposed in clinical exercise testing protocols [26]. The treadmill was set to a speed of 2.74km/hour and an incline of 10% (Stage 1 of the BTP) [8]. The workload was intensified by altering the speed and the incline that were progressively increased every three minutes [8]. The RPE was assessed close to the end of the last minute of every exercise stage [12]. The test was carried out for as long as possible, until volitional exhaustion was reached [8]. Upon termination of the test, the time of the session was recorded together with the inclination of the treadmill. The ambient temperature and relative humidity of the Clinical Biomechanics laboratory where the study was conducted were kept stable during both trials.

### Data analysis

Results were statistically analysed using the IBM Statistical Package for Social Sciences (SPSS) program version 23. A probabil-

ity level of  $p < 0.05$  (two-tailed) was considered statistically significant. Values are presented as means  $\pm$  SD or % ( $n$ ) unless otherwise indicated. The Shapiro-Wilk test was used to determine normality of data. Differences in variables of interest including the Bruce Test scores and the Borg 6-20 RPE rating scores were tested using the Wilcoxon Signed Rank test (non-normal data) to compare means of both minimalist and structured footwear at different stages of the study.

**Results**

**Patient Demographics**

A total of 30 participants, including 20 males and 10 females participated in this study. The mean age for the study group was 24.8 years (SD  $\pm$  4.03), with a mean weight of 69.9kg (SD  $\pm$  12.07) and a height of 172cm (SD  $\pm$  8).

**Bruce treadmill protocol**

A significant difference was found in the estimated VO<sub>2</sub> max scores between structured and minimalist footwear ( $p = 0.038$ , table 1) when using the Bruce protocol. The mean estimated VO<sub>2</sub> max with structured footwear was 76.5 mL/kg-1/min-1 and a median of 75.4 mL/kg-1/min-1 (SD  $\pm$  6.60 mL/kg-1/min-1). The estimated mean VO<sub>2</sub> max with minimalist footwear was 77.48 mL/kg-1/min-1, with a median of 75.02 mL/kg-1/min-1 (SD  $\pm$  6.89 mL/kg-1/min-1).

Footwear	N	Mean mL/kg-1/min-1	Std. Deviation	p-value
Structured – VO <sub>2</sub> Max	30	76.52	6.596	0.038
Minimalist – VO <sub>2</sub> Max	30	77.48	6.886	

**Table 1:** Wilcoxon Signed Ranks Test result of the estimated VO<sub>2</sub> max scores between structured and minimalist footwear.

**Borg 6-20 RPE - rate of perceived exertion**

No significant difference was found in this study between the mean Borg 6-20 RPE rating scores of structured and minimalist footwear ( $p = 0.32$ ). The mean RPE rating scores in all of the stages, are presented in table 2. Although no significant difference was found, it is important to note that whilst all the participants wearing both structured and minimalist footwear reached stage 7 on the BTP protocol, in stages 8 and 9 the number of participants in minimalist footwear exceeded those in structured footwear implying better endurance when using minimalist footwear.

BTP	Footwear	Sample Size	Mean Score	Std. Deviation	p-value
Stage 1	Structured	30	6.03	0.183	0.317
	Minimalist	30	6.00	0.000	
Stage 2	Structured	30	6.60	0.675	0.439
	Minimalist	30	6.50	0.572	
Stage 3	Structured	30	8.33	1.155	0.183
	Minimalist	30	8.07	1.311	
Stage 4	Structured	30	10.43	1.794	0.546
	Minimalist	30	10.47	1.592	
Stage 5	Structured	30	12.97	1.810	0.193
	Minimalist	30	12.43	1.794	
Stage 6	Structured	30	15.23	1.942	0.125
	Minimalist	30	14.60	2.094	
Stage 7	Structured	30	18.47	2.300	0.178
	Minimalist	30	17.90	2.604	
Stage 8	Structured	11	19.27	1.191	0.078
	Minimalist	14	18.57	2.209	
Stage 9	Structured	4	20.00	0.000	1.000
	Minimalist	6	20.00	0.000	

**Table 2:** Wilcoxon Signed Ranks Test result of the Borg 6-20 RPE rating score between structured and minimalist footwear at different stages of the Bruce Treadmill Protocol (BTP).

**Discussion**

The results of this study support our hypothesis that general endurance was found to be significantly higher when wearing minimalist footwear in long distance recreational runners. When compared to structured footwear, the study concludes that running in minimalist footwear demonstrates higher efficiency. The Rate of Perceived Exertion (RPE) was only found to be marginally higher in structured footwear but not significantly different when compared to minimalist footwear.

Although similar published studies concluded that minimalist footwear improves efficiency when compared to structured footwear, in most cases results were not significant or were inconclusive. Bootier [6] investigated the effect of biomechanical efficiency and metabolic economy when wearing the Vibram Five Fingers, consisting of a 0mm heel to toe drop, and a conventional structured footwear. Results showed slight, non-significant improvements in

efficiency ( $p < 0.89$ ) and economy ( $p < 0.93$ ) when running in the Vibram Five Fingers footwear when compared to a conventional structured footwear. In another study [27], investigated the long-term effects of transitioning to minimalist footwear over an eight-week period on running economy. Results from this study demonstrated a slight improvement in running economy over time when in minimalist footwear, however, statistically there was no significant difference. Furthermore, Cochrum, *et al.* [28], compared running economy between barefoot running, minimalist footwear and shod running in nine recreational runners. They concluded that running economy is not affected by barefoot running or by any footwear in those participants that already have experience with minimalist footwear.

To date, there is still no consensus between clinicians, runners and coaches with regards to the ideal running shoe to achieve optimal performance and general endurance in long distance running. Since physical exercise and sports are today being advocated as important elements to improve general health status and weight loss, with recreational running being picked up by many individuals, it is of utmost importance to provide recreational runners and coaches with accurate evidence-based information regarding potential implications when choosing the appropriate footwear for long distance running.

A limitation in the present study was that the sample size was rather small. Therefore, it may have limited statistical power. Larger prospective longitudinal follow-up studies should be performed in this specific population in order to fully understand and determine the optimum footwear to render improvements in running performance. One other limitation was that participants wore their own structured footwear. Since there were variations in models and makes, this could have been a potential weakness that might have influenced results, similarly seen in a study by Miller, *et al.* [9]. However, despite this, all the participant's structured footwear met the criteria required set at the start of the study. Another possible limitation of this study could have been that the study was conducted in a laboratory-based environment and described only immediate effects of minimalist shoes versus structured footwear. However, findings indicated a significant improvement in the estimated  $VO_2$  max when using the Bruce Treadmill Protocol, which is an important indicator of the endurance capacity during prolonged exercise due to an increase in aerobic capacity. The findings of our

study provide additional insight to the running community with regards to the choice of footwear for long distance recreational runners.

## Conclusion

This study has provided evidence with regards to the beneficial effect of minimalist shoes on the general endurance when compared to structured footwear in long distance recreational runners, which is currently lacking in the field of footwear running research. Larger prospective longitudinal follow-up studies are warranted in this specific population in order to fully understand and determine the optimum footwear to render improvements in running performance.

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## Competing Interests

The authors declare that they have no competing interests.

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