

The Acute Effects of Heel to Toe Drop on Running Economy

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TABLE OF CONTENTS

Page 1: Title

Page 2: Table of contents

Page 3: Abstract

Page 4: Chapter I

Page 8: Chapter II

Page 12: Chapter III

Page 15: Chapter IV

Page 17: Chapter V

Page 19: References

ABSTRACT

The purpose of this study was to assess how the running economy of experienced runners was affected when wearing 4mm and 0mm heel to toe drop shoes as opposed to regular running shoes. Previous studies have shown that barefoot running and running in lower heel to toe drop shoes increases running economy (Squadrone & Galozzi, 2009). The participants (n=23; 18 male and 8 female) were subjected to 3 separate tests that were each 20 minutes. The tests were performed within 90 minute, the order randomized. During the first test, the subject ran for 20 minutes at a speed they would run at for 1 hour. During the second and third test, the subject ran at the same speed in their randomly chosen shoes. Gas analysis was used to measure VO₂ in kilograms and measurements were taken one time per breath for 20 minutes with a Vacumed mini-CPX. Using one way repeated ANOVA, results were not significant ($p>.05$). The results of this study show that there was not a significant difference in running economy between running with 4mm or 0mm heel to toe drop shoes and running with regular running shoes.

Chapter I

INTRODUCTION

The running world has exploded with the new topic of minimalist and barefoot running. Views on preferred style of running are drastically being changed from the old way of a cushioned heel foot strike to a forefoot strike. Minimal heel-to-toe drop (HTTD) shoes are promoting the new desired forefoot strike. This strike pattern reduces the risk of injury, “Evidence that barefoot and minimally shod runners avoid rear foot strikes with high impact collisions may have public health implications” (Lieberman 1).

This study will research the effects on running economy (RE) when using 4mm and 0 mm heel to toe drop shoes compared to regular running shoes (RRS). The shoes used comes in a 4 millimeter HTTD and a 0 millimeter drop, when most RRS have a HTTD of around 12-16 millimeters. Running shoe companies have already begun the production of minimalist shoes as their popularity continues to grow. Consumers need more research performed in order to make a change in their running style instead of just trusting the companies’ claims.

PROBLEM STATEMENT

The problem was to study the affect on running economy when using a minimalist running shoe with a 4 millimeter drop compared to regular running shoes.

The problem was to study the effects 0mm drop shoes have on running economy compared to regular running shoes.

PURPOSE

The purpose of this study was to determine if a 4-millimeter heel to toe drop in running shoes would affect running economy.

The purpose of this study was to determine if 0 mm heel to toe drops in shoes would affect running economy.

SIGNIFICANCE

This study was important to conduct because there has been a limited amount of research with minimalist drop shoes and their effect on running economy. There have been studies in the past that focus on the weight of running shoes and their effect on running economy; There have also been studies that examine the amount of cushioning in the running shoe on foot strike pattern and injury (Flaherty, 1994). Although these factors were the old focus of runners and shoe companies, minimalist shoe research should be the focus now. More information is needed on some different brands of minimalist shoes and how they may affect running economy.

DELIMITATIONS

1. This study will contain 25 college athletes, 10 men and 10 women of college age.
2. The sample will consist of college runners who have volunteered for the study.
3. Limited to people who are fit, do not have flat feet, and can fully commit.
4. A Gas Spirometer and treadmill will be used to analyze running economy.

LIMITATIONS

1. The sample size is small (aprox. 25). Therefore, this must be considered when interpreting the data and results.
2. The activities of the subjects' daily lives cannot be controlled for.
3. The amount of subjects that learn to run with proper minimalist shoe technique cannot be controlled for.
4. Volunteers have inherent bias compared to non-volunteers.

ASSUMPTIONS

1. Subjects are going to run in their test shoes routinely on their own.
2. Machines read accurate measurements of gas analysis.
3. All the subjects' regular running shoes will have HTD of 12-16mm.

HYPOTHESIS

4 millimeter drop shoes will improve running economy when compared to regular running shoes.

0 millimeter drop shoes will improve running economy compared to regular running shoes.

RATIONALE FOR HYPOTHESIS

Based on previous research on barefoot and minimalistic shoes, there are a number of reasons for the increase in running economy. Several studies have demonstrated shoe weight affects RE and minimalistic shoes have a lighter weight

compared to regular running shoes. These studies found that a difference of 100 grams of shoe weight relates to between $\pm 0.5\%$ and $\pm 1.0\%$ in VO_2 , and also found a 4.7% higher VO_2 in runners wearing 700-gram shoes compared to barefoot (Flaherty, 1994). Another study found minimal shoe running is 2.4 to 3.3% more economical than running in RRS; controlling for shoe mass, stride frequency and foot strike type (Perl, et al., 2012).

Besides weight, minimalistic shoes allow a more natural FFS, which has been shown to be more biomechanically efficient.

OPERATIONAL DEFINITIONS

1. Fit: Someone with a normal range BMI
2. Runners: Someone who runs at least 3 times a week for 30 minutes.
3. Overweight: BMI over 25

ABBREVIATIONS

BF: Barefoot shoes

HTD: Heel-to-toe Drop

FFS: Fore foot strike

RFS: Rear foot strike

RRS: Regular running shoes

RE: Running economy

Chapter II

LITERATURE REVIEW

RUNNING ECONOMY

Running Economy (RE) may be a better predictor of performance than VO₂ max (Saunders et al., 2004b). RE is regarded as an important measure in determining success for distance runners (Daniels, 1985).

Burkett, Kohrt, and Butchbinder, showed that wearing shoes increases the energy cost of running and they found that oxygen consumption during running increased as the amount of mass they added to the foot increased. It was also noted that shoes and orthotics represented 1% of body mass of the participants and in turn, increased oxygen consumption by 3.1% (1985). In a study done by Flaherty, he found that oxygen consumption during running at 12 km/h was 4.7% higher in shoes with a mass of 700 g per pair than in bare feet (1994). This 4% increase would hardly be noticed by a novice runner, but surely would have an impact on a competitive runners performance. Several studies have validated the effects of shoe weight, minimalist footwear, and bare feet on RE (Bootier, 2012). Previous research found that a difference of 100 grams of shoe weight relates to between $\pm 0.5\%$ and $\pm 1.0\%$ in VO₂ (Flaherty, 1994).

In a recent study looking at effects of shoe mass and mechanics (Divert et al., 2008), weight was added to subjects' feet without adding a cushioned sole and increased energy cost was attributed to shoe mass and not gait changes. Divert et al. (2008) also theorized that the shock-absorbing properties of shoe cushioning might take away energy that might otherwise be stored and reused as elastic energy, causing a net efficiency loss.

In a study done by Frederick, he reported that oxygen consumption can increase significantly when thicker shoe inserts are used during treadmill running (1986).

According to Stefanyshyn and Nigg, the materials used for cushioning in shoes absorb energy, and stiff midsoles should produce a 2% saving of energy compared with standard midsoles (2000).

BAREFOOT VERSUS CONVENTIONAL SHOES

Humans have engaged in endurance running for millions of years but the modern running shoe was not invented until the 1970s. For most of human evolutionary history, runners were either barefoot or wore minimal footwear such as sandals or moccasins with smaller heels and little cushioning relative to modern running shoes (Lieberman, 2010). Today, shoe companies advertise their thick cushioned heel shoes reduce impact and injury. However, there is no convincing evidence supporting the case that today's running shoes actually do anything to reduce the rate of running injury (Lieberman, 2010).

Conventional running shoes limit proprioception, facilitate non-barefoot running style, and hypothetically cause foot weakness and inflexibility (Lieberman, 2012). Conventional shoe running relies on cushioning and support against heel strike; in contrast, minimalist-shoe running relies on changing technique into a more natural, barefoot running style (Gyimesi, 2011). Barefoot running's characteristic foot strike patterns, stride lengths and stride rates, physiological adaptations, and running cost improvements support the hypothesis of injury prevention and improved performance (Lieberman, 2012).

BAREFOOT VERSUS CONVENTIONAL SHOES: IMPACT FORCES

Traditionally, people who run in cushioned running shoes have report they run with greater impact force when running barefoot. However, Divert et al. found when subjects performed on a sufficient number of steps, barefoot running leads to a reduction of impact peak in order to reduce the high mechanical stress occurring during repetitive steps (2005). Divert et al. study of 35 participants refutes common thinking that running barefoot increases impact forces. Divert et al. also found subjects, even when instructed to run with a heel-to-toe strike would switch to a mid-foot strike (2005). This switch to forefoot running is characterized by lower impact peaks, according to Cavanagh (1980). However, Komi et al. reported a higher impact force in barefoot than in jogging shoes (about 1800 N in barefoot versus 1350 N wearing jogging shoes at 3m. s⁻¹) (1987). But, De Wit et al. reported no significant difference for vertical impacts when comparing the two manners of running (2000). Kerrigan et al. showed that shod runners have greater knee flexion torques, varus torques, and hip internal rotation torque compared to barefoot athletes, which lead to greater stresses on the legs and feet (2009).

The variation in impact peaks between different strike types can be explained by two related factors (Derrick, 2004; Nigg, 2010). The first factor is that during FFS impact, the foot is first plantar flexed and then goes through controlled dorsiflexion with an ankle that is compliant. In a RFS, however, the foot starts and remains dorsiflexed and the ankle is stiff during the same phase of time. Consequently, the effective mass or the percentage of mass that must completely stop and transfer momentum with the ground at impact is much higher with RFS (Derrick, 2004; Nigg, 2010).

The second factor, compliance, explains why FFS creates no major impact peak.

Compliance is the dampening of ground reaction forces at foot strike (Bootier, 2012).

With RFS, a runner normally lands with more knee extension and a stiffer knee and ankle than a runner with FFS, who dorsiflexes the ankle and flexes the knee more during the phase of impact, allowing for more effective dampening of forces in the lower extremity (Lieberman et al., 2010). This example clarifies the reason why when most people jump, they land on the ball of the foot, and the principle is similarly applicable to barefoot and minimalist running, which is fundamentally repeated jumping from one leg to the other leg (Lieberman, 2012).

BAREFOOT VERSUS CONVENTIONAL SHOES: STRIDE DIFFERENCES

Barefoot runners also have a tendency to use slower stride frequency (SF) and longer stride length when instructed to run in conventional shoes at the same speed (Divert et al., 2008; Squadrone & Gallozi, 2009). Lieberman found the opposite, stating barefoot running result in shorter strides and greater frequencies with shorter stance phases than shod athletes (2010). A number of studies (Divert et al., 2008; Jenkins & Cauthon, 2011; Squadrone & Gallozi, 2009) have found that SF of elite shod runners normally range between 170-180 steps per minute (SPM) even at lower speeds such as 6 mi/hr; however, sub-elite runners frequently use a lower average SF of around 150-160 SPM at similar speeds. Studies of sub-elite barefoot runners affirm that these runners have a tendency to use a higher SF than shod runners, ranging from 175-182 SPM at speeds of 6.7 mi/hr (Divert et al., 2008; Jenkins & Cauthon, 2011; Squadrone & Gallozi, 2009).

Chapter III

SUBJECTS

The subjects participating in this experiment include those who are male or female students attending Fort Lewis College. They will meet the operational definition of being “fit” and a “runner.” Ages of the participants will be between 18 and 47 years old. Subjects used on a volunteer basis recruited through e-mailing soccer and cross-country coaches.

INCLUSION AND EXCLUSION REQUIREMENTS

INCLUSION:

- Persons who match the operational definition of a “runner”
- Persons who match the operational definition of being “fit”
- Persons who volunteer from Fort Lewis College

EXCLUSION:

- Persons who match the operational definition of “over weight”
- Persons with flat feet
- Persons with foot or knee injuries within the last year or that impacts their ability to run without pain
- Persons who are pregnant
- Persons with high blood pressure or other cardiovascular disease
- Persons under the influence of drugs or alcohol

MATERIALS

This experiment will require the use of the exercise science laboratory. Equipment used in this lab will be the use of the treadmill to allow the subjects to run in one spot at a consistent speed and time. The gas analysis mask to be worn by subject will accurately measure gases. Along with the mask, the gas analysis machine will accurately interpret gas and convert into useable data. Also, a scale and measuring tape will be used to measure weight and height respectively.

PROTOCOL\METHODS

Participants will be asked to come to the initial meeting with their conventional running shoes. First, subjects will read and acknowledge their participation is voluntary, they have signed an informed consent form and they have signed recognizing the risks involved in their participation. Then, they will be weighed, their shoes will be weighed, have their height measured, and they will fill out a demographic sheet. Participants will then randomly draw pieces of paper depicting the order in which they will run in their shoes. Next, participants will be given instructions to run on the treadmill for 20 minutes continuously at a comfortable speed, in which they could repeat for two additional 20-minute runs. After placing the gas analysis mask on their face, they will start warming up for 5 minutes making sure the equipment is functioning properly. Then they will run the required time of 20 minutes in the first randomly chosen shoe. Afterwards they will take a 5 minute break to get a drink of water and change shoes. Then, the participants will repeat two additional 20 minute bouts in the order in which they drew the type of shoe to run in.

CALCULATIONS AND STATISTICS

This study looks at the relationship between conventional running shoes and minimalist shoes and their effect on running economy. Because this experiment is looking at the differences between conventional shoes and minimalist shoes and the same subjects are being tested twice, a paired t-test was chosen.

This study will also evaluate if there is a difference between the control and the acute affects of the 4 mm and 0mm shoes.

This study will evaluate the difference between the 4mm and 0 mm drop shoes.

Finally, this study will calculate results with and without incorporating in the differences of shoe weight.

Chapter IV

RESULTS

SUBJECTS

The subject's physical characteristics are shown in Table 1. The subjects ranged in age from 18-42 years old with an average age of 21.9 years old. The subjects ran at speeds ranging from 7.2 to 13.68 kph, with an average speed of 8.78 kph. All the subjects met the inclusion criteria and there were 8 girls and 18 men, however 2 subjects were excluded due to results that were extraneous, and thus only 23 subjects were included in the results.

Table 1. Subject Characteristics

Characteristic	Mean±SD
Height(cm)	175±7.1
Weight (kg)	67.6 ± 8.1
Age (y)	21.9 ±5.7
Running Speed (kph)	8.78 ± 1.46

The shoes, as shown in Table 2, were all very similar in weight for the respected trials. The average control shoes weight was .599 kg, ranging from .362 to .907 kg.

Table 2. Shoe Characteristics: Weight in kg

Characteristic	Mean±SD
Control	.599±.13
4mm	.424±.094
0mm	.247±.064

DATA RESULTS

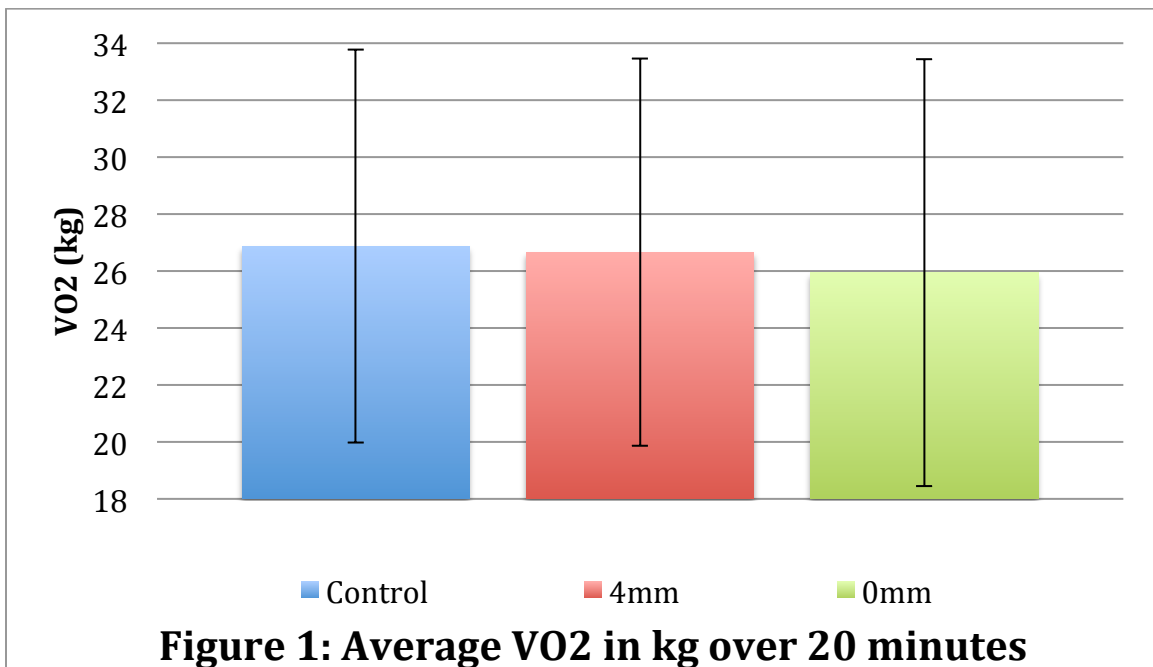
The results of the repeated one-way ANOVA for VO₂ in kg are presented in Table 3. The repeated one-way ANOVA was chosen to compare differences between the three independent groups where the subjects were tested more than 2 times. The f-stat (1.04) was smaller than the f-crit (3.23), and the P-value (.35) was greater than .05, thus the null hypothesis was accepted. The P-value is very high and thus there is a 65% chance of getting the results randomly by chance.

Table 3:

Anova: Two-Factor Without Replication

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Shoes	9.98	2	4.99	1.04	0.35	3.23
Error	190.48	40	4.76			
Total	3207.85	62				

The average VO₂ values in kg are presented in Figure 1 below. This figure supports the null hypothesis stating the 0mm shoes and the 4mm will not affect running economy.



Chapter V

CONCLUSION

Based upon the data collected and after analysis, the data does not support the hypothesis. This hypothesis stated that the 0mm drop shoe would be more economical than the 4mm and the control. However, the ANOVA showed no statistical difference, thus the null hypothesis was accepted.

DISCUSSION

This study was conducted in order to see if minimalist running shoes make a significant impact on running economy. The research of this study only investigated the acute affects of these minimalist running shoes. The main selling points of minimalist running shoes are that they help decrease injury frequency and improve running economy. Although this was not the result we came to in our study, it has been displayed in other similar studies in our field. “Minimally shod runners are modestly but significantly more economical than traditionally shod runners regardless of strike type, after controlling for shoe mass and stride frequency” (Perl, 2012). This research seems to make minimal running shoes appear as if they are everything that they are built up to be. Shoe mass is a common main comparison point and difference maker in most studies. Several studies have validated the effects of shoe weight, minimalist footwear, and bare feet on running economy (Bootier, 2012).

The hypothesis stated that running economy would be more economical in the 0mm compared to the 4mm and control, however there was no statistical significance. The mean values for the control (26.8 kg) 4mm (26.6 kg) and 0mm (25.9 kg) showed a slight trend toward the 0mm being the most economical, however the ANOVA showed no statistical difference between the groups. The f-stat (1.048) was smaller than the f-crit (3.23), and the P-value (0.359) was greater than .05, therefore the null hypothesis was accepted.

The results of this study can be due to several reasons. One reason could be attributed to participants not changing their strike pattern from a rear foot strike to a fore foot strike, which has been shown to be more economical (Lieberman et al, 2000). Another reason could be participants were unable to adapt to the changes in heel to toe drop. Therefore, they were uncomfortable and as a result, worked harder to accommodate to the differences. A couple other factors that may have influenced the recorded results are the runners' experience and the timetable available for the study. The subjects used in the study were experienced and often runners. This is something that could give such results as no significant changes because these runners are trained to run at a certain stride frequency, stride type, and breathing pattern that they are used to controlling for. Between each trial and shoe change, these trained subjects could have adjusted each shoe quickly to how they are accustomed to running. The other aspect to be accounted for is the timetable available for the study. Only the acute affects of minimalist running shoes were measured and all trails taken in the same testing period. If there was an adaptation

period to the minimalist running shoes after the first testing period, a second trial run in the shoes could have showed a major difference in running economy.

RECCOMENDATIONS

Some ways to improve the test to be more accurate would be first to increase the population size, have a closer ratio of men to women, and to better represent runners, get participants from a wider range of athletes, instead of mainly the cross country and men's club soccer team. Not only population, but also the design of the study should be addressed. The participants should have at least a week to run in their next pair of shoes before being tested in them, so that they can get used to how they are different from their previous pair. Some participants found it difficult to run 20 minutes in one shoe, then break for water, switch shoes and run again for 20 minutes. If they had time to adapt, then this may not be as difficult of a change. The VO₂ machine, Vacumed mini-CPX, could have attributed to some error as there were times when it wasn't working and the tube collected lots of condensation, which collected as water, possibly blocking some of the air to be accurately analyzed.

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