

Research article

The Effect of Training in Minimalist Running Shoes on Running Economy

Sarah T. Ridge ¹✉, Tyler Standifird ², Jessica Rivera ¹, A. Wayne Johnson ¹, Ulrike Mitchell ¹ and Iain Hunter ¹

¹Department of Exercise Sciences, Brigham Young University, Provo, UT, USA

²Department of Exercise Science and Outdoor Recreation, Utah Valley University, UT, USA

Abstract

The purpose of this study was to examine the effect of minimalist running shoes on oxygen uptake during running before and after a 10-week transition from traditional to minimalist running shoes. Twenty-five recreational runners (no previous experience in minimalist running shoes) participated in submaximal VO_2 testing at a self-selected pace while wearing traditional and minimalist running shoes. Ten of the 25 runners gradually transitioned to minimalist running shoes over 10 weeks (experimental group), while the other 15 maintained their typical training regimen (control group). All participants repeated submaximal VO_2 testing at the end of 10 weeks. Testing included a 3 minute warm-up, 3 minutes of running in the first pair of shoes, and 3 minutes of running in the second pair of shoes. Shoe order was randomized. Average oxygen uptake was calculated during the last minute of running in each condition. The average change from pre- to post-training for the control group during testing in traditional and minimalist shoes was an improvement of $3.1 \pm 15.2\%$ and $2.8 \pm 16.2\%$, respectively. The average change from pre- to post-training for the experimental group during testing in traditional and minimalist shoes was an improvement of $8.4 \pm 7.2\%$ and $10.4 \pm 6.9\%$, respectively. Data were analyzed using a 2-way repeated measures ANOVA. There were no significant interaction effects, but the overall improvement in running economy across time (6.15%) was significant ($p = 0.015$). Running in minimalist running shoes improves running economy in experienced, traditionally shod runners, but not significantly more than when running in traditional running shoes. Improvement in running economy in both groups, regardless of shoe type, may have been due to compliance with training over the 10-week study period and/or familiarity with testing procedures.

Key words: Footwear, training, oxygen consumption.

Introduction

Many people enjoy the sport of running for overall fitness as well as a competitive sport. How long people can run at a given speed depends on many factors, including running economy. Running economy is in part determined by the ability of the muscles to store and release elastic energy (Saunders et al., 2004). If the body can more efficiently use oxygen in storing and releasing elastic energy, then the athlete should be able to run faster, for longer periods of time (Saunders et al., 2004). For years, athletes have sought new ways to improve their running economy.

In recent years, running in minimalist shoes has become increasingly popular. The purpose of minimalist shoes is to mimic barefoot running which, according to proponents of barefoot running, is the way humans

evolved to run (Squadrone and Gallozzi, 2009). While traditional running shoes have an elevated padded heel and shock absorbers, minimalist shoes are designed to provide just enough protection against potentially harmful terrain whilst allowing similar flexibility to running barefoot.

Factors affecting running economy have been studied for many years (Saunders et al., 2004). Some of the known factors which can either improve or impede running economy include, but are not limited to: distance, strength training, velocity, altitude exposure, stride length, and running kinematics (Tartaruga et al., 2012). Researchers have looked at the effect of minimalist shoes on running economy using submaximal and maximal VO_2 testing procedures with varied results (Lussiana et al., 2013; Perl et al., 2012; Sobhani et al., 2014; Squadrone and Gallozzi, 2009; Warne and Warrington, 2014). Two studies noted a significant improvement in running economy in minimalist running shoes compared with traditional shoes (Perl et al., 2012; Squadrone and Gallozzi, 2009). One study used experienced barefoot or minimalist shoe runners and showed improved running economy in minimalist shoes regardless of which foot strike mechanics the runners used (Perl et al., 2012). Another study also used experienced barefoot runners and reported improved running economy in minimalist shoes compared to traditional shoes (Squadrone and Gallozzi, 2009). Interestingly, there was no significant difference in running economy between minimalist shoe and barefoot running or barefoot and traditional shoe running. Warne and Warrington (2014) employed a four-week familiarization period, where all of the runners continued to train their typical weekly mileage in traditional shoes, while transitioning gradually into using the minimalist running shoes. This study was the only study that found a statistically significant improvement in running economy due to training. The fact that they used runners without experience in running barefoot or with minimalist running shoes might have played a role in these findings. Three other studies found small, but not statistically significant differences in running economy between minimalist and traditional shoes (Lussiana et al., 2013; Paulson and Braun, 2014; Sobhani et al., 2014). Sobhani et al. (2014) assessed the effect of three different types of shoes on running economy, including minimalist shoes. Paulson and Braun (2014) compared the running economy of female distance runners barefoot, in minimalist shoes, and in traditional running shoes, while Lussiana et al. (2013) looked at running economy in traditional and minimalist shoes

when running on slopes. Sobhani et al. (2014) and Lusiana et al. (2013) used habitually shod runners, while Paulson and Braun (2014) used runners who were accustomed to doing some barefoot training, though no minimalist shoe running.

The varying results in previous studies from using runners with and without experience in minimalist shoes lead us to question the effect that transitioning to using minimalist shoes would have on runners with no previous experience in minimalist shoe running. In addition, most of the previous studies assessed the effect of minimalist shoes on running economy during one data collection session. This study is the first to test runners with no experience in minimalist shoes and a control group before and after a 10 week transition training period. With this design, a relationship may be established between transitioning to minimalist shoes and improved running economy.

Therefore, the purpose of this study was to look at the effect of minimalist shoes on running economy before and after a 10-week transition from traditional running shoes. The first hypothesis was that a group transitioning to minimalist shoes from traditional running shoes would demonstrate improved running economy when comparing changes within group pre- to post-training. The second hypothesis was that while there would be no difference between the minimalist shoe group and the control group during pre-training testing in minimalist or traditional shoes, the minimalist shoe group would have better running economy than the control group when running in the minimalist shoes during post-training testing (comparing between groups).

Methods

Fifty experienced runners were recruited as part of a larger study. Twenty-five (11 women, 14 men) of those runners participated in both pre- and post-training VO_2 testing. To qualify for the study each participant had to be injury free for six months prior to starting the study, and was running 15-30 miles per week in traditional running shoes. Traditional running shoes were defined as running shoes with a cushioned elevated heel, arch supports, and a rigid sole. Runners were excluded if they had any experience in minimalist running shoes. Minimalist running shoes were defined as shoes without an elevated heel or cushioning, and with minimal artificial support. The study was approved by the Brigham Young University institutional review board and study participants read and signed the informed consent prior to starting the study. Participants were randomly assigned to either the control group or the experimental group who would be transitioning to minimalist shoes by drawing a group assignment from one of two paper bags – one for male subjects and one for female subjects. At the start of the study, each bag contained an equal number of “control” and “minimalist” assignments. The minimalist shoes used were Vibram FiveFingers (VFF). Over the ten-week training period all participants kept a record of their total mileage per week. The participants in the control group continued to run in traditional running shoes, while the individuals in the

experimental group began to transition to minimalist running shoes. The experimental group followed a training regimen as recommended by Vibram, on the VFF website in January 2011 to transition slowly from traditional shoes to minimalist shoes (“Vibram FiveFingers,” 2011). The training involved replacing some of their weekly mileage with mileage completed wearing the VFF.

During the first week of training participants in the experimental group were instructed to run between 1-2 miles in the VFF, while maintaining the rest of their typical mileage in traditional running shoes. During the following weeks, weeks 2 and 3, they were instructed to run in the VFF for an additional 1-2 miles each week. After week 3 the participants were encouraged to increase mileage in the VFF as they felt appropriate, depending on symptoms of pain. The reasoning behind following the flexible protocol, as recommended by Vibram, was to simulate the most realistic situation possible, allowing the participants the flexibility that typical runners would experience as they transition from traditional to minimalist running shoes. The runners logged the time spent wearing the running shoes, and the distance and time of their runs as well as noting any pain. The participants were also instructed to keep their mileage consistent week to week. Throughout the course of study, the participants in both the control and experimental groups were instructed to keep the same traditional running shoe when they were not running in the VFFs.

Prior to the training, the participants’ running economy was measured while running in both traditional running shoes and minimalist shoes. The traditional running shoes used were not standardized; they were the shoes that the participant regularly trained in. The running economy of each participant was measured with this same protocol again at the end of the 10-week transition. The participants chose individual running speeds, based on the participant’s 5k or 10k pace. This speed was kept constant throughout the 9-11 minutes of running during the pre- and post-training testing. Oxygen uptake was measured as they ran in two submaximal conditions, one in VFF and one in traditional shoes. The order of shoe type was randomized for each testing session using either a random number generator or by having the researcher hold a number in each hand (hidden from the subject) and allowing the subject to choose a hand (in either case, 1=vibram or 2=traditional shoe). This randomization resulted in 17 participants running in VFF first during pre-training testing and 7 participants running in VFF first during post-training testing. Oxygen uptake was recorded using Parvo Medics True Max 2400 (Sandy, UT). Participants ran for three minutes as a warm up while attached to the device, wearing their first set of shoes. During the following three minutes, oxygen uptake was measured. In between conditions, the participants changed shoes before the second data collection was performed. This also lasted three minutes. If oxygen uptake had not reached a plateau at the end of the 3-minute data collection, the test was extended another minute to ensure a steady state submaximal effort. The average oxygen uptake was recorded during the last minute of running in each stage, to allow

for the runner to acclimate to the equipment. Data from the final minute of running were averaged and used for further analysis. Descriptive statistics are presented as mean \pm standard deviation. Normal distribution was checked by the Shapiro-Wilk normality test. Running economy data were then analyzed using a 2-way (training group by testing condition) repeated measures ANOVA with statistical significance set at $p < 0.05$.

Results

Ten experimental group runners and 15 control group runners were included in these analyses. Participants' descriptive data is listed in Table 1. Of the runners who began participation in this study, 4 experimental group runners dropped out of the study due to an injury related to the study. Two other runners (1 from the experimental group and 1 from the control group) dropped out due to injuries that were unrelated to the study. Therefore, data used for these analyses are from all subjects who were able to complete pre- and post-training VO_2 testing.

Table 1. Table of participants' characteristics. Data are means (\pm standard deviation).

	Control Group (n=15)	Experimental Group (n=10)
Height (cm)	1.73 (.09)	1.74 (.14)
Weight (kg)	68.2 (13.5)	71.8 (13.4)
Age (years)	28.3 (6.7)	24.1 (5.5)
Sex (# male, # female)	7, 8	6, 4

Average running speed and pre- and post-training VO_2 measurements are shown in Table 2. Results of the 2-way repeated measures ANOVA showed that there was no significant difference in running economy between the two groups before training or after training ($p = 0.586$). Taken together, both groups showed improved running economy during post training measurements in both shoe conditions ($p = 0.015$). No group by time interaction ($p = 0.443$) or group by condition ($p = 0.885$) interactions were observed.

Discussion

The purpose of this study was to examine the effects of 10 weeks of training in minimalist running shoes on running economy. The data supported our first hypothesis – after 10 weeks of training, the VFF group improved their running economy. However, the second hypothesis was not supported, in part because the experimental and control groups showed improvement in their running economy after the ten-week training period.

The average improvement in the VFF group was

much higher than control, regardless of test shoe, after 10 weeks of training. Nine out of the 10 VFF runners showed improved running economy at the end of the study. The control group showed much more variability during post-training testing, as evidenced by the large standard deviations in the percent change from pre- to post-training testing (Table 2).

While we expected an improvement in running economy in the VFF group, the improvement in the control group was surprising. However, the improvement in both groups may have been the result of participating in a study and being accountable for the miles they ran. This may have led to more consistent running, which could potentially lead to greater fitness and thus improved oxygen uptake when running at the same velocity. The other study to have measured runners pre- and post-training found a significant improvement in running economy in minimalist running shoes; however, a small improvement in the post-training traditionally shod conditions was also found (Warne and Warrington, 2014). Since there was not a separate control group training in only traditional running shoes in that study, those results could have been similar to the results seen in this study, possibly caused by the effect of participating in a study.

A unique aspect of this study was following two groups of runners over a transition period: a control group and an experiment group. Simulating a realistic experience of a traditionally shod runner transitioning into minimalist shoes, this study used runners who had no experience in minimalist shoes or barefoot running. There was no significant difference in running economy pre-training between the two groups as was predicted. However, after the 10 weeks of training in the minimalist shoes, there was still no significant difference in running economy between the VFF group and the control group. It is possible that the VFF group in the present study was not fully transitioned to the minimalist shoes. In fact, of the 9 VFF runners that we have training log data for, only 4 were running more mileage in the VFF than in their traditional shoes at the end of the study. From this data, we can see that running economy increases may not become evident until runners are comfortable and fully transitioned to minimalist footwear.

In similar studies, the running economy of participants who were experienced in minimalist shoes were tested (Perl et al., 2012; Squadroni and Gallozzi, 2009). Since those participants were habitually minimalist shoe runners, it is possible that the differences seen when traditionally shod came as a result of running in an unfamiliar shoe type. In the aforementioned studies assessing the effect of different shoes on running economy, two which did not find significant improvements in running

Table 2. Average (\pm SD) VO_2 measurements for each group, in each shoe condition during pre- and post-10 weeks of training.

Time	Control Group			Experimental Group		
	Traditional	VFF	Speed	Traditional	VFF	Speed
Pre	42.9 (7.4)	42.0 (7.3)		42.6 (4.1)	42.6 (5.4)	
Post	40.8 (5.2)	39.9 (4.8)	3.45 (.44)	39.1 (5.8)	38.2 (5.7)	3.34 (.46)
% change (pre-post)	3.1 (15.2)*	2.8 (16.2)*		8.4 (7.17)*	10.4 (6.88)*	

VO_2 measurements are in $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, running speed measurements are in m/s. p-values for various comparisons are listed in the Results section. * denotes improvement from pre- to post-training testing.

economy in minimalist running shoes did not use participants with experience in minimalist or barefoot running (Lussiana et al., 2013; Sobhani et al., 2014). By providing a ten week training transition for one group of the participants and using the other group as a control, the current study attempted to see if the results showing an improvement in running economy were unique only because of the unfamiliarity of the different shoe from the habitually used shoe. Based on our results, it seems possible that after experience with minimalist shoes, running economy does improve. Unfortunately, we are not able to confirm that statement without more testing. Due to the high injury rate in this study, we were not able to do more testing following the same transition protocol.

One possible reason for the variability of the results seen in our study is that we used a sub-maximal test. This allowed for variability in when the subject reached a plateau of VO_2 and therefore may not have provided the same narrow window of comparison as a VO_2max test would have in assessing running economy. VO_2max testing may indicate a more accurate representation of oxygen uptake. In similar studies, with the exception of the study by Warne et al. (2014), VO_2max was also not measured, rather, a VO_2 sub-maximal protocol was used instead (Lussiana et al., 2013; Perl et al., 2012; Sobhani et al., 2014; Squadrone and Gallozzi, 2009). In this study, participants chose personalized running speeds based on their 5k or 10k pace. The speeds were consistent between the pre-training trial and the post-training trial. A study investigating running economy at different velocities in well-trained runners measured VO_2max , and also measured VO_2 results for different incremental speeds lower than the maximal. No differences in running economy were found in intensities between 60-90% of VO_2max thus concluding that sub-maximal VO_2 measurements are a reliable representation for running economy (Helgerud et al., 2010). These results confirm the results of other previous research which also indicates that sub-maximal VO_2 testing were reliable (Helgerud, 1993). Using the same individualized running speed during pre-training and post-training data collection helped to keep inaccuracies from the variety of speeds to a minimum, and we therefore believe that sub-maximal VO_2 testing was appropriate for this study.

Another possibility for the improvement found in both groups in this study was familiarity with testing procedures. Most runners are not accustomed to running with a mouthpiece, breathing into a machine. By allowing a three-minute warm-up run, participants had a small window in which to familiarize themselves with the equipment before results were recorded. It is possible that the overall improvement seen post-training was because the participants were more comfortable running attached to the mouthpiece and tubing since it was their second time participating with the protocol.

Possible limitations of the study were that either foot-strike or shoe mass could have affected the results, neither of which we controlled. There are many views among coaches about how much foot-strike affects runners' biomechanics, and there is contrasting evidence on whether or not strike-pattern affects running economy

(Hasegawa et al., 2007). One study looked at traditionally shod runners and the effect the foot-strike could have upon running economy (Shih, Lin, & Shiang, 2013). Their results indicated that being shod or barefoot made little difference to running economy rather, a forefoot strike would improve running economy in comparison to a heel-strike. Another study controlled for foot-strike by having their participants fore-foot strike and also heel-strike, in both minimalist and traditional running shoes, and found no significant difference in running economy (Perl et al., 2012). Although participants in this study were not measured for foot-strike angle or changes in foot-striking pattern during this testing, according to the results previously indicated, it should not have affected the results (Perl et al., 2012).

The fact that we did not control for shoe mass was another limitation in this study. We believe though that shoe mass does not affect the results. One study assessed the effect that adding mass to the shoe would have on running economy (Divert et al., 2008). By using specially designed diving socks, and differently weighted shoes, they discovered that the added mass rather than shoe had the greater effect on running economy. Contrary to these results, a different study controlled for shoe mass by adding weight to the minimalist shoes to make them weigh the same as the traditional shoes (Perl et al., 2012). This study still found an improvement in running economy. Therefore, it seems that differences in shoe mass do not account for the results seen. Though we did not measure each shoe in this study prior to testing, average mass of traditional running shoes is approximately 350-400 grams, while the VFF were approximately 300 grams. Our results also show no differences in running economy between shoes worn during the same testing session. The improvements after training were similar with each group, regardless of type worn during testing.

Conclusion

Both groups showed improvement in running economy after the 10 week training period; when considered together, there was an overall significant improvement in running economy of 6.15% ($p = 0.015$) after the 10 week training period, regardless of shoe type. Therefore, we can conclude that minimalist running shoes alone do not improve running economy in experienced, traditionally shod runners any more than training in traditional running shoes. However, since the experimental group showed greater (though not statistically significant) improvement than the control group, it seems possible that with more subjects and a more controlled transition protocol, significant improvement in running economy may be seen in runners who have transitioned to minimalist shoes.

Acknowledgements

Financial support for this project was provided by internal funds from the Department of Exercise Sciences at Brigham Young University.

References

- Divert, C., Mornieux, G., Freychat, P., Baly, L., Mayer, F. and Belli, A. (2008) Barefoot-shod running differences: shoe or mass effect?

International Journal of Sports Medicine **29**, 512-518.

- Hasegawa, H., Yamauchi, T. and Kraemer, W.J. (2007) Foot Strike Patterns of Runners at the 15-km Point During an Elite-Level Half Marathon. *Journal of Strength and Conditioning Research* **21**, 888-893.
- Helgerud, J. (1993) Maximal Oxygen Uptake Anaerobic Threshold and Running. *European Journal of Applied Physiology* **68**, 155-161.
- Helgerud, J., Støren, O. and Hoff, J. (2010) Are there differences in running economy at different velocities for well-trained distance runners? *European Journal of Applied Physiology* **108**, 1099-1105.
- Lussiana, T., Fabre, N., Hébert-Losier, K. and Mourot, L. (2013) Effect of slope and footwear on running economy and kinematics. *Scandinavian Journal of Medicine & Science in Sports*, **23**, e246-253.
- Paulson, S. and Braun, W.A. (2014) Mechanical and physiological examination of barefoot and shod conditions in female runners. *International Journal of Sports Medicine* **35**, 789-793.
- Perl, D.P., Daoud, A.I. and Lieberman, D.E. (2012) Effects of footwear and strike type on running economy. *Medicine and Science in Sports and Exercise* **44**, 1335-1343.
- Saunders, P.U., Pyne, D.B., Telford, R.D. and Hawley, J.A. (2004) Factors Affecting Running Economy in Trained Distance Runners. *Sports Medicine (Auckland, N.Z.)* **34**, 465-485.
- Shih, Y., Lin, K.-L. and Shiang, T.-Y. (2013) Is the foot striking pattern more important than barefoot or shod conditions in running? *Gait & Posture* **38**, 490-494.
- Sobhani, S., Bredeweg, S., Dekker, R., Kluitenberg, B., van den Heuvel, E., Hijmans, J. and Postema, K. (2014) Rocker shoe, minimalist shoe, and standard running shoe: a comparison of running economy. *Journal of Science and Medicine in Sport* **17**, 312-316.
- Squadrone, R. and Gallozzi, C. (2009) Biomechanical and physiological comparison of barefoot and two shod conditions in experienced barefoot runners. *The Journal of Sports Medicine and Physical Fitness* **49**, 6-13.
- Tartaruga, M.P., Brisswalter, J., Peyré-Tartaruga, L.A., Ávila, A.O.V., Alberton, C.L., Coertjens, M., Cadore, E.L., Tiggemann, C.L., Silva, E.M. and Krueel, L.F.M. (2012) The Relationship Between Running Economy and Biomechanical Variables in Distance Runners. *Research Quarterly for Exercise and Sport*, **83**, 367-375.
- Vibram FiveFingers. (2011) Available from URL: <http://www.vibramfivefingers.com>
- Warne, J.P. and Warrington, G.D. (2014) Four-week habituation to simulated barefoot running improves running economy when compared with shod running. *Scandinavian Journal of Medicine & Science in Sports* **24**, 563-568.

Key points

- Running in minimalist footwear did not result in a change in running economy compared to running in traditional footwear prior to 10 weeks of training.
- Both groups (control and experimental) showed an improvement in running economy in both types of shoes after 10 weeks of training.
- After transitioning to minimalist running shoes, running economy was not significantly different while running in traditional or minimalist footwear.

✉ Sarah Ridge, PhD

116B RB Brigham Young University, Provo, UT 84602, USA

AUTHOR BIOGRAPHY



Sarah T. RIDGE

Employment

Department of Exercise Sciences, Brigham Young University.

Degree

PhD

Research interests

Prevention and development of overuse injuries in athletes, optimizing athletic performance.

E-mail: sarah_ridge@byu.edu



Tyler STANDIFIRD

Employment

Department of Exercise Science and Outdoor Recreation, Utah Valley University.

Degree

PhD

Research interests

Orthopedic gait and footwear biomechanics during running.

E-mail: tstandifird@gmail.com



Jessica RIVERA

Employment

Department of Exercise Sciences, Brigham Young University.

Degree

BS

Research interests

Minimalist shoe running, Performance in distance running.

E-mail: jessiriv@gmail.com



A. Wayne JOHNSON

Employment

Department of Exercise Sciences, Brigham Young University.

Degree

PhD, PT

Research interests

Rehabilitation and rehabilitative ultrasound imaging of spinal, leg and foot muscles, Minimalist shoe running, Whole-body vibration, Flexibility, and outcomes of rehabilitation.

E-mail: wayne_johnson@byu.edu



Ulrike H. MITCHELL

Employment

Department of Exercise Sciences, Brigham Young University.

Degree

PhD, PT

Research interests

Posture, minimalist shoe running, spine and intervertebral disc

E-mail: rike_mitchell@byu.edu



Iain HUNTER

Employment

Department of Exercise Sciences, Brigham Young University.

Degree

PhD

Research interests

Biomechanics of distance running related to performance and injury.

E-mail: iain_hunter@byu.edu