

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

EVALUATION OF ENERGY EXPENDITURE WHEN WEARING HOKA RUNNING
SHOES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Science in Clinical Exercise Physiology

Kelsey Loy

College of Science and Health
Clinical Exercise Physiology

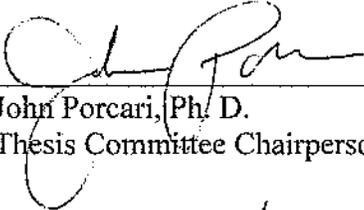
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SHOES

By Kelsey Loy

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology

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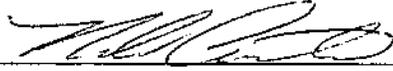
John Porcari, Ph. D.
Thesis Committee Chairperson

5/12/15
Date



Carl Foster, Ph. D.
Thesis Committee Member

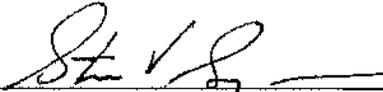
5/12/15
Date



Naoko Aminaka, Ph. D.
Thesis Committee Member

5/12/2015
Date

Thesis accepted



Steven Simpson, Ph.D.
Graduate Studies Director

6/10/15
Date

ABSTRACT

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The purpose of this study was to determine if HOKA shoes positively or negatively affect oxygen consumption while running. Subjects included 16 proficient runners (8 males and 8 females), between 20-65 years of age. All subjects ran 3, 6-minute bouts at a self-selected pace. Each subject ran in HOKA shoes, standard New Balance running shoes, and New Balance shoes with a weight added to match that of the HOKA's mass. Subjects were allowed a 4-minute break to recover and change shoes between bouts. No significant differences were observed in VO_2 , HR, or energy expenditure between the three shoe conditions. Additionally, RPE remained unchanged. Despite their new design aspects, HOKA shoes do not seem to significantly affect running economy.

ACKNOWLEDGMENTS

First and foremost I'd like to thank my parents. Without their unwavering love and support, I wouldn't be where I am in today. Whether it be learning life lessons on the local basketball courts or quietly sipping coffee together in the early morning hours, all of my best memories involve them. No child could ask for better role models. No adult could ask for better friends. I owe everything to them.

I'd also like to express my gratitude to my entire thesis committee, notably John Porcari. I know that the process of working with all of us students can become quite taxing. Their tireless efforts and patience is greatly appreciated.

Finally, I'd like to thank my close friends and classmates. This has been one of the most difficult and yet, somehow, rewarding years of my life. Through the peaks and valleys, they've stuck with me. I can't imagine going through this journey without them. I don't even want to try. Thank you all so incredibly much.

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INTRODUCTION

For runners, the importance of footwear cannot be overstated. Like any other piece of athletic gear, utilizing the proper equipment can affect not only an individual's performance, but also determine safety. Much research has been conducted to determine desirable characteristics for running footwear. However, much remains unknown and new products are routinely introduced to the market with inadequate background research.

In 2010, a company by the name of HOKA ONE ONE (Richmond, CA) launched a line of running shoes that feature a significantly thicker midsole with a rocker bottom. Created for long distance and ultra runners, this unique structure is designed to support an easier transition from the midfoot to the forefoot, while offering increased cushioning from the repeated impact of running.

To date, little to no research has been done on this product and how it affects energy cost. However, data that pertain to certain aspects of this particular shoe can be used to infer its potential influence on running economy. The three most prominent variations in design are HOKA's thickly cushioned soles, a soft compliant midsole, and rocker bottom technology. Looking at each of these facets independently can give a better understanding of this product.

The company claims that with 50% more material added to the sole, these shoes potentially allow for more shock absorption with each foot contact. However,

this attribute inevitably results in increased weight added to the lower extremities. HOKA's product, the Stinson Tarmac shoe, weighs approximately 337 grams. A standard running shoe weighs approximately 200 grams. Previous research has shown that every 100 grams of weight added to each foot during running raises the energy cost by approximately 1% (Frederick, 1985). With this in mind, it is likely that the increase in weight could negatively impact running economy.

When considering the midsole, studies comparing the stiffness of various materials are applicable. Most shoes on the market today fall under one of two categories. They incorporate a soft, compliant midsole or a firm and more rigid material. In 2003, a study was done to test how this variation in design can alter running economy. No significant differences were found between the two designs. However, some subjects showed a consistent variation of up to 2% in running economy. This indicates that individual characteristics or gait patterns may influence how one reacts to these materials (Nigg et al., 2003).

Lastly, the effect of the rocker sole on running must be examined. As a technology that was originally developed for therapeutic purposes in the 1980s, rocker shoes have since been modified as "fitness" or "toning" shoes. The premise is that the rocker bottom sole creates instability, which would require more muscle activation and ultimately increase energy expenditure. With the birth of these new shoes, a line of research emerged. Unfortunately, these studies provide conflicting data.

Porcari, Greany, Tepper, and Foster (2010) found no difference in energy expenditure or muscle activation when subjects walked at various speeds in Skechers

Shape-Ups, Reebok's EasyTone, or MBT rocker shoes in comparison to a standard pair of New Balance running shoes. Conversely, Sobhani et al. (2014) compared the energy expenditure when running barefoot, in standard shoes, or when wearing rocker shoes. They found that wearing rocker shoes resulted in an average increase of 4.5% in energy cost when compared to standard shoes.

To our knowledge, no studies have examined differences in energy cost while running in HOKA shoes versus standard running shoes. The purpose of this study was to determine if HOKA shoes positively or negatively affect oxygen consumption while running.

METHODS

Subjects

Subjects for this study were 16 proficient runners (8 males and 8 females), between 20-65 years of age. Proficiency was defined as individuals who ran at least 15 miles per week and were habituated to exercising on a treadmill. Subjects were recruited from the University of Wisconsin-La Crosse campus. Subjects provided written informed consent before any tests were completed. This investigation was approved by the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects.

Procedures

All testing took place in the Human Performance Laboratory, located in Mitchell Hall, on the University of Wisconsin – La Crosse campus. Subjects were required to attend one testing session, which lasted approximately 1 hour. This session began with completion of necessary paperwork and 5 minutes of practice running on the treadmill with HOKA shoes. Individuals then ran at a self-selected pace for 6 minutes while wearing one of the three shoe conditions. These three options include the HOKA shoe, a standard New Balance running shoe, and the New Balance shoe with a weight added to match that of the HOKA's mass. Upon completion of each run, subjects were allowed a 4-minute break to recover and change shoes. They then ran for an additional 6 minutes in one of the other shoe

conditions. After their final 4-minute rest, they ran for 6 more minutes in the remaining pair of shoes. Trials were performed at the same speed and the order of shoe conditions was randomly assigned.

Throughout each trial, oxygen consumption (VO₂) was measured continuously with an AEI metabolic analyzer (AEI Technologies, Pittsburgh, PA). Heart rate (HR) was recorded each minute with a Polar heart rate monitor (Polar Electro, Inc, Kempele, Finland) and Rating of Perceived Exertion (RPE) was assessed at the termination of each running trial using the 6-20 Borg scale (Borg, 1973). Energy expenditure (kcal) during each 6-minute run was calculated from the oxygen consumption data. The last three minutes of each running session were averaged and utilized for statistical analysis.

Statistical Analysis

Standard descriptive statistics were used to characterize the subject population. Repeated measures ANOVA was used to compare the physiological and subjective responses to running in the HOKA, New Balance, and weighted New Balance shoes. Alpha was set at $p < .05$ to achieve statistical significance.

RESULTS

Descriptive characteristics of the subjects are presented in Table 1. The overall physiological and subjective responses to each of the shoe conditions are presented in Table 2. Physiological responses separated by gender are presented in Table 3.

Table 1. Physical Characteristics of Subjects

	Age (yrs)	Height (in)	Weight (lbs)
Males	33.38 ± 17.27	70.75 ± 1.83	173.88 ± 13.15
Females	22.75 ± 1.58	66.75 ± 1.75	140.25 ± 15.53

No significant differences were observed in VO₂, HR, or energy expenditure between the three shoe conditions.

Table 2. Overall physiologic responses to running in HOKA, New Balance, and Weighted New Balance shoes.

	HOKA	New Balance	Weighted New Balance
HR (bpm)	161 ± 14.6	163 ± 11.9	162 ± 12.7
VO ₂ (ml/kg/min)	42.7 ± 4.89	42.6 ± 5.30	42.9 ± 5.39
kcal/min	15.3 ± 3.21	15.3 ± 3.28	15.4 ± 3.34
RPE	12.5 ± 1.46	12.3 ± 1.40	12.5 ± 1.41

Females had significantly higher heart rates than males for all shoe conditions. Conversely, females had significantly lower VO₂ and caloric expenditure values than males under all three shoe conditions. There was no difference in RPE between genders.

Table 3. Physiologic responses of males and females to running in HOKA, New Balance, and Weighted New Balance Shoes

	HOKA	New Balance	Weighted New Balance
HR (bpm)			
Male	154 ± 12.8	159 ± 9.4	154 ± 7.3
Female	168 ± 13.1*	168 ± 12.9*	171 ± 11.2*
VO ₂ (ml/kg/min)			
Male	45.5 ± 4.56	45.8 ± 4.63	46.0 ± 4.63
Female	40.0 ± 3.62*	39.3 ± 3.81*	39.9 ± 4.48*
kcal/min			
Male	18.0 ± 2.05	18.1 ± 1.77	18.1 ± 2.04
Female	12.7 ± 1.39*	12.5 ± 1.39*	12.7 ± 1.61*
RPE			
Male	12.8 ± 1.91	12.1 ± 1.46	12.4 ± 1.51
Female	12.3 ± .89	12.5 ± 1.41	12.6 ± 1.41

*Significantly different than males (p<.05).

DISCUSSION

As a relatively new product on the market, HOKA's design presents the fitness world with a new concept for a running shoe. Its thickened rocker sole evokes questions regarding how it will affect running economy, particularly in the company's target market of long distance runners. The purpose of this study was to answer that question by comparing the energy expenditure of running in HOKA shoes versus a standard running shoe and a weighted standard shoe. With an abundance of new products entering the market every day, it is important to determine whether or not these products are beneficial to the target population.

It was found that running in all three shoes yielded similar HR, VO_2 , and energy expenditure responses. In addition, the RPE remained constant across all three shoe conditions. The only significant differences seen were between genders. Females had higher heart rates and lower energy cost regardless of which shoe was being worn.

Considering past research performed on the energy cost of adding weight to the lower extremities, one may have expected to see an increase in the physiological responses related to the weight of the shoes (Frederick, 1985). However, the actual weight difference between the shoe conditions was less than expected. In order to ensure any potential changes would be captured, the heaviest road shoe in the HOKA line was selected for this study. This shoe averaged 339.6 grams for male sizes and 267.4 grams for female sizes. When compared with the standard shoe, the HOKA shoes only weighed an average of 72.2 grams more per shoe. Based on the data of

Frederick, a difference of 72.2 grams would account for less than a 1% increase in energy cost. In contrast, previously studied rocker bottom shoes often averaged anywhere from 200-400 grams heavier per pair than the tested standard shoes (Gjovaag, Dahlen, Sandvik, and Mirtaheri, 2011; Koyama, Naito, Ozaki, and Tanagiya, 2012). This may explain a certain portion of the increased oxygen consumption in those studies which found a difference.

The results of this study are similar to those of Porcari et al. (2010) and Santo et al. (2012), who also found that the rocker sole shoes did not affect energy cost. Studies that have found a difference in energy cost often attribute the increase to instability created by the rocker sole. The lack of difference in the current study could be attributed to the adjustment in design between the previously studied rocker shoes and the HOKA shoes. Skecher Shape-Ups and the MBT shoes were manufactured for the purpose of creating instability via an unstable sole design. Based on the results of this study it could be inferred that the HOKA shoes are more stable and thus more conducive to efficient running.

Combining this knowledge with the fact that perceived exertion also remained unchanged leads us to the conclusion that HOKA shoes may be suitable for runners who are seeking a more cushioned shoe option. However, as shoes that are geared towards long distance or ultra runners, studying longer running bouts in each shoe condition may be beneficial. Data found in 6-minute run may not be transferrable to a run of much longer length.

Additionally, it should be noted that each of these trials were run at a 0% grade. There is some evidence that walking on a grade could positively affect energy

cost. Specifically, Gjovaag et al. (2011) had subjects walk at four different combinations of speed and incline. These sessions consisted of a slow pace with no grade, slow pace with a 10% grade, a fast pace with no grade, and a fast pace with a 10% grade. No significant difference was seen at 0% grade. However, walking at a fast pace up a 10% grade did elicit a 5.2% increase in VO_2 as well as a 9 beat per minute increase in HR. A significant increase in RPE was also found. Future researchers may want to study whether or not running in HOKA shoes at grade would have changed the results of this study.

CONCLUSION

When comparing the energy expenditure of running in HOKA shoes versus standard shoes, no significant difference was seen. Additionally, HR response and RPE also remained unchanged. The unique aspects of the HOKA shoes do not seem to significantly affect running economy. Although the HOKA shoes were heavier, the difference in weight may not have been substantial enough to evoke a change in physiologic response. As a new product with potentially beneficial characteristics such as increased cushioning, HOKA shoes may be a suitable alternative to a more traditional shoe type.

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APPENDIX A
INFORMED CONSENT

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Evaluation of Energy Expenditure When Wearing HOKA Running Shoes

Purposes and Procedures

I, _____, give my voluntary informed consent to participate in this study that is designed to determine energy expenditure while wearing HOKA running shoes. In comparison to standard running shoes, HOKA shoes are characterized by a significantly thicker sole as well as a rocker bottom curvature.

I have been informed that my participation in this study will involve three visits to the Human Performance Laboratory in Mitchell Hall, on the UW-La Crosse campus. The length of the visits will be approximately 1 hour each. The first session will entail completion of necessary paperwork and acclimation to equipment. I will be allowed to walk in a pair of HOKA shoes for approximately 15 minutes. The second session will involve running at a self-selected pace for 30 minutes while wearing either the HOKA shoe or a standard running shoe. For the third and final session, I will run for an additional 30 minutes in the opposite shoe to complete my participation. Prior to testing, I will be hooked up to a chest strap to record my heart rate and a snorkel-like mouthpiece to collect my expired air.

Potential Risks

Because of the curved nature of the sole of the shoe I may experience some muscle soreness following the testing session. As with any exercise, there exists the possibility of a cardiovascular complication (e.g., heart attack or stroke). However, in healthy, well-trained individuals such as myself, the risk of serious complications is thought to approach zero. If an emergency should occur, individuals trained in CPR will be in the laboratory at all times. Additionally, the laboratory has a standard emergency plan and an Automated External Defibrillator (AED) is readily available.

Rights and Confidentiality

My participation in this study is entirely voluntary and I can withdraw from the study at any time, for any reason, without penalty. In the event that the results of this study are published in the scientific literature, my name and personal information will not be identified. My results will remain confidential. Only the investigator and appropriate laboratory personnel will have access to my individual data.

APPENDIX B
REVIEW OF LITERATURE

REVIEW OF LITERATURE

For runners, the importance of footwear cannot be overstated. Like any other piece of athletic gear, utilizing the proper equipment can affect not only an individual's performance, but also determine safety. Much research has been conducted to determine desirable characteristics for running footwear. However, much remains unknown and new products are routinely introduced to the market with inadequate background research.

In 2010, a company by the name of HOKA ONE ONE (Richmond, CA) launched a line of running shoes that feature a significantly thicker midsole with a rocker bottom. Created for long distance and ultra runners, this unique structure is designed to support an easier transition from the midfoot to the forefoot, while offering increased cushioning from the repeated impact of running.

To date, little to no research has been done on this product and how it affects energy cost. However, data that pertain to certain aspects of this particular shoe can be used to infer its potential influence on running economy. The three most prominent variations in design are HOKA's thickly cushioned soles, a soft compliant midsole, and rocker bottom technology. Looking at each of these facets independently can give a better understanding of this product.

The company claims that with 50% more material added to the sole, these shoes potentially allow for more shock absorption with each foot contact. However, this attribute inevitably results in increased weight added to the lower extremities. HOKA's product, the Stinson Tarmac shoe, weighs approximately 337 grams. A standard running shoe weighs approximately 200 grams. Previous research has shown

that every 100 grams of weight added to each foot during running raises the energy cost by approximately 1% (Frederick, 1985). With this in mind, it is likely that the increase in weight could negatively impact running economy.

When considering the midsole, studies comparing the stiffness of various materials are applicable. Most shoes on the market today fall under one of two categories. They incorporate a soft, compliant midsole or a firm and more rigid material. In 2003, a study was done to test how this variation in design can alter running economy. No significant differences were found between the two designs. However, some subjects showed a consistent variation of up to 2% in running economy. This indicates that individual characteristics or gait patterns may influence how one reacts to these materials (Nigg et al., 2003).

Lastly, the effect of the rocker sole on running must be examined. As a technology that was originally developed for therapeutic purposes in the 1980s, rocker shoes have since been modified as “fitness” or “toning” shoes. The premise is that the rocker bottom sole creates instability, which would require more muscle activation and ultimately increase energy expenditure. With the birth of these new shoes, a line of research emerged. Unfortunately, these studies provide conflicting data.

Porcari et al. (2010) found no difference in energy expenditure or muscle activation when subjects walked at various speeds in Skechers Shape-Ups, Reebok’s EasyTone, or MBT rocker shoes in comparison to a standard pair of New Balance running shoes. Conversely, Sobhani et al. (2014) compared the energy expenditure when running barefoot, in standard shoes, or when wearing rocker shoes. They found

that wearing rocker shoes resulted in an average increase of 4.5% in energy cost when compared to standard shoes.

To our knowledge, no studies have examined differences in energy cost while running in HOKA shoes versus standard running shoes. The purpose of this study was to determine if HOKA shoes positively or negatively affect oxygen consumption while running.

Energy Cost of Loading Feet

It has been known since the early 1980s that loading the extremities, particularly the feet, will result in a greater energy expenditure while the body is in motion. In 1985, it was reported that an addition of 100 g of weight added to each foot raises the aerobic demands of running by about 1% (Frederick, 1985). Around the same time, a study done by Martin (1985), yielded similar data. Subjects included 15 highly trained males. Each subject was required to run at a speed of 12 km per hour under five different loading conditions. The conditions were no weight added, 0.5 kg, and 1.0 kg added to both the thigh and feet. Oxygen consumption and HR were monitored. All five sessions resulted in significantly different values, with the exception of the HR response with thigh loading. Notably, there was approximately a 7.2% increase in VO_2 per kg of load added to the feet.

Since then, several studies have validated these findings. In 2008, Divert et al. studied whether running economy was, in fact, affected by the mass of a shoe or whether gait patterns changed and influenced energy expenditure. Conditions studied included running barefoot, in ultra light socks, in light diving socks, in heavy diving socks, in light shoes, and in standard shoes. Each running bout was completed at a

uniform speed for a duration of 4 minutes. Oxygen consumption remained constant while running barefoot or in the ultra light socks, but was significantly higher in all other modes. These findings suggest that the variation in energy expenditure was a result of the weight differences alone and that gait changes did not play a role in the disparity.

Effect of Exercising in Rocker Soled Shoes

A large pool of research regarding the potential benefits of rocker shoes has been published. Unfortunately, not all of the findings have been in agreeance. Studies finding rocker shoes to increase, decrease, or have no effect on energy expenditure all exist. First, we will examine research that has found a correlation between the utilization of rocker bottom shoes and an increase in oxygen consumption.

Sobhani et al. (2014) compared the energy cost of running in rocker shoes, minimalist shoes, and standard shoes against each other to distinguish which had preferable energy economy. It was found that rocker shoes' oxygen consumption was increased by an average of 4.5% in comparison to standard running shoes. Although a certain percentage of this number can be attributed to the weight of the shoes, it does not account for the entirety of the difference seen.

Several other studies have found similar results. In 2012, Koyama, Naito, Ozaki, and Tanagiya had 14 subjects walk at various speeds in both an unstable shoe and a traditional walking shoe. After a 20-minute warm-up, subjects walked at speeds of 3, 4, 5, 6, and 7 km per hour at a 0% grade for 3 minutes during the first session. The second trial consisted of an identical warm-up followed by walking at 3.6 km per hour. This speed increased to 7.2 km per hour in increments of 0.9 km per hour every

6 minutes. This yielded data showing an increase in HR, VO_2 , and muscle activity while walking in Skecher Shape-Ups shoe. It should be noted that the mean mass of the unstable shoe was 1.00 kg while the standard shoe weighed only 0.54 kg per pair. This can account for a certain amount of the energy expenditure increase.

Yap, Nakamae, and Henry (2012) also compared the energy cost of Skecher Shape-Ups to a standard shoe. However, this research design accounted for the weight difference and looked at energy expenditure over a 40-minute period in order to ensure that any potential changes in energy expenditure were due to shoe design rather than a difference in weight. Thirty adults who had never worn this particular rocker shoe before were tasked with walking, climbing stairs, and other types of light exercise for 40 minutes in both a weighted control shoe and the Shape-Ups. Interestingly, there was a significant increase in energy expenditure while wearing the Shape-Ups compared to a standard shoe, but only for the first 5 minutes of exercise. It appears that after this time period, individuals acclimated to the unstable shoe condition.

Another commonly tested rocker sole shoe are Masai Barefoot Technology shoes (MBT). Two separate studies compared exercising in MBTs to a standard shoe. The first study had subjects walk at a slow pace with no grade, slow pace with a 10% grade, a fast pace with no grade, and a fast pace with a 10% grade. No significant differences were seen in the physiological responses except for walking at a fast pace up a 10% grade. This condition provoked a 5.2% increase in VO_2 as well as a 6.6% increase in HR, and a significantly higher RPE. It is important to note that the pair of

MBT shoes weighed an average of 432 grams more than the standard pair of shoe in this experiment (Gjovaag, Dahlen, Sandvik, and Mirtaheeri, 2011).

A study by Maffiuletti, Malatesta, Agosti, and Sartorio (2012) evaluated oxygen consumption of 29 obese subjects while both standing still and walking at a predetermined comfortable speed in MBT shoes. Findings showed a 5-7% increase in VO_2 while standing still and walking. The researchers attributed this to increased shoe mass and an increase in muscle activation.

Fukuchi, Worobets, and Stefanyshyn, (2013) investigated the affects of wearing Mark's Warehouse Calotones on energy cost. Calotones are similar in structure to other rocker shoes on the market and weigh approximately 120 grams more than a standard walking shoe. With that in mind, 12 women walked for 5 minutes at 1.4m/s in both standard New Balance shoes as well as the Calotones. It was found that there was a 3.4% increase in energy expenditure while walking in the rocker shoe. Once again, the heavier mass can explain a portion of this increase, but not all of it.

In contrast to the aforementioned studies, several studies found no difference in VO_2 when exercising in rocker sole shoes. Santo, Roper, Dufek, and Mercer (2012) had 28 subjects walk on the treadmill for 10 minutes in standard shoes, standard shoes with additional weight equivalent to the rocker bottoms, and finally in the rocker bottom shoes themselves. They found no difference in energy expenditure between any of the shoe conditions.

A study by Porcari et al. (2011) studied the energy expenditure and electromyographic response to walking in Skecher's Shape-Ups, Masai Barefoot

Technology (MBT), and Reebok EasyTones in comparison to a New Balance running shoe. Twelve women walked for 5 minutes at three different speeds and grades. There were no significant differences in VO_2 , heart rate, or caloric expenditure between any of the conditions. In fact, the only difference that was observed was a significantly higher RPE for MBT shoes at 3.5 mph and 5% grade.

Finally, a study by Demura and Demura (2012) actually found a decrease in energy expenditure while wearing curve-soled shoes. In that study, Stretch Walker rocker shoes and MBT shoes were tested against flat-bottom shoes. Ten subjects walked at 50% of maximum walking speed for 6 minutes in each shoe. Walking in Stretch Walker yielded a VO_2 of 953 ml/min compared to the flat-bottomed shoe which elicited a VO_2 of 1017 ml/min. Wearing MBT shoes resulted in a VO_2 of 980ml/min.

Miscellaneous Rocker Shoe Research

Slightly different in nature, but equally applicable research has been done looking at more abstract aspects of rocker shoes. A study by Hansen and Wang (2011) examined the effects of shoe radius on oxygen consumption. Eleven subjects walked at a self-selected pace in five different shoes with varying sole radii. These shoe conditions consisted of a standard pair of shoe without a rocker sole, a pair with 25% of leg length, 40% of leg length, 55% leg length, and a shoe with a flat three inch lift added to the sole. It was found that walking in all three rocker shoes, regardless of radius, were more energy efficient than walking in the flat shoe. In addition to this, the 40% of leg length shoe produced a lower oxygen consumption

than the standard shoe. This data led to the conclusion that VO_2 may be dependent on the specific radius of the rocker bottom itself.

The second study looked at the effect rocker shoes play when worn by a specific population requiring therapeutic assistance. Fifteen patients who had undergone an ankle arthrodesis (a surgically achieved bony fusion of the tibiotalar joint) walked barefoot, in normal shoes, and in MBT shoes at 1.25 m/s for 5 minutes. When oxygen consumption was compared, it was found that the MBT's caused a significant increase in oxygen uptake. Authors attributed this to both the unstable sole design as well as the increased mass of the shoe (Van Engelen et al., 2010).

Compliant Midsoles

A great deal of effort has been put into the assessment of desirable midsole qualities. In terms of injury prevention, foot comfort, and overall performance, optimal midsole characteristics can prove paramount. As early as 1983, it was determined that energy recovery from a running shoe depends on the material of the sole itself (Clark, Frederick, and Cooper, 1983). Despite this, it still remains unclear as to what specific material is most advantageous. Nigg et al. (2002) examined the rigidness of midsoles and how they affect energy expenditure. Comparing an elastic midsole with medium hardness to a soft and gel-like midsole yielded less than conclusive results. It was found that, generally, oxygen consumption did not differ between the two conditions. However, researchers noted that some individuals' oxygen consumption consistently showed up to 2% differences.

Summary

Previous research on rocker bottom shoes has found inconsistent results when comparing energy expenditure to a standard shoe. Some studies have found an increase in energy expenditure while others have found no difference. It has been definitively shown, however, that heavier footwear can directly lead to an increase in caloric expenditure. This aspect alone may increase the cost of exercising in HOKA shoes versus a standard shoe. In addition, soft compliant soles have been found to affect energy expenditure differently on an individual basis when compared to a more rigid material. All of these factors are applicable to the current study.

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