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The Effects of Hiking Poles on Performance and Physiological Variables During Mountain Climbing

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ABSTRACT

Duckham RL, Bassett DR, Fitzhugh E, Swibas T, McMahan A. The Effects of Hiking Poles on Performance and Physiological Variables During Mountain Climbing ***JEP****online* 2009;12(3):34-41. Walking with poles is not new; in fact, it has been around for decades. Hikers and mountaineers have long used walking poles to aid in going up and down hill, on the assumption that they increase safety over the uneven terrain, ease the strain placed on the spine and lower extremities; enhance balance, and reduce the impact forces on the body. However, there have been no studies investigating the performance effects of hiking poles. The primary purpose of this study was to compare performance when hiking with and without poles during a maximal effort mountain ascent. In addition, the study determined if there were differences in physiological responses and effort when hiking with and without poles. 15 physically active men and women (mean age 29±6) hiked with and without hiking poles up a 4.42 km trail (426 m elevation gain). Performance was determined by the time taken to reach the top of the mountain. In addition, differences in heart rate (HR), estimated energy expenditure (EE), ratings of perceived exertion (RPE), and blood lactate (LA) accumulation were measured. When hiking with or without poles, there were no significant differences found for any of the outcome variables: Time-to-completion (53.24±5.31 vs. 52.74± 4.47min), average HR (160 ± 16 vs. 159 ± 15 bpm), estimated EE (889 + 235 vs. 875 ± 211 kcal), RPE (16.2 ± 2.2 vs. 17.1± 2.0) or blood lactate (LA) accumulation (6.23 ± 2.5 vs. 7.23 ± 3.88mmol/l). In conclusion, performance and physiological responses did not differ when hiking with and without poles on a maximal effort mountain ascent.

Key Words: Heart Rate, Energy Expenditure, Blood Lactate, RPE

INTRODUCTION

Walking is one of the most popular leisure-time physical activities among U.S. adults (1,2) and it is often recommended for previously inactive individuals. However, as fitness levels improve, walking speeds must be increased in order to see additional improvements. This means that individuals may need to engage in race walking or jogging in order to achieve a cardiovascular training effect. However, race walking is a skill that is not easily acquired, and jogging can lead to problems such as lower extremity injuries (3-5).

An alternative exercise mode is walking with poles. This provides a total body workout while avoiding the high impact forces of jogging. Walking with poles is not new; in fact, it has been around for decades. Hikers and mountaineers have long used walking poles to aid in going up and down hill, on the assumption that they increase safety over an uneven terrain, ease the strain placed on the spine and lower extremities, enhance balance, and reduce the impact forces on the body (6-8).

Biomechanists have shown that the use of hiking poles reduces loading of the lower extremities (6-9), leading to speculation that this may reduce injury rates. In addition, exercise physiologists have examined the effects of hiking poles on the metabolic and heart rate responses to walking (9-13). Some researchers report that pole use increases oxygen consumption by 12 to 23%, and increases heart rate by up to 6 to 18 beats per minute (11-13) at a constant speed. Other researchers state that the main benefit to using poles is that they reduce ratings of perceived exertion, even though physiological responses such as oxygen uptake and heart rate remain the same (9,10)..

A limitation of past research on pole walking is that most of these studies have used treadmills, which do not account for the pole-to-ground interaction and uneven terrain that occurs in the natural environment (12-14). Only two studies have examined the use of hiking poles in a field setting (10,11). In addition, previous studies examined the effects of hiking poles during submaximal efforts; no studies have examined the effects of hiking poles on maximal exercise performance.

Thus, the purpose of this study was to determine the performance differences when hiking with and without poles during a 4.42 km maximal effort mountain ascent. In addition, the study sought to determine if there were differences in heart rate, estimated energy expenditure, rating of perceived exertion and blood lactate accumulation. Based on previous research, we hypothesized that there would be an improvement in performance times when hiking with poles.

METHODS

Subjects

The participants included fifteen physically active, non-smoking adults (7 males and 8 females) between the ages of 18-40 (mean age 29 $\pm$ 6 years). The participants were familiar with hiking and hiked an average of 4 times per year. All participants were recruited by advertisement and word-of-mouth from the University of Tennessee student body and surrounding community.

Procedures

Testing was performed both in the Applied Physiology Laboratory, as well as in the field. Field-testing was conducted on the Rich Mountain trail, in the Great Smoky Mountain National Park. The trail was 4.42 km with an elevation gain of 426 meters.

After the initial telephone interview, each participant was required to complete four days of testing. On the first day, each participant visited the Applied Physiology Laboratory. Upon arrival at the laboratory, the participants were asked to read and sign an informed consent form approved by the Institutional Review Board. In addition, participants filled out a health history questionnaire to assess their health status. Individuals were excluded from the study if they reported being pregnant, having high blood pressure, having cardiovascular or pulmonary diseases, or recent orthopedic problems. Each participant's body mass was measured using a physician's scale, and height was measured with a stadiometer. Body mass index (BMI) was calculated by dividing the weight in kilograms by height in meters squared (15).

Maximal oxygen uptake (VO_{2max}) was measured using a metabolic measurement system (Parvo-Medics True Max 2400). The metabolic measurement system measured the participant's expired gas via a Hans-Rudolf 2-way non-rebreathing value, which was placed in the participant's mouth, with a tube connected to the measurement system. The participant wore a nose clip to ensure all expired air was measured during the test. The Balke super standard treadmill test was used to measure the maximal oxygen uptake (16). (This test required the participant to walk on the treadmill at a constant speed of 6.1 km at a 4% grade. After each minute of the test, the grade of the treadmill was increased by 2%. Once a 20% grade was reached, the time of each stage increased to 2 minutes. The grade continued to increase until the participant reached exhaustion. The highest 60-s VO_2 value recorded during the test was considered the VO_{2max}.)

Heart rate was measured each minute throughout the test using a Polar heart rate monitor. An electrode belt was strapped around the chest just below the breast and the heart rate watch was placed on the wrist. A fingertip blood sample was taken 3 minutes post-exercise, by collecting 100ul of blood in a capillary tube. The blood sample was put into a Yellow Springs Instruments (YSI) blood lactate tube containing cetrimonium bromide and sodium fluoride, capped and shaken. Blood lactate was analyzed in the Applied Physiology lab by a trained technician using an automated lactate analyzer (YSI 2300 Stat Plus).

After the VO_{2max} test, each participant was instructed on the correct technique for using hiking poles. The poles were adjusted to the correct height, making sure that when the poles are planted the elbow is bent at a 90º angle (17,18). Participants were instructed to relax the shoulders, with the hands and poles close to the body. With further instruction a forward stride was taken with one foot and the opposite arm; the pole was planted and then the arm swung backwards as the other arm and leg moved forward. All participants practiced the technique on Rich Mountain trail one week before the field-testing began.

On two subsequent days (one week apart) the participants met at an arranged location where they were instructed to hike at a maximal effort from the trailhead to the mountaintop. A counter-balanced design was used. One half of the participants were assigned to hike with poles on day one, and with no poles on day two; for the remaining participants, the order of treatments was switched. The participants were informed that this was a maximal effort time trial but they were not to run. Participants started at 5-minute intervals. The time taken to walk the trail was measured using a stopwatch. During the trail ascent, heart rate and estimated energy expenditure was measured each minute using a Polar S610i downloadable heart monitor. Once the participant reached the top of the trail, a fingertip blood sample was collected 3-minutes post-exercise, for the purpose of determining blood lactate levels. Each blood sample was put into a tube, marked, and placed on ice to be analyzed in the laboratory within 24 hours of the test. Participants were instructed on the proper use of the Borg 15 point scale, and were asked to rate their perceived exertion immediately after completing the trail (19-21).

Statistical Analyses

Statistical analyses were completed using SPSS 13.0 version for Windows (SPSS Inc., Chicago, IL). Initially, a multivariate repeated measures analysis was carried out to determine if order had any effect on blood lactate, time-to-completion, HRmax, average heart rate, energy expenditure and ratings of perceived exertion (RPE). The same analysis was run to determine if gender affected the variables mentioned above. Because neither order nor gender was significant at alpha 0.05 they were not included in further analyses. To analyze the effects of poles, paired t-tests were used to evaluate maximal heart rate, average heart rate, blood lactate, and energy expenditure (Kcal). Ratings of perceived exertion (RPE) were analyzed using Wilcoxon matched pairs (a non-parametric test), due to the scale being ordinal. Statistical significance was determined using an alpha level of 0.05.

RESULTS

Physical Characteristics

The descriptive characteristics of the participants are shown in Table 1. Their height (1.750 ± .078), weight (70.0 ± 10.0 kg) and BMI (23.4 ± 2.77 kg·m^{-2}) were typical of a young, active population.

The performance of each participant was determined by the time taken to finish the 4.42 km trail and the blood lactate accumulation. When all the participants' times and blood lactate accumulation values were examined, there was no significant difference between hiking with and without poles (*p*=.570 and *p*=.347 respectively) (Table 2).

Table 1. Descriptive Characteristics of Participants.

	Mean	SD
Age (years)	29.0	6.0
Height (cm)	175.0	0.078
Weight (kg)	70.04	10.05
VO_{2max} (ml·kg^{-1}·min^{-1})	46.25	8.4
HRmax (bpm)	186.0	12.0
Post-exercise Blood Lactate (mM)	10.79	3.54

VO_{2max} = Maximal oxygen uptake HR_{max} = Maximal heart rate

Physiological Responses

The physiological responses were determined by the highest heart rate ($HR_{highest}$), heart rate average (HR_{avg}), estimated energy expenditure (Kcal), and rating of perceived exertion (RPE). Figure 1 shows the similarity of the heart rate responses graphed at 5-minute intervals for the two conditions: walking with and without poles. Table 2 shows paired t-test analyses for HR_{max}, HR_{avg}, and estimated energy expenditure. There were no significant differences (*p*=.733, *p*=.673 and *p*=.638 respectively). RPE was analyzed using a Wilcoxon matched pairs, non-parametric test, and no significant difference was observed (*p* = .059).

Table 2. Performance and Physiological Variables.

	With Poles	Without Poles
Lactate (mM)	6.2 ± 2.5	7.2 ± 3.9
Highest HR (bpm)	181 ± 13	180 ± 12
HRavg (bpm)	160 ± 16	159 ±15
Time to Completion (min)	53.2 ± 5.3	52.7 ± 4.5
Estimated EE (Kcal)	889 ± 235	875 ± 211
RPE (Borg Units)	16.2 ± 2.2	17.1 ± 2.0

Values are mean ± SD; Subjects (n=15); df (14); p<0.05

DISCUSSION

The main finding of this study was that the use of hiking poles had no effect on performance time, blood lactate accumulation, HR_{max}, HR_{avg}, estimated energy expenditure (kcal) or RPE, during a maximal effort mountain ascent.

The results of this study, in terms of heart rate and energy expenditure, are at variance with the findings of other researchers [11-13], who found an increase in oxygen uptake (VO_2), heart rate (HR), and energy expenditure when walking with poles at a constant speed. Porcari et al. (12) and Rodgers et al. (13) required their subjects to walk with and without poles on a motor driven treadmill, and found that VO_2 increased by 23% and 12%, respectively; HR increased by 18 and 11 bpm, respectively. Church et al. (11) found an increase of approximately 20% in oxygen uptake when walking with poles. Their subjects were required to walk on a level 200 m track.

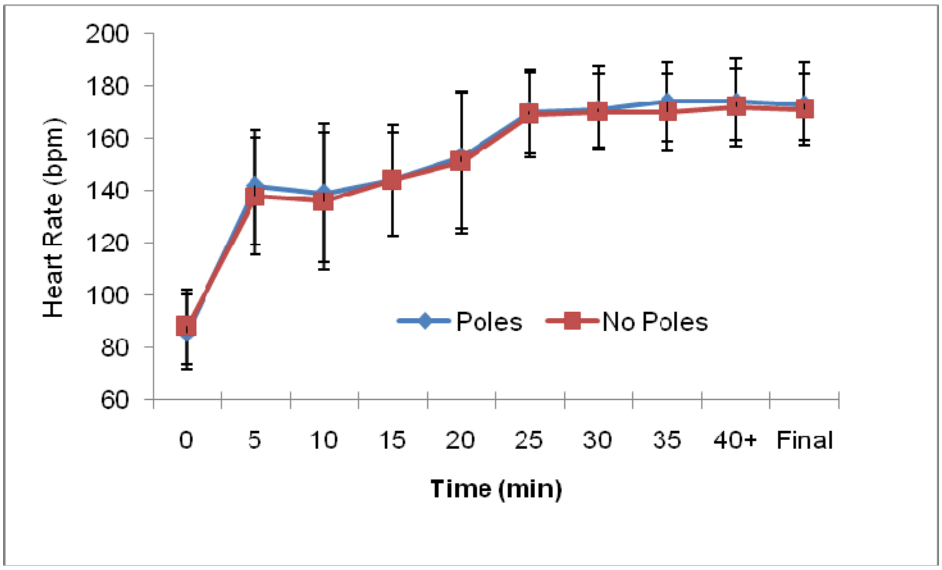

Figure 1. Heart rate Responses vs. time during hiking with and without hiking poles. Values are mean ± SD.

The findings of this study support work by Jacobson et al. (9,10), who found no significant increase in HR, VO_2, VE and energy expenditure when walking with and without poles. Jacobson et al (9,10) found no significant differences in both treadmill and field tests. Both of these studies required subjects to walk with hiking poles and a 15-kg backpack. The difference between the present study and Jacobson's study, versus that of other researchers (11-13), could have been due to the poling technique. When using hiking poles the arm action is not exaggerated. The exaggerated straight-arm swing used in earlier studies (11-13) probably generated the greater increases in physiological responses. However, the objective of the hiking pole technique is to use the poles for balance and reducing lower extremity loading. Thus, the additional upper body involvement used to propel the poles could have offset the reduced work of the lower extremities. This would support the findings of research on combined leg and arm work, which showed that central physiological responses did not change when arm actions were added to leg work (22-24).

Relative Perceived Exertion

Although the present study supported work of Jacobson et al (9,10) in terms of HR, VO_2, VE, and energy expenditure, it did not support their findings on RPE. Jacobson et al. (9,10) found that RPE decreased when uphill walking with the poles. They suggested that the decreased RPE could have been due to the added stability provided by the poles. The reason that hiking poles did not reduce RPE in the present study could have been due to the intensity at which the participants worked during each condition. In both the pole and no pole conditions the participants were hiking at an all-out effort, and they worked at approximately 88-89% of their maximum heart rate. Interestingly, even though the results of RPE were not significantly different, during a follow up question to all participants, asking if they found the hike to be easier with the poles or without, 14 out of the 15 participants reported that it was easier with the poles. They stated that the poles reduced the lower back and leg pain the day after the hike. This suggests that during hiking, the poles do help to reduce lower extremity loading (supporting earlier biomechanical research (7,8,25,26) even if central physiological responses remain the same.

To our knowledge this study was the first to examine the performance effects of hiking poles during a maximal effort. Performance was determined by time-to-completion for a mountain ascent. This study showed no significant effect on performance when walking with and without poles. The subjects were not trained with the arms, so they may have been unable to make a significant contribution to the total work with their arms. The similarities in blood lactate accumulation during the two conditions support earlier work on arm, leg, and combined arm-plus-leg exercise, which found that all combinations of exercise give similar blood lactate readings (22).

Further Research

Further research on hiking poles is needed to explore the effects on performance and physiological responses. One suggestion would be to study the physiological response while carrying a loaded backpack. Jacobson et al. (10) in an earlier study examined this question; however, the trail distance (50 m x 4 reps) was very short, and no benefits of using hiking poles were found. Different results may be found with a longer trail, which would impose a greater challenge. Since most of the participants who undertook the study were familiar with hiking and were young, active individuals, it would be interesting to study an older population where leg strength and balance could be limiting factors. Finally, it would be interesting to examine the effects of long-term training with poles on the possible performance benefits of using poles.

CONCLUSION

In conclusion, the use of hiking poles did not significantly improve performance during a maximal effort, uphill hike. However, the subjects reported that the poles reduced lower back and lower extremity pain the day following the hike, even though no significant effect was found in the rating of perceived exertion between the two conditions (poles vs. no poles, respectively).

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