ABSTRACT

Erickson, J.D.A. Physiological responses to recreational snowshoeing in females. MS in Adult Fitness/Cardiac Rehabilitation, December 1998, 34pp. (J. Porcari).

The purpose of this study was to provide descriptive data relative to exercise intensity when subjects snowshoed at a self-selected pace on both flat and variable terrain. Ten female (age = 27.3 $\pm$ 7.08 yr., ht = 167.07 $\pm$ 5.28 cm, wt = 65.8 $\pm$ 6.63 kg) volunteers snowshoed at a self-selected pace for 30 minutes on both flat and variable terrain courses, in random order. It was found that HR (144 vs 161 bpm) and RPE (13.8 vs 15.0) were significantly ($p < .05$) higher on the variable course compared to the flat course. VO_2 (37.9 vs 39.5 ml/kg/min) tended to be higher on the variable course, however the difference was not significant ($p > .05$). Caloric expenditure for the 30 minutes averaged 372 and 387 Kcal on the flat and variable courses, respectively. These results indicate that snowshoeing at a self-selected pace for 30 continuous minutes provides sufficient intensity to increase cardiovascular endurance and alter body composition.

PHYSIOLOGICAL RESPONSES TO RECREATIONAL SNOWSHOEING IN FEMALES

A MANUSCRIPT STYLE THESIS PRESENTED

TO

THE GRADUATE FACULTY

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THEISIS FINAL ORAL DEFENSE FORM

Candidate: Jeff D.A. Erickson

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

The candidate has successfully completed the thesis final oral defense.

Thesis Committee Chairperson Signature — Date: 3/31/98

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This thesis is approved by the College of Health, Physical Education, and Recreation.

Associate Dean, College of Health, Physical Education, and Recreation — Date: 4-8-98

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INTRODUCTION

Regular participation in aerobic exercise has been shown to a have positive effect on cardiovascular fitness and health (2). According to the Surgeon General's report (9), the popularity of exercise has increased tremendously in the last decade and approximately 40% of the adults in the United States exercise on a regular basis. While walking and jogging are perhaps the most widely employed modes of aerobic activity, some people do not feel comfortable participating in these forms of exercise during the winter months.

Nearly 1 million people are expected to try snowshoeing this winter. That is up from 440,00 in 1994, according to the National Sporting Goods Association (6). The growing popularity of snowshoeing has dramatically increased due to the recent technology in the anatomy of the snowshoe. Snowshoes have become easier to use with the advancements of simpler binding systems and light aluminum frames. In 1991, Tubbs Snowshoe Company (Stowe, Vermont) (8) developed the T-91 binding. The T-91 is a pivoting binding system which results in a full range of motion of the heel, allowing a more efficient stride. The T-91 binding system also features a steel crampon, which improves traction on variable terrain.

Although there has been extensive research analyzing the energy cost of various modes of aerobic activities, little information is available on the physiological effects of snowshoeing. Those studies which have examined the energy cost during locomotion in snowshoes have neglected critical variables, have used very few subjects, and used widely different methods. These factors are crucial because energy cost can vary dramatically based on the weight and size of the snowshoe, depth of snow, depth of footprint depression, and level of the terrain (1,4,5,7,10).

As a mode of aerobic exercise, it seems logical that snowshoeing can be used to improve and maintain cardiovascular fitness. According to the American College of Sports Medicine (ACSM) (2), any activity that uses large muscle groups, can be maintained continuously, and is rhythmical in nature can be used as an aerobic modality. Recreational snowshoeing seems to meet all of these requirements. The purpose of this study was to examine the physiological responses to recreational snowshoeing at a self-selected pace on a flat course and on a course with variable terrain.

METHODS AND PROCEDURES

Subject Selection

Ten apparently healthy female volunteers between the ages of 21 and 39 were used as subjects. All subjects were recreational athletes free of any known cardiovascular, respiratory, or orthopedic conditions that might preclude participation in this study. Prior to participating in any practice or testing sessions, each subject completed an informed consent approved by the Institutional Review Board of the University of Wisconsin-La Crosse (see Appendix A).

Practice

The proper procedures of snowshoeing were explained and demonstrated to the subjects. Each subject was then instructed to walk through a trial course to become familiar with the techniques of walking with snowshoes. During this trial period, subjects stretched and were allowed a warm-up period.

Testing Procedures

Each subject completed 30 minutes of snowshoeing on both a flat and variable course in random order. A period of at least 24 hours was allowed between tests. Testing was done on two predetermined courses. The flat course had a 0% grade and the other course had variable terrain with an average grade of 18%. Grade was determined using topographical surveying techniques.

Courses were marked with surveyor flags in increments of 100 yards, with a total of 500 yards in each direction. Each subject was instructed to snowshoe at a self-selected pace at an intensity corresponding to approximately 13-15 on the Borg Scale (3) (see Appendix B). A standard script explaining the testing procedures and RPE scale was read aloud to each subject before the test (see Appendix C). Subjects were to walk on fresh, unpacked snow throughout the entire test, by placing their lateral side of the snowshoe beside their previous track. Speed was determined by measuring the exact distance covered in the 30 minutes of the test.

During the testing, oxygen consumption (VO_2), caloric expenditure (Kcal), and respiratory exchange ratio (RER) were measured each minute using an Aerosport KB1-C (Aerosport, Ann Harbor, MI). The KB1-C was calibrated before and after each test. The gas analyzers of the KB1-C were calibrated using standard laboratory gases, and a 3.00 L calibration syringe was used to calibrate the pneumotach. Heart rate (HR) was measured using a Polar XL heart rate monitor (Polar, Inc., Stamford, CT) every minute. At the conclusion of each session, subjects were asked to rate their overall perceived exertion using the Borg RPE scale.

The snowshoes used in this study were the Tubbs, Katahdin model (Tubbs Snowshoe Co., Stowe, VT). The snowshoe dimensions are 8" x 25" and weighed 3.1 lbs per pair. Snow depth was measured on the testing days by measuring the base of the snowpack in six different locations, plus any new accumulation of snow. To gauge flotation, the depth of the snowshoe depressions was measured. Depression was measured with a straight edge placed horizontally across the snowshoe print. Three vertical measurements were taken from the lateral, medial, and posterior sides of the snowshoe imprint. Three random prints were measured and the average of those imprints was calculated. Wind velocity was determined by a hand-held anemometer (Sims, Model BT, Annapolis, MD). Temperature (C^0) was determined before testing, and periodically taken throughout the day using a hand-held mercury thermometer. Barometric pressure (P_{bar}) measurements were measured in the Human Performance Laboratory at the University of Wisconsin-La Crosse before testing.

Statistical Analysis

Basic descriptive statistics were used to characterize the subject population and to summarize the physiological responses to the two different courses. Paired t-tests were used to compare the responses between the two different courses. The alpha level was set at .05 to represent statistical significance.

RESULTS

Descriptive characteristics of the subjects are summarized in Table 1, and the physiological responses to snowshoeing on the two courses are presented in Table 2. HR and VO_2 responses for a typical subject on each course are presented in Figures 1 and 2.

Table 1. Descriptive Physical Characteristics of Subjects (N = 10)

Variable	Mean ± Standard Deviation	Range
Age (yrs)	27.3 ± 7.08	21-39
Height (cm)	167.07 ± 5.28	158-173
Weight (kg)	65.8 ± 6.63	57-77

All testing was completed over a seven day period, with weather and snow conditions being fairly stable. The average temperature was –3° C and ranged from -12.2° to 1° C. Average wind speed was 7.8 mph with a range of 6 to 11 mph. The average snow base was 14 cm and the new accumulation was 13.5 cm. The average lateral, medial, and posterior depressions were 11.5 cm, 10.9 cm, and 8.3 cm, respectively. The walking speed of the subjects on the flat course averaged 3.23 mph and on the variable course speed averaged 2.93 mph which was found to be significantly different ($p < .05$).

Table 2. Physiological Responses to Snowshoeing on Flat and Variable Terrain

Variable	Flat Course	Variable Course
HR (bpm)	144 ± 10.79	161 ± 9.21 *
VO_2 (ml/kg/min)	37.9 ± 4.45	39.5 ± 8.60
Kcal (per/min)	12.4 ± .64	12.9 ± .76
RER	.96 ± .10	.98 ± .08
RPE	13.8 ± 1.22	15.0 ± 1.33 *

All values represent mean ± standard deviation.
*Significantly different from flat courses ($p < .05$).

Overall, the subjects worked at a significantly ($p < .05$) higher HR (17 bpm) and RPE (1.2 units) on the variable course compared to the flat course. The VO_2, Kcal, and RER values were also higher on the variable course but they were not significantly ($p > .05$) different.

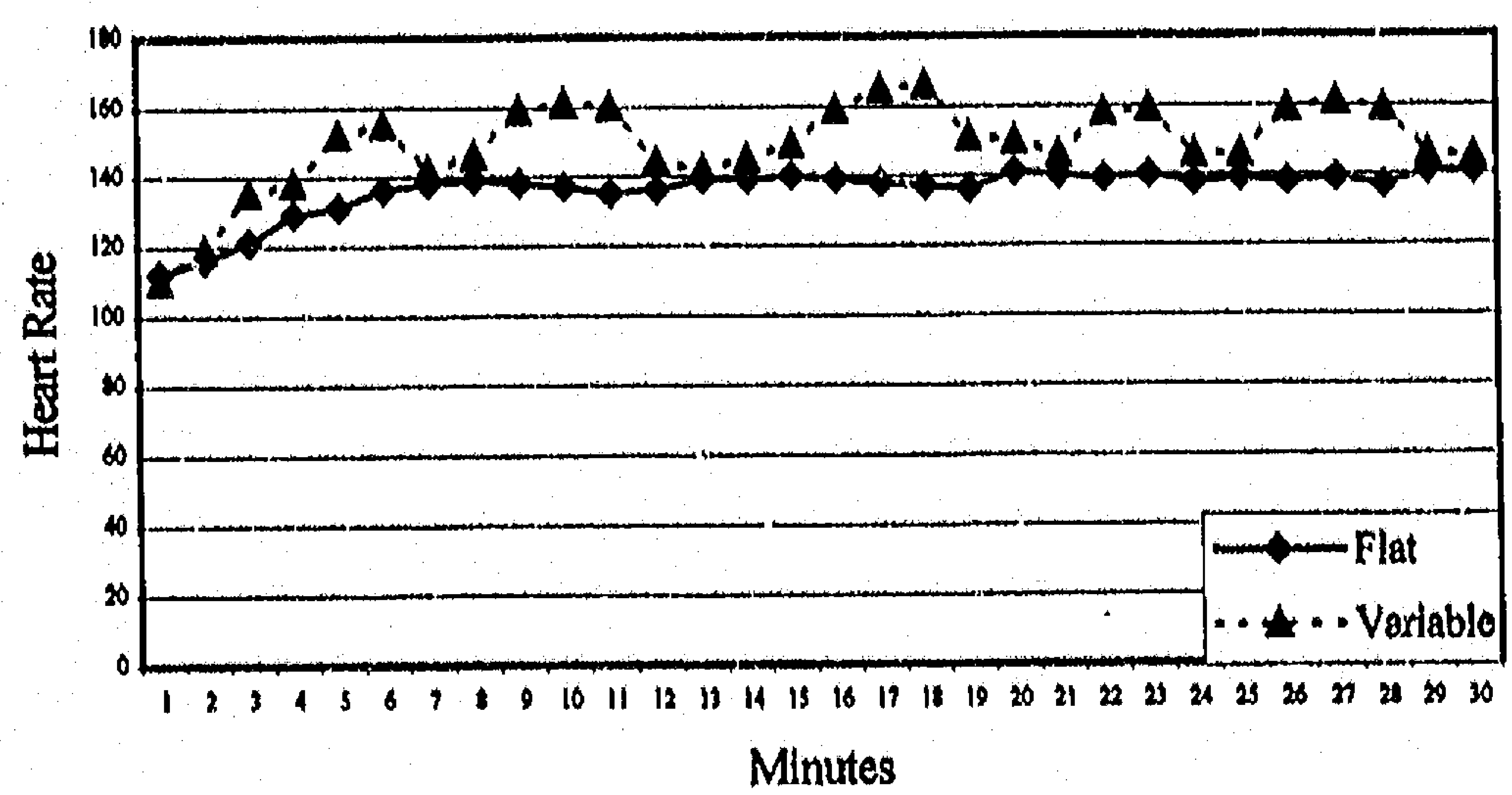

Figure 1. HR Response of a Typical Subject on Flat and Variable Terrain.

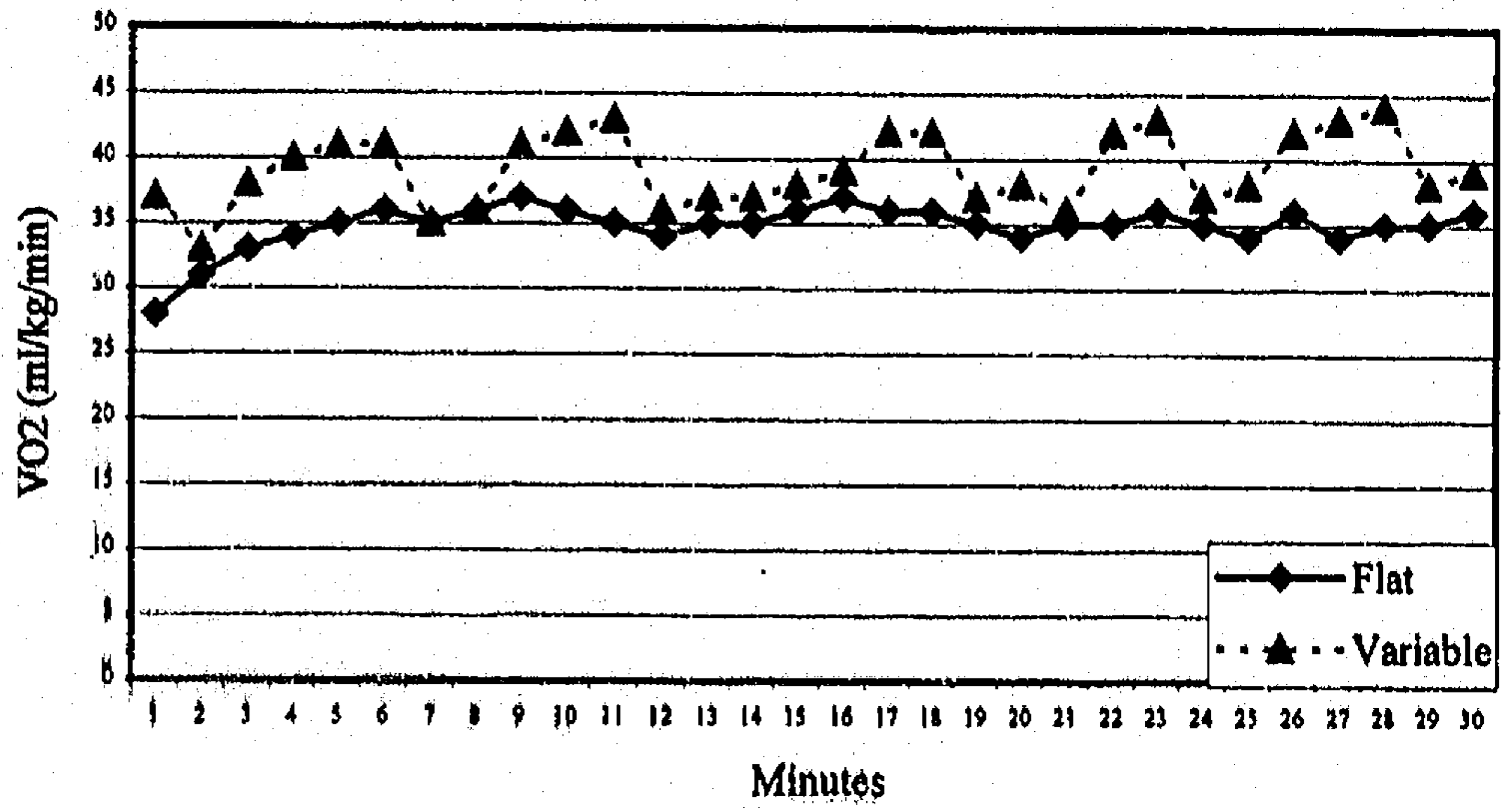

Figure 2. Oxygen Consumption of a Typical Subject on Flat and Variable Terrain.

DISCUSSION

To date, there is a limited amount of research that has been completed on the energy costs of recreational snowshoeing. Studies that have been done failed to measure and report some crucial variables which can potentially alter the physiological effects of this mode of activity (1,4,5,7,10). The purpose of this study was to investigate the physiological responses to recreational snowshoeing on two different courses.

In the present study, the HR response (bpm) was 75% of maximal HR while snowshoeing on the flat course, and 83% of maximal HR on the variable terrain. These values are within the guidelines recommended by ACSM (2) for increasing cardiorespriratory endurance. The differences in HR between the courses indicate that subjects were working at a higher intensity on the variable course.

In agreement with the HR data, the average VO_2 was 37.9 ml/kg/min (2.46 L/min) on the flat course and 39.5 ml/kg/min (2.56 L/min) on the variable terrain. Even though

VO_2 was slightly higher on the variable courses, the difference was not significantly different. This can be explained by the fact that on the variable course subjects worked much harder on the uphill portion of the course, but the downslope of the variable terrain allowed subjects to recover and use less oxygen. Subjects worked at an average RPE of 15.0 on the variable terrain, and 13.8 on the flat course. These results again indicate that subjects were working at a higher intensity on the variable course.

When compared to other studies, Knapick, Hickey, Ortega, Nagel, and Pontbriand found an average HR of 127 bpm and VO_2 of 1.36 L/min (5). Buskirk et al. (4) studied 8 subjects who snowshoed at 2.2 mph and found an average VO_2 of 1.28 L/min. Rodgers, Buck, and Klopping (7) also studied subjects who snowshoed at 2.2 mph and estimated VO_2 to be 2.45 L/min. HR was not reported in these last two studies (4,7).

The results of the current study showed that subjects apparently worked at a higher intensity compared to other studies. Possible factors that may have contributed to the difference in energy cost and HR between the past studies and the current study could be fitness level of the subjects, perceived intensity level, speed of snowshoeing, size of snowshoes, grade of terrain, and snow depth.

In the current study, subjects snowshoed at an intensity level corresponding to approximately 13-15 on the Borg RPE scale. This corresponds to 3.23 mph on the flat course and 2.93 mph on the variable terrain. Past studies did not assess perceived exertion during the tests and subjects generally snowshoed at a slower speed (1,4,5,7,10).

The present study used the same standard model of snowshoes for each subject. Knapick et al. (5) used 4 different models of snowshoes which ranged in size, shape, and weight. Other studies did not report the overall dimensions or weight of the snowshoes (1,4,7,10). The binding systems could be a contributing factor to the differences in the physiological responses. Newer binding systems pivot and allow a greater range of motion at the ankle which could affect energy cost.

Grade of terrain also effects the energy consumption. The current study utilized both a flat and variable terrain. The other studies neglected to report the levels of the terrain (1,4,7,10). Another factor influencing physiological responses is the depth of the snow. During the current study, the average snow depth was 27.5 cm and depressions averaged 10.3 cm. The other studies (1,4) failed to report the snow depth or were less than 15 cm in depth (5,7,10). Without any documentation of these critical variables, no significant comparisons can be made between these past studies and the current study.

Total caloric expenditure during the 30 minutes of testing on the flat course was 372 Kcal and on the variable terrain was 387 Kcal. This is comparable to running a nine minute mile, cycling at 10 to12 mph, or cross country skiing at 4 to 5 mph (2). This level of caloric expenditure should have a positive impact on those individuals who are trying to control their body weight.

To conclude, it appears that recreational snowshoeing can be used as an effective modality to increase cardiorespiratory endurance and affect body composition. The achieved intensity is within the recommendation of ACSM and the caloric expenditure compares favorably to other popular aerobic activities (2). With the increased popularity of snowshoeing various organizations sponsor special snowshoe races throughout the United States. The structured events will aid in maintaining recreational athletes exercise compliance during the winter months. Since a majority of the population does not feel safe walking and running outside during winter conditions, snowshoeing may be an enjoyable alternative aerobic exercise during the winter months.

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APPENDIX A

INFORMED CONSENT

Energy Costs of Recreational Snowshoeing

I, ____________________, volunteer to participate in a study investigating the energy costs of recreational snowshoeing. I understand the test will consist of a 30 minute session at a self selected pace on a mapped course. I realize that I will be carrying a portable oxygen analyzer that will be used to calculate expired air that has been explained and demonstrated to me during the test. My heart rate will be recorded throughout the tests with a heart rate monitor strapped to the chest.

I understand that my participation in this research study will require a minimum of 2 days consisting of practice sessions, and walking on two courses, varying in terrain, for 30 minutes in each session. All sessions will be scheduled at my convenience and conducted by Jeff D.A. Erickson under the direction of Dr. John Porcari.

I consent to the publication of the results of this study so long as the information is anonymous and disguised so that no identification of individual subjects can be made. I further understand that although a record will be kept of my participation in the experiment, all experimental data collected from my participation will be identified by number only.

As with any exercise, there exists the possibility of adverse changes occurring (i.e. dizziness, shortness of breath, muscle fatigue, etc.) during the test. In addition, I may feel tired at the end of exercise. There also my be a risk of hypothermia and/or frostbite. If any abnormal observations are noted, the test will be immediately terminated.

I consider myself to be in good health and to my knowledge I am not infected with contagious disease or have any limiting physical condition or disability, especially with regard to my heart, that would preclude my participation in the exercise tests as described above. I have read the foregoing and I understand what is expected of me. Any questions which may have occurred to me have been answered to my complete satisfaction. I, therefore, voluntarily consent to be tested. Furthermore, I know I may withdraw from these tests at any time.

I hereby acknowledge that no representations, warranties, guarantees of assurances of any kind pertaining to the procedure have been made to me by the University of Wisconsin-LaCrosse, the officers, administration, employees or anyone acting on behalf of them. Concerns about any aspects of this study may be referred to the principal researcher (Jeff D.A. Erickson (608) 788-3791) and thesis advisor (Dr. John Porcari, ESS Room 216 Mitchell Hall (608) 785-8684).

Signed:______________________________ Date:______________

Researcher:___________________________ Date:______________

APPENDIX B

BORG RATE OF PERCEIVED EXERTION SCALE

BORG RPE SCALE (3)

6

7 VERY, VERY LIGHT

8

9 VERY LIGHT

10

11 FAIRLY LIGHT

12

13 SOMEWHAT HARD

14

15 HARD

16

17 VERY HARD

18

19 VERY, VERY HARD

20

APPENDIX C

DESCRIPTION OF TESTING PROCEDURES

DESCRIPTION OF TESTING PROCEDURES

"The test to be performed will last for a duration of 30 minutes. Surveyor flags are marked every 100 yards. As you get to the last flag, which is 500 yards, turn around and place your lateral side of your snowshoe parallel but not touching your previous track. Walk in fresh snow throughout the entire course. This is a scale for rating of perceived exertion. Perceived exertion is the overall effort of distress of your body during exercise. The number 6 represents no perceived exertion or leg discomfort and the number 20 represents the greatest amount of exertion that you have ever experienced. Snowshoe at a self-selected pace, which will be at a pace that you can maintain at a level of 13-15 on this scale. At the end of the test I will ask you what number indicates your rating of perceived exertion during the test. Do you have any questions?" (2)

APPENDIX D

DATA COLLECTION SHEET

Data Collection Sheet

Date: ____/____/____

Subject I.D. ______ Course: _______ Age: _______

Height (in): ________ Weight (kg): __________

Distance (yds): _________

RPE: ______

Depression Depths (cm):

Medial: _____,_____,_____
Lateral: _____,_____,_____
Posterior: _____,_____,_____

Temperature (C°): ______

APPENDIX E

SUBJECT SNOWSHOEING

APPENDIX F

PREPARATION OF SUBJECT

APPENDIX G

SNOWSHOES

APPENDIX H

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Introduction

Today, people are seeking different ways to enjoy outdoor recreation. Recreational athletes are always looking for different modes of exercise that offer a low impact aerobic exercise. With the new technology offered by the advancement in snowshoes, the sport of snowshoeing has grown tremendously in the recent years. According to the National Sporting Goods Association, in 1996 over 1 million people tried the sport of snowshoeing (6). Snowshoeing is one of the fastest growing recreational winter sports, second only to snowboarding (10).

History of Snowshoeing

The use of snowshoes dates back over a long span of human history. The earliest evidence shows the first device to serve as a foot extender for easier travel over the snow originated in Central Asia about 4000 B.C. "Foot extenders" were used as means of travel during the earliest migrations from Central Asia north into Siberia and Scandinavia. Without snowshoes there was no easy way for the early settlers to successfully settle the north, as there was no efficient means to hunt, trap, or explore. These earliest snowshoes were made mostly of birch and ash, used untanned cowhide for the lacing, and were more than 7 feet long (7).

Early pioneers looked to new designs, and in so doing inventors studied animals that have adapted to travel. Early designs mimicked animals, which were able to traverse deep snow. These designs were named accordingly i.e., (beavertail and bearpaw).

These designs are still manufactured today for the traditionalists. Through the 1800's and into the 1900's, snowshoeing gained popularity as a recreational sport. In Canada, snowshoe clubs and recreational events were formed in the early 1900's to advance and celebrate the sport (7). Cross country skiing was the new fad in the early 1970's and early 80's, which put a virtual halt to recreational snowshoeing (14).

Technological Developments

Traditional snowshoes are not as user friendly as modern versions. Traditional snowshoes require new coats of lamination once or twice a season, and the binding systems limit the movement of the heel and toe. Modern snowshoes feature a lighter metal alloy frame, solid fabric decking, and a revolutionary binding system. Tubbs (Tubbs Snowshoe Co, Stowe, VT) developed a TD-91 binding, crampon system in 1991 (14). This binding system allows the toe and heel to move independently of the snowshoe, and the steel crampons give the snowshoer increased traction control on variable terrain. These new features of modern snowshoes makes snowshoeing very easy to learn. With all of the advancements of the anatomy of the snowshoe, the sport of snowshoeing has increased dramatically (3).

Walking in Snow with Boots

It has been generally accepted that energy expenditure will increase if the terrain is not completely solid. Many studies have indicated a strong linear relationship between energy expenditure and depth of depression with a high correlation indicating that as the depth of depression increased so did energy expenditure (8,9,11,12,13).

As indicated by Heinonen, Karvonen, and Ruosteenoja (5), it is evident that walking in snow, even at slow walking speeds, is an extremely strenuous form of locomotion. Seven male subjects walked at a self-selected pace on level, snow-covered fields. Footprint depressions were calculated from 30 to 50 measurements, ranging from 0 to 43 cm. It was found that calories/kg of body weight per horizontal meter walked, denoting energy cost, ranged from .6 on firm ground with no depression to 9.5 cal/kg/m in deep snow with a 39 cm depression. As the depth of the footprint depression increased, length of stride and speed decreased while energy consumption increased linearly (5).

Ramaswamy et al. (9) studied the relationship between the looseness of snow and energy expenditure. The caloric expenditure of walking on loose, deep snow was determined using 12 soldiers. The subjects walked on level ground at normal speeds while the depression of the tracks in the snow were measured and averaged for 20 steps. Depressions ranged from approximately 1.5 to 63 cm. This study was in agreement with past studies, (5,8) finding that oxygen consumption increases linearly as depth of snow increases. Ramaswamy et al. (9) noted that when snow depth exceeded 37 cm, the oxygen consumption seemed to rise asymptotically despite the fact that the increasing depth of snow resulted in slower walking speeds. It was concluded that it can be well understood that walking in very deep snow, which requires high energy requirements, cannot be maintained for a long period of time.

In a more recent study Smolander, Louhevaara, and Hakola (11) assessed the physiological strain to walking on snow with differing boot weights. Seven male and three female subjects walked on a treadmill and a snow field while wearing three types of boots: winter jogging boots, rubber boots, and rubber safety boots. The depth of the footprint depression in the snow was calculated from an average of 40 depressions. Depth of footprint depression averaged 26.1, 25.6, and 26.1 cm in the winter jogging boots, rubber boots, and rubber safety boots, respectively. The results indicated that walking in snow substantially increased pulmonary ventilation, oxygen consumption (VO_2), carbon dioxide production, respiratory exchange ratio (RER), and HR compared with with walking on the treadmill. Oxygen consumption was also slightly, but systematically higher with the heavier rubber boots and rubber safety boots than with the lighter winter jogging boots. This study also found that walking in snow is strenuous work. HR was increased by 50 bpm and oxygen consumption was three times higher walking in snow than walking on a treadmill.

Pandolf, Haisman, and Goldman (8) tested 10 male subjects who walked at speeds of 1.5 mph and 2.5 mph on both the treadmill and in snow of varying depths. Again, energy expenditure increased linearly with increasing depth of footprint depression and with walking speed. Energy cost measured when the subjects walked until exhaustion averaged 51.4 ml/kg/min and ranged from 39.7 ml/kg/min to 61.1 ml/kg/min, indicating a very high exercise intensity.

Snowshoeing Studies

There has been a limited amount of research done on the physiological effects of snowshoeing. Studies conducted have failed to report many crucial factors of the testing procedures. These factors can influence energy cost and the validity of the research.

In the most recent study, Knapick, Hickey, Ortega, Nagel, and Pontbriand (4) studied the energy cost of walking in four different types of snowshoes. The four snowshoes tested were the Pride Assault, Montana, British Assualt, and the U.S. Army Standard, which ranged in weight from 2 to 3 kg (4.4-6.6 lbs). Energy cost was examined while four marines walked at 4 km/hr (2.4 mph) on an open field with each of the four snowshoes. The subjects had previously trained one day with each snowshoe before the data collection was to take place. The grade of the field was about 2.4% and each subject walked once downhill and once uphill with each snowshoe. Each test was 336 meters long and took approximately 5 minutes to complete. To gauge flotation, the depth of the snowshoe depression was measured. To determine overall depression, the lateral, medial, and posterior measurements were calculated and averaged from at least 10 representative measurements. Depth of depression on each course averaged 5 cm, while subjects snowshoed in 8 cm of new snow on top of an unreported snow base. Oxygen consumption of the subjects on the downhill portion of the course averaged 16.8 to 20.2 ml/kg/min while the HR ranged from 123 to 136 bpm. Oxygen consumption on the uphill portion of the course ranged from 21.0 to 24.5 ml/kg/min while HR ranged from 143 to 155 bpm. The findings of this study indicate a strong linear relationship between energy expenditure and depth of depression with a correlation of .87 indicating that as depth of depression increased so did energy expenditure.

Buskirk et al. (2) studied 8 men walking at 3.7 km/hr. They found an average energy cost of 6.21 kcal/min and oxygen consumption of 17.5 ml/kg/min. Neither the snowshoe characteristics nor depth of snow were reported. Rodgers et al. (10) studied individuals who walked at 3.7 km/hr with a snowshoe depression of about 9 cm. They estimated that oxygen consumption was 35 ml/kg/min. They did not report the type of snowshoe used during the data collection. Allen and O' Hara (1) studied 9 infantryman who snowshoed at 2.0 to 3.6 km/hr while carrying equipment estimated at 23 to 27 kg. They found an average oxygen consumption of .98 l/min. Walking pace was highly variable and the depth of depression and snowshoe type were not reported. Worsley (15) also reported on a number of soldiers walking in snowshoes with packs at various speeds, where the depression did not exceed 5 cm. The oxygen consumption was 19 ml/kg/min which was predicted using an equation.

Summary

As the popularity of snowshoeing has increased in recent years, so has the questions of what degree of cardiovascular effects can be obtained by recreational snowshoeing. Studies on the physiological effects of snowshoeing often neglected to report crucial variables which have been shown to alter the physiological effects of either walking in snow or snowshoeing. By documenting the physiological responses to snowshoeing, it may motivate participants to use this mode of exercise during the winter months.

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