PHYSIOLOGICAL RESPONSES OBTAINED DURING EXERCISE ON THE STAIRMASTER GAUNTLET WITH AND WITHOUT THE USE OF HANDS

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ABSTRACT

HEILMAN, P. S. Physiological responses obtained during exercise on the StairMaster Gauntlet with and without the use of hands. MS in Human Performance, 1991, 80pp. (N.Butts).

This investigation was designed to determine if there were sig diffs in the physiological responses (VO_2, VE, METS, RER, Kcals, HR, and RPE) with hands (WH) or without hands (WOH) during exercise on the StairMaster Gauntlet (SM). Two discontinuous protocols utilizing 6, 8, 11, 14, and 17 METS were performed on 20 healthy college females. The ANOVA indicated there were sig ($p < .05$) diffs between all stages and methods WOH condition which resulted in higher values. Since the ANOVA indicated a sig ($p < .05$) interaction, the Bonferroni method indicated that all values representing VO_2, VE, METS, Kcals, and HR were sig ($p < .01$) higher WOH. The RER at 11 and 14 METS were sig ($p < .01$) lower WH. The RPE at 8, 11, and 14 METS were also sig ($p < .01$) lower WH. As the intensity increased, the differences in methods also increased for all physiological variables except HR. WH was found to overestimate the values at the higher intensities. It was concluded that the use of handrails during SM exercise decreases the metabolic requirements of exercise.

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CHAPTER I

INTRODUCTION

Aerobic exercise has become an important aspect in our daily life. With today's rapidly advancing technology, exercise machines and equipment are being updated continuously. The step ergometer is a new exercise machine which has become one of the "hottest items" in fitness clubs today. Is the step ergometer a fad? According to DeBenedette (1990) stair climbers can provide a high intensity workout for the large muscle groups in the back, buttocks, and lower legs in a short amount of time.

Step ergometers are not only used in fitness clubs but have been used for training and testing in other areas. Verstraete and Bassett (1989) used the step ergometer as a training mode for women and found a significant difference in resting heart rate, resting blood pressure, and maximal oxygen consumption as a result of a 12-week training program. Ben-Ezra and Verstraete (1988) found the step ergometer to be an excellent tool that is more task specific and better meets the needs of fire fighters. Several studies (Doherty, 1989; Hanson, Wiswell, Girondola, & Hall, 1989; Holland, Hoffmann, Vincent, Mayers, & Caston, 1990; Riddle & Orringer, 1990) have compared the metabolic responses to stepping with other modes of exercise on healthy individuals.

Holland et al. (1988) tested coronary heart disease (CHD) patients comparing step ergometers with treadmills to determine a protocol that compared with the Bruce protocol on the treadmill. They found no significant difference among the first four stages and concluded that simulated stair climbing may be appropriate for rehabilitation in CHD patients.

There are two basic types of step ergometers. The first type utilizes steps that revolve on a treadmill that are motor driven with full size steps. The second type of stair climber is known as the stepper. There are several types of steppers which involve pedals that can be worked against the weight of the subject or they can be motor driven.

Many of these step ergometers are computerized, giving workout protocols, METS, calories expended, and flights of stairs climbed. These features have also made the step ergometers increasingly popular.

Need for the Study

Experimental research has not kept up with the popularity of the step ergometer. Although it has become very popular, only a few researchers have studied the actual use of these machines. Although with the use of hands for both balance and support and without the use of hands have been researched during exercise on the treadmill (Beadle, Holly, & Amsterdam, 1990; McConnell & Clark, 1987; Von Duvillard & Pivirotto, 1991; Zeimetz, McNeill, Hall, & Moss, 1985) only one study (Barrett, 1989) has been found which investigated hand use during step ergometry. Research has shown that when hands are used during treadmill exercise the energy costs are reduced (American College of Sports Medicine (ACSM), 1991; McConnell & Clark, 1987; Von Duvillard & Pivirotto, 1991; Zeimetz et al., 1985). It is assumed that the use of hands would also reduce the energy cost while performing on a step ergometer, however, not enough research has been done to verify this assumption.

Statement of the Problem

The purpose of this investigation was to determine if the physiological responses would be altered with and without the use of hands on the StairMaster Gauntlet in healthy college-aged females.

The hands were to be used only for balance and not for support. Since there are no pressure gauges on the StairMaster Gauntlet and the instructions advise using the handrails for balance only, this study was designed to compare the physiological responses while exercising with and without the use of hands.

Null Hypotheses

1. There will be no significant differences in the physiological responses obtained during submaximal and maximal exercise with or without the use of hands on the StairMaster Gauntlet.
2. There will be no significant difference between the preprogrammed MET levels and the MET levels actually performed with or without the use of hands.

Assumptions

The following assumptions were made for this study:

1. All subjects were healthy and free from physical limitations that would preclude participation in a maximal exercise test.
2. All subjects felt comfortable on the StairMaster after sufficient practice sessions.
3. All subjects performed to their best ability on the StairMaster Gauntlet for each test.
4. Handrails were used for balance only and not for body support.
5. The subjects' diets were consistent 24 hours prior to performing both tests.
6. All subjects refrained from exercising 24 hours prior to performing either test.
7. A steady state was achieved during each MET level of the protocol.

8. The Q-Plex was calibrated and performed accurately.
9. The procedures for each test were consistent.
10. The first test did not influence the results of the second test.
11. The stepping frequency of the StairMaster Gauntlet was held constant during each of the 4 minute stages.

Limitations

The limitations of this study were:

1. All female subjects (N = 20) were volunteers from the University of Wisconsin-LaCrosse.
2. At least two practice sessions were conducted to familiarize the subjects with the equipment until the individual could perform sufficiently with the tester's approval.
3. The StairMaster Gauntlet was limited to 17 METS.
4. There was no control over motivation and attitude of the subjects.

Delimitations

The delimitations of this study were:

1. Each subject completed both tests within 2 weeks with and without hands.
2. The order of the tests was randomly assigned.
3. The protocol was the same for all subjects.
4. The hand placement was left up to the subject's comfort.

Definition of Terms

Absolute Oxygen Uptake ($l \cdot min^{-1}$) - the amount of oxygen consumed in liters per minute.

Borg's Rating of Perceived Exertion (RPE) - a scale used to assist in monitoring the intensity level of the individual's perceived exertion.

Kcal - unit of work or energy equal to the amount of heat required to raise the temperature of one kilogram of water 1° C (Fox, Bowers, & Foss, 1988) which was calculated by the Q-plex I and based upon the RER.

Maximal Heart Rate - predicted maximal heart rate according to age (220 - age).

MET - one MET is equivalent to 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and represents the oxygen cost when the individual is at rest.

MET Level - the stages of the protocol based on the predicted metabolic cost that is needed to perform the exercise.

Q-Plex I (Quinton Instruments) - an open circuit metabolic system used to measure the exhaled gases to determine VO_2, VCO_2, RER, $VO_2 \cdot kg^{-1}$, METS, and kcals.

Relative Oxygen Uptake (VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$) - the amount of oxygen consumed in milliliters per body weight (kg) per minute.

Respiratory Exchange Ratio (RER) - volume of carbon dioxide produced divided by the volume of oxygen consumed which was analyzed by Q-plex through the subject's exhaled gases.

StairMaster Gauntlet (Randal Inc.) - a motor driven step ergometer that revolves around a treadmill.

Steady State - the physiological responses, such as VO_2 and heart rate remain constant during an exercise stage and was assumed to occur within 4 minutes.

With Hands - handrail contact was made but the hand placement was left up to the individual's comfort to simulate a workout at various intensities. The subjects were instructed to use their hands only for "balance".

Without Hands - the individual was not allowed to contact the support rail unless it was during the two minute rest period. Temporary contact was allowed if the individual tripped or lost her balance.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The increasing use of stair climbing and simulated stair climbers provide exercisers with a greater variety of exercise. The following chapter discusses the recommended modes of exercise, physiological responses related to stair climbing, the use of handrails, and how METS are used. There were limited studies on the StairMaster or any other simulated stair climbers at the time of this review.

Modes of Exercise

According to the American College of Sports Medicine (ACSM, 1991), for an activity to maintain or develop cardiorespiratory fitness, it must require use of large muscle groups, be maintained continuously for 20-60 minutes, and be rhythmical and aerobic in nature. The intensity should be 60-90% of maximal HR or 50-85% of the HR_{max} reserve. The ACSM (1991) has suggested the following modes of activity to maintain and/or develop cardiorespiratory fitness: walking-hiking, running-jogging, cycling-bicycling, cross-country skiing, dancing, rope skipping, rowing, stair climbing, swimming, skating, and various endurance game activities. Many studies have been performed comparing the energy cost of these activities and are discussed later in this chapter.

When comparing actual energy costs of various activities, the majority of the researchers used a simulated protocol which was based on predicted MET levels while the actual METS were the variables being measured. The majority of these predicted MET levels were based on the ACSM (1991) guidelines. Comparisons were usually made between the actual, measured energy costs and those predicted using the ACSM's values.

Physiological Responses Related to Stair Climbing

Stair Climbing

Stair climbing refers to climbing a flight of stairs or simulated stairs. The oxygen cost varies according to step height, step rate, and whether the individual is stepping up or down. Stair climbing is often used for testing in the fitness field when equipment is limited. Stair climbing is easy to do, cost efficient, and may be used for training or testing. Stair climbing has both a negative and positive component. The oxygen cost of stepping down is 1/3 that of stepping up and is known as the negative component (ACSM, 1991).

Studies have been performed comparing stair climbing with other activities. Ballor, Becque, and Katch (1988) compared the metabolic responses of treadmill running, cycle ergometry, and simulated climbing which used a hydraulic resistant apparatus. They found that the treadmill elicited a higher VO_2max while maximal HR, V_E, and RPE were not significantly different among modes of exercise. They reported that cycling and simulated climbing elicited a 6% and a 7% lower VO_2max value, respectively, than that which could be obtained on the treadmill.

Recently Riddle and Orringer (1990) compared the physiological responses of exercise on the StairMaster 4000 PT with the treadmill and found a significantly lower submaximal and maximal VO_2 during each stage on the StairMaster 4000 PT. As the workloads increased, the difference in VO_2 between the two tests increased. The actual MET levels achieved on the StairMaster 4000 PT were less than those estimated by the manufacturer. Based on the results of Riddle and Orringer's study, the StairMaster 4000 PT console has been reprogrammed to more realistically reflect actual MET levels (J. Peterson, personal communication, April 10, 1991).

<u>StairMaster Gauntlet</u>

The StairMaster Gauntlet is designed for individuals who are capable of exercising between 4-17 METS for up to 45 minutes. The work intensity and exercise duration can be altered according to the individual's needs. The various workouts are preprogrammed at different intensity levels for training purposes and variety. Workouts can also be programmed by the individual using the computerized console or operated manually to fit the individual. The StairMaster Gauntlet is a revolving step-treadmill which requires the individual to continually step up, thus only the positive component is used while performing on the StairMaster Gauntlet.

In 1989, Hanson and associates compared oxygen costs between StairMaster Gauntlet and actual stair climbing using a step frequency of 50 and 65 step$\cdot$min^{-1}. They found oxygen consumption on the StairMaster to be lower than stair climbing but the difference was not significant. Only positive work was being performed on the StairMaster while positive and negative work were performed on the stair climbing.

Both healthy individuals and cardiac patients have been tested when comparing the StairMaster to the treadmill. In 1989, Doherty compared the physiological responses on the StairMaster and treadmill at intensities of 9-13 METS. Doherty (1989) found no significant differences in actual V_E (l$\cdot$min^{-1}), VO_2 (ml$\cdot$kg$^{-1}\cdot$min^{-1}), HR, and RER. Holland et al. (1990) also tested healthy subjects on the StairMaster and treadmill and found no significant difference at maximal V_E (l$\cdot$min^{-1}), VO_2 (ml$\cdot$kg$^{-1}\cdot$min^{-1}), HR, RER, and peak time. They concluded that the StairMaster is a valid testing and training mode. When testing cardiac patients Holland et al. (1988) found a slightly higher V_E ($l \cdot min^{-1}$), VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$), HR, and RER on the StairMaster when compared to the corresponding treadmill intensities, but these differences were not significant.

Females and fire fighter were used to determine if the StairMaster could be used for training or fitness testing. Verstraete and Bassett (1989) conducted a 12-week training program on females using the StairMaster. Resting HR and blood pressure decreased while VO_2max increased as a result of training. They concluded that the StairMaster is an excellent cardiovascular training mode.

Ben-Ezra and Verstraete (1988) compared physiological responses of fire fighters on the treadmill and StairMaster. They found maximal V_E ($l \cdot min^{-1}$) to be higher during the stair climbing and maximal HR and VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) were significantly lower, 7% and 2% respectively, on the StairMaster. Even though the results showed that oxygen consumption on the treadmill was higher, fire fighters found that the StairMaster was a more task specific testing and training tool than the treadmill when measuring oxygen consumption in these individuals. Fire fighters need a high VO_2 to compensate for equipment and extreme environmental conditions which increase the energy required while on a rescue mission. Ben-Ezra and Verstraete suggested the

StairMaster is more appropriate to use for testing fitness levels of fire fighters.

Barrett's (1989) study is the only investigation that has addressed the effect of using hands during exercise on a step ergometer. She compared three hand usages, no handrail support, moderate handrail support (10-20% body weight), and heavy handrail support (30-40% body weight) in which she looked at VO_2, V_E, RER, HR, and RPE at six different stages. Her overall findings showed that as hand support increased the physiological variables decreased.

Use of Handrails

What effect does the use of handrails have on the oxygen requirements while exercising on a treadmill? Most treadmills have handrails for safety purposes. Often subjects, especially coronary heart disease (CHD) patients, use these rails for support during treadmill exercise. The ACSM (1991) has indicated that the Bruce protocol, the most popular protocol for testing CHD patients, resulted in a 10-20% error in VO_2 estimation due, in part, to the use of the handrails. Individuals often use these handrails to help extend their exercise time, relieve the stress of the exercise, and help keep up with the pace of the activity.

A few studies (Beadle et al., 1990; McConnell & Clark, 1987; Von Duvillard & Pivirotto, 1991) have shown a decrease in submaximal VO_2 but an increase in treadmill time when using handrails for support compared to not using the hands. McConnell and Clark (1987) tested CHD subjects and suggested that when submaximal prediction equations are used to estimate maximal exertion, one should be certain that the equations allowed for handrail support. They found oxygen consumption was overestimated by as much as 15% when hands were used. Von Duvillard and Pivirotto (1991) tested healthy females. They found that handrail support produced lower submaximal VO_2 values and longer treadmill time thus overestimating the predicted VO_2max by 1 MET. Beadle et al. (1990) tested healthy subjects on the treadmill and found that the use of hands during graded exercise testing (GXT) reduced oxygen consumption. They developed a prediction equation that can be used to estimate VO_2 more accurately on the treadmill when hands are used during GXTs.

Zeimetz et al. (1985) warned testers to be aware of the methods, applications, and predicted values obtained when hand support was being used during testing. They tested five different methods of handrail support by varying hand positions and amount of support. They reported as much as a 30% decrease in oxygen consumption at a given workload when the hands were used. These results clearly indicate that using the handrails during treadmill exercise decreases the VO_2, HR, and energy expended, while increasing performance capacity thus overestimating the predicted metabolic cost of the exercise.

METS

METS are metabolic units used to measure intensity of work. METS are directly related to oxygen consumption and are used mostly in clinical settings to prescribe exercise regimes. One MET is equal to 3.5 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$ and is defined as the amount of oxygen consumption relative to body weight during the resting state. When used in exercise prescription for example, 10 METS requires 10 times the resting oxygen consumption or 35 ml $O_2 \cdot kg^{-1} \cdot min^{-1}$. Many modern exercise machines have programmed MET levels, including the StairMaster, to help determine the intensity level for the individual.

Estimated MET levels are preprogrammed in the StairMaster Gauntlet console. The preprogrammed MET levels are based on the ACSM (1991) guidelines using one plus, $steps \cdot min^{-1}$ times a constant [$MET = 1 + (steps \cdot min^{-1} * .1161)$]. Although this constant is provided by the manufactor, they do not provide the basis on which it was determined.

These estimated MET values represent the energy cost of the activity while using the handrails for balance. The energy costs can be altered if the advice of the Randal Company is not followed. The company suggested that handrails should be used for balance only and support of the body may alter the MET values at that stepping rate. The company indicated that supporting the body weight with the hands can result in a lower energy expenditure and MET values compared to the estimated values. Although this information is given, they do not supply any data indicating the magnitude of the differences.

Summary

The ACSM (1991) guidelines suggest that an individual needs to exercise 20-60 minutes continuously at 60-90% maximal heart rate to maintain or increase cardiorespiratory fitness. Several types of exercise modes including stair climbing can be used to achieve this goal. Many studies have indicated that stair climbing is an excellent activity for healthy and cardiac patients and can be used for testing or training.

Comparative studies on the treadmill have shown that the use of hand support decreases the metabolic responses to exercise. To reduce the inaccuracy of the predicted MET levels, step users and researchers need to be aware of the techniques, methods, and procedures they use. The StairMaster has been found to be an excellent training and testing tool that is an acceptable mode of exercise. The Randal Company suggested that the handrails be used for balance only, in order to prevent a misrepresentation of the MET values actually worked.

METS are directly related to oxygen consumption and are often used for exercise prescription. Estimated MET values are used on many modern exercise machines, including the StairMaster, to help regulate intensity for individuals on an exercise prescription. The StairMaster console is designed to use METS to control the workload.

CHAPTER III

METHODS AND PROCEDURES

Subjects

Twenty healthy female students from the University of Wisconsin-La Crosse, volunteered to participate in this study. The physical characteristics of the subjects are presented in Table 1 and individual data are presented in Appendix A.

Table 1. Means and standard deviations of the subjects' physical characteristics

Variable	Mean	Standard Deviation	Range
Age (yrs)	22.80	2.35	19 - 27
Height (cm)	166.25	36.34	152 - 175
Weight (kg)	59.61	1.20	50 - 76

Laboratory Orientation

The subjects reported to the Human Performance Laboratory (HPL), signed an informed consent (see Appendix B), and experienced at least two practice sessions (on separate days) on the StairMaster Gauntlet. During the first orientation session the subject was given an explanation of the testing procedures, the equipment being used, Borg's Rating of Perceived Exertion (RPE) scale, and pretest instructions (see Appendix C). The subject signed the informed consent and was asked if she had used a step ergometer and if so, which kind. Height and weight were taken before the first practice session.

The practice sessions were performed using the head gear, nose clips, and mouth piece. The subject was allowed to stretch before beginning the session. The first session used both hand methods and all stepping rates to familiarize the subject with the StairMaster Gauntlet. An abbreviated protocol using 3 minute intervals at each stage was used to simulate the submaximal and maximal levels that were to be performed during the actual testing. The RPE scale was used to familiarize the subject with judging effort.

Additional sessions were used if the subject felt inadequate with the StairMaster or if the investigator deemed it necessary. Questions were answered during and after each session.

Hand Placement

Both conditions, with and without hands, were used during the practice sessions. When using the hands the subject was allowed to place her hands on the rails at any position she found comfortable. She was also instructed that her hands should be used only for balance rather than supporting her body.

Without the use of hands, the subject was not allowed to contact the support rails unless she tripped or was in the resting stage of the protocol. The hand positions were alternated every minute during the practice sessions.

Equipment

Q-Plex

The Q-Plex I is an open circuit automated metabolic system made by Quinton Instrument Company. To allow adequate warm up time, the Q-Plex was turned on 30 minutes prior to the testing. The barometric pressure, relative humidity, and room temperature were measured. The relative humidity and room temperature were determined with a sling psychrometer which involved reading a wet and dry bulb after being slung for a minute. The Q-plex was then calibrated using these known values. A 3.002 l syringe pump was used to calibrate the pneumotach for volume flow. Tanks of high and low percentages of oxygen and carbon dioxide, previously determined by the Scholander technique, were used to calibrate the gas analyzers in the Q-plex.

The subject's height, weight, and age were entered into the computer and the final pretest calibration was administered. All respiratory hoses and connections were checked before beginning to test. The following parameters were printed each minute as the computer and Q-Plex configured the results of the test: test time, V_E ($l \cdot min^{-1}$),

VO_2 ($l \cdot min^{-1}$), VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$), RER, METS, kcal, RPE, and HR.

StairMaster Gauntlet

The StairMaster is a motor driven step ergometer which consists of 8 inch steps that revolve around a treadmill. A start and stop button is located on the right handrail and a digital computer can be programmed for various workloads. This program operated on the basis of METS rather than speed.

The digital computer was programmed for a practice and a testing protocol. The protocols started with a 5 minute warm up at 6 METS (see Table 2). The second stage started at 8 METS and increased 3 METS per stage. The practice protocol consisted of 3 minute stages while the testing stages contained 4 minute stages. A rest was allowed whenever needed during the practice sessions. During the tests a 2 minute rest was required after each stage.

Heart Rate Monitor

Heart rates were determined using a UNIQ-CIC heart rate watch which was programmed to determine heart rates every minute. A transmitter placed on an elastic belt just below the chest was positioned on the left side. The watch (receiver) was placed on the left handrail in front of the subject. Heart rates were taken 20 seconds before the end of each minute of each stage and edited into the computer.

This method was used for a back up if the programmed method failed.

Rating of Perceived Exertion

Borg's (1982) RPE scale was used throughout the test to monitor the individual's perception of the level of exercise intensity. The 15 point scale started at 6 which represents very, very, light fatigue and proceeded to 20 which represented the hardest the individual has ever worked (see Appendix D).

Tests

Test Procedure

The subject performed submaximal and maximal levels of step ergometry during both tests. The two tests were performed at the same time of day within 7-14 days of each other. The person's weight was recorded before each test.

The subject stretched while the final preparations were made on the Q-Plex. A set protocol (see Table 2) was used for all subjects. A discontinuous protocol with 4 minute exercise periods and 2 minute rest periods was used to obtain steady states. With or without the use of hands was randomly determined prior to the subject's arrival using the fish bowl method. The instructions of the test were given after she was prepared with the head gear, nose clip, and mouth piece. The RPEs and HRs were recorded at the end of each stage of the protocol.

Table 2. Testing protocol

Stage	Time (min)	METS*	Steps•Minute*
Warmup	0- 4:59	6	40
Rest	5:00- 6:59		
1	7:00-10:59	8	56
Rest	11:00-12:59		
2	13:00-16:59	11	80
Rest	17:00-18:59		
3	19:00-22:59	14	103
Rest	23:00-24:59		
4	25:00-27:00	17	127

* Indicated on StairMaster console.

Termination of the Test

Termination of the test occurred when the individual could no longer continue, grasped the handrails during the no hands protocol, or finished 17 METS. A maximal level of VO_2 was assumed to have been reached if two out of the five following criteria were met. The physiological criteria were RER > 1.0, VO_2 leveled off, and age predicted maximal heart rate (220 - age) was reached. Other required factors that indicated maximal effort were volitional exhaustion and RPE of at least 19.

Statistical Analysis

A two-way analysis of variance (ANOVA) with repeated measures was performed on the data from the two test conditions to determine if there were significant differences in the physiological responses with or without the use of hands. The alpha level was adjusted using the Bonferroni (Thomas & Nelson, 1990) method to identify significant differences.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this investigation was to determine if physiological responses were altered with and without the use of hands on the StairMaster Gauntlet during exercise on 20 healthy college females. The physiological responses of VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$ and $l \cdot min^{-1}$), VE ($l \cdot min^{-1}$), METS, RER, Kcal, HR, and RPE were analyzed comparing with and without hands.

All subjects were female volunteers between the ages of 19-27 years from the University of Wisconsin-LaCrosse. After the subject requirements were explained and they decided to take part in the investigation, two questions were asked: if they ever used a stair climber before and, if so, which kind? Six subjects had prior experience on the StairMaster 4000 PT and none had prior experience with the StairMaster Gauntlet. Practice sessions were arranged at the subject's convenience. Full head gear was used during these practices until the subject felt comfortable at the appropriate stages and the tester believed the subject could perform adequately.

Two tests were performed using both hand methods at the preprogrammed levels of 6, 8, 11, 14, and 17 METS. The tests were performed in random order chosen by the fish bowl method. Heart rates were determined by the UNIQ-CIC heart rate monitor and recorded at the end of each minute. The respiratory responses were also assessed each minute using the Quinton [Q-plex I], but only the data obtained during last minute of each MET level performed were used in the analysis. The subjects selected their rating of perceived exertion from the Borg's RPE scale during the last minute of each stage.

The Statistical Analysis System (SAS) program was used to determine if there were significant differences between stages and methods using a two way ANOVA with repeated measures at the $p < .05$ level of confidence. The Bonnferroni (Thomas & Nelson, 1990) method was used to compare methods at each stage if the ANOVA resulted in a significant interaction between the methods and stages.

Results

The overall means and standard deviations for combined data with and without the use of hands according to stage or MET levels (6, 8, 11, and 14 METS) are given in Table 3. Only the first four MET levels were compared since only one subject completed both tests at the 17 MET stage. The two way ANOVA revealed a significant ($p < .05$) difference among all MET levels with each higher MET level producing significantly higher values (see Table 3). These differences were expected due to the increasing workloads, therefore, in comparison of the stages, the null hypothesis was rejected.

Table 3. The overall means and standard deviation for all variables comparing stages/MET levels regardless of hand condition

Variable	6 METS N = 20	8 METS N = 20	11 METS N = 20	14 METS N = 15
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	22.9[a] 1.5[b]	29.0 1.6	38.3 2.2	47.7* 4.4
VO_2 ($l \cdot min^{-1}$)	1.43 0.18	1.81 0.21	2.39 0.26	3.01* 0.41
V_E ($l \cdot min^{-1}$)	33.5 4.5	42.8 6.1	62.7 10.9	91.3* 18.2
MET	6.5 0.4	8.3 0.5	10.9 0.6	13.7* 1.1
RER	0.80 0.04	0.83 0.03	0.91 0.04	0.98* 0.05
Kcal	6.9 0.9	8.8 1.0	11.8 1.3	15.1* 2.2
Heart rate ($beats \cdot min^{-1}$)	116.2 12.8	134.5 14.4	160.2 13.6	176.1* 10.7
RPE	7.9 1.4	10.1 1.4	13.2 1.7	15.4* 1.9

a = mean
b = standard deviation
Note. Significant ($p < .05$) difference occurred among all stages for all variables.

The two way ANOVA revealed significantly ($p < .05$) lower physiological responses when the hands were used compared to the responses when the hands were not used, regardless of stages. Overall, using hands significantly decreased the physiological demands needed to perform on the StairMaster (see Table 4). Therefore the null hypothesis indicating no significant difference between methods was rejected.

Table 4. The overall means and standard deviation for all variables comparing with and without hands regardless of stage

Variable	With Hands	Without Hands	Mean Difference
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	32.4[a] 8.9[b]	34.8 9.8	2.4*
VO_2 ($l \cdot min^{-1}$)	2.04 0.61	2.17 0.66	0.13*
V_E ($l \cdot min^{-1}$)	51.8 20.9	58.9 25.6	7.1*
MET	9.2 2.5	10.0 2.8	0.8*
RER	0.86 0.07	0.88 0.09	0.02*
Kcal	10.0 3.1	10.8 3.4	0.8*
Heart rate ($beats \cdot min^{-1}$)	140.3 25.8	149.3 25.7	9.0*
RPE	11.0 3.0	11.7 3.4	0.7*

a = mean
b = standard deviation
Note. Significant ($p < .05$) difference occurred among all stages for all variables.

If an individual worked at a specific MET level on the StairMaster, was there a significant difference if a person uses their hands? The ANOVA indicated there was a significant ($p < .05$) interaction between methods and stages, therefore the Bonferroni method was used between the corresponding stages (see Figures 1-8).

A significant ($p < .01$) difference was found between the methods for each stage for oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$ & $l \cdot min^{-1}$), ventilation ($l \cdot min^{-1}$), METS, kcal, and heart rate. In all cases, using the hands resulted in lower values. No significant ($p > .01$) difference was found for the RER at 6 and 8 METS, and the RPE at 6 METS. All the other RER and RPE values were significantly higher without hands comparing methods at each stage. While the null hypotheses were accepted for RER at 6 and 8 METS, and RPE at 6 METS, all other null hypotheses were rejected for the methods at all stages for oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$ and $l \cdot min^{-1}$), ventilation ($l \cdot min^{-1}$), METS, kcal, heart rate, and for RER at 11 and 14 METS and RPE at 8, 11, and 14 METS.

The comparison and differences of the programmed MET levels and the actual METS performed with each method are given in Table 5. The comparison of each method to the predicted MET level at each stage was made using the Bonferroni (Thomas & Nelson, 1990) method. The null hypotheses indicating no difference between programmed and

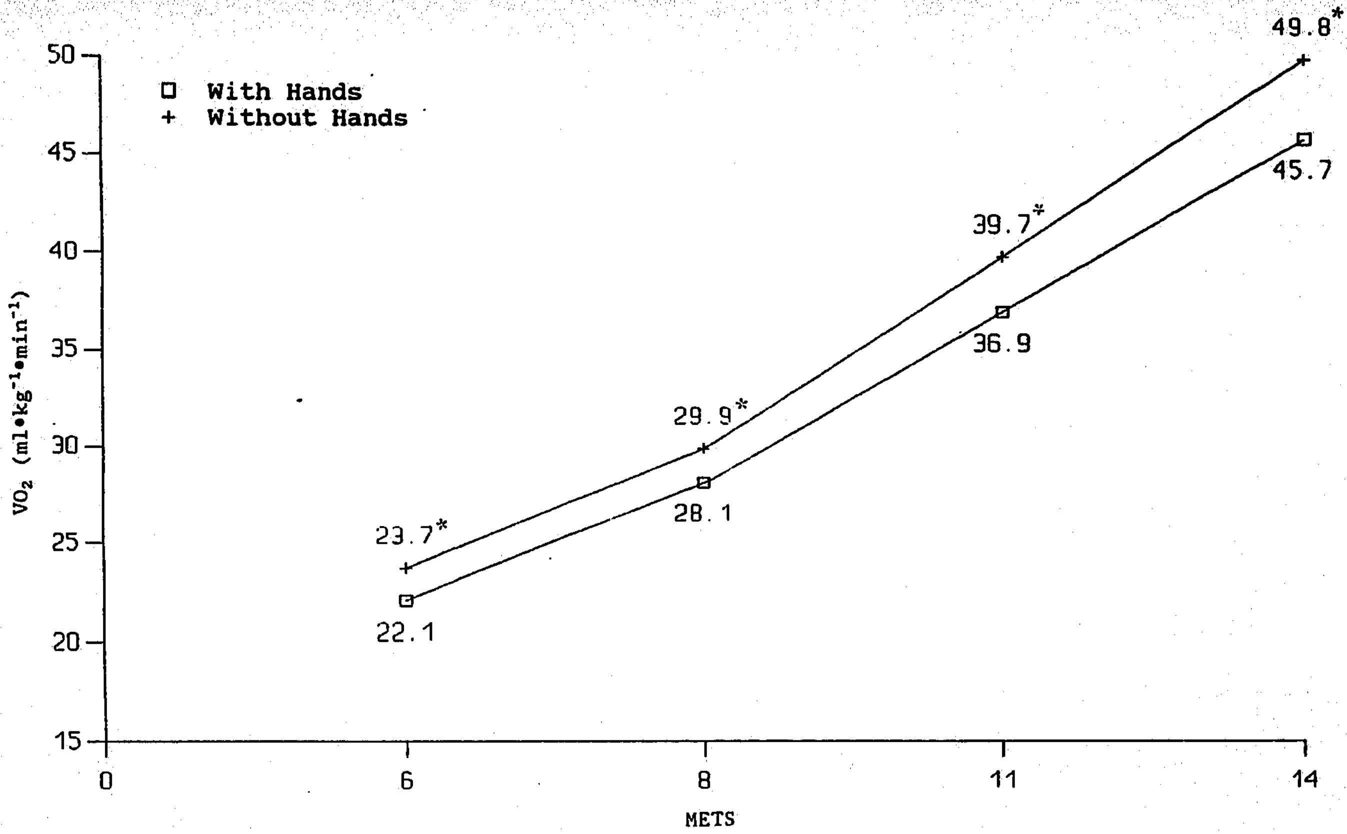

Figure 1. Comparison of VO_2 (ml•kg^{-1}•min^{-1}) at each MET level with and without hands. * Without hands signigicantly higher ($p<.01$).

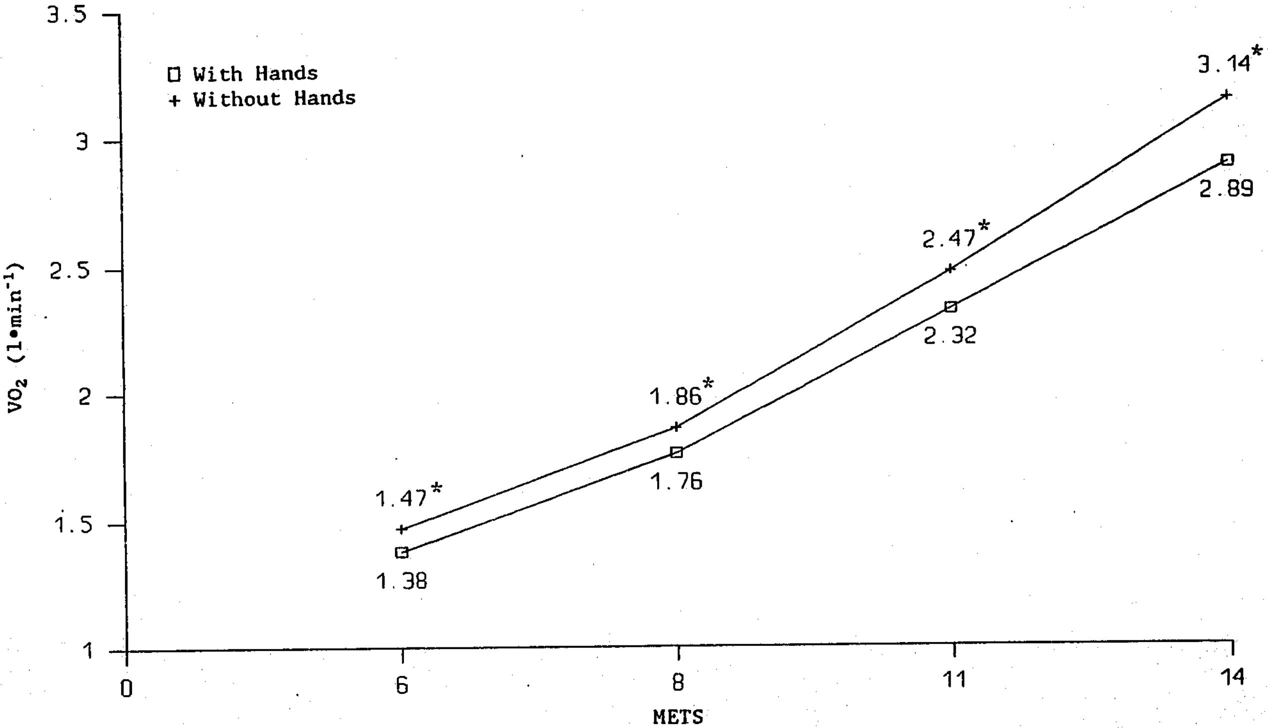

Figure 2. Comparison of VO_2 ($l \bullet min^{-1}$) at each MET level with and without hands.
* Without hands significantly higher ($p<.01$).

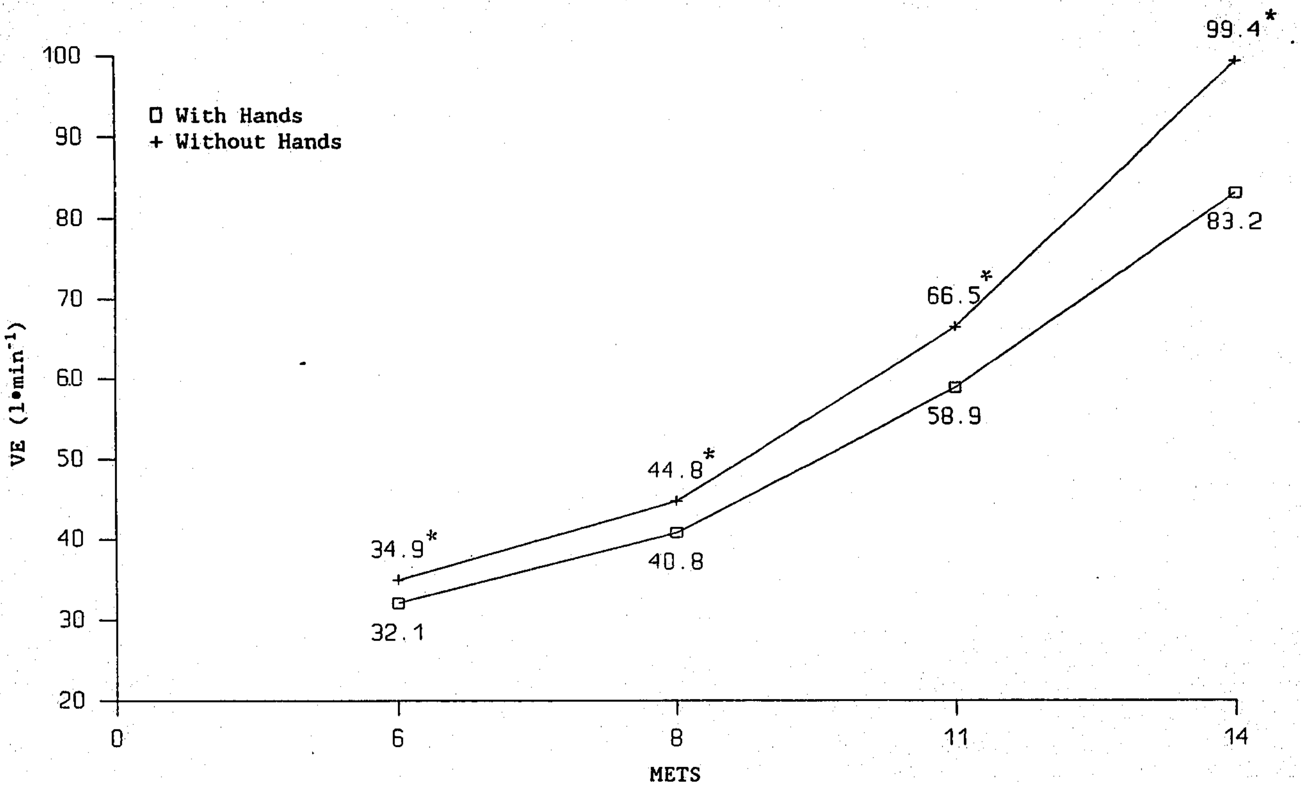

Figure 3. Comparison of VE ($l \bullet min^{-1}$) at each MET level with and without hands.
* Without hands significantly higher ($p<.01$).

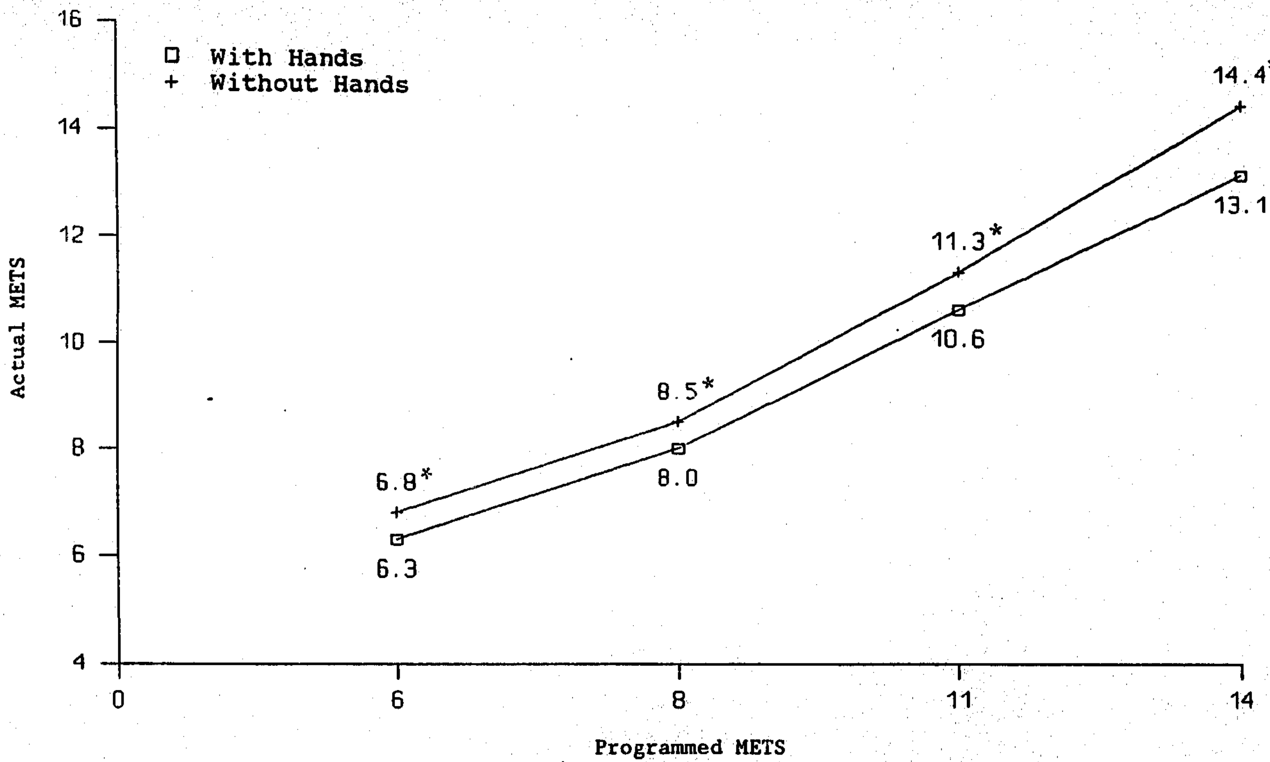

Figure 4. Comparison of actual METS at each MET level with and without hands.
* Without hands significantly higher ($p<.01$).

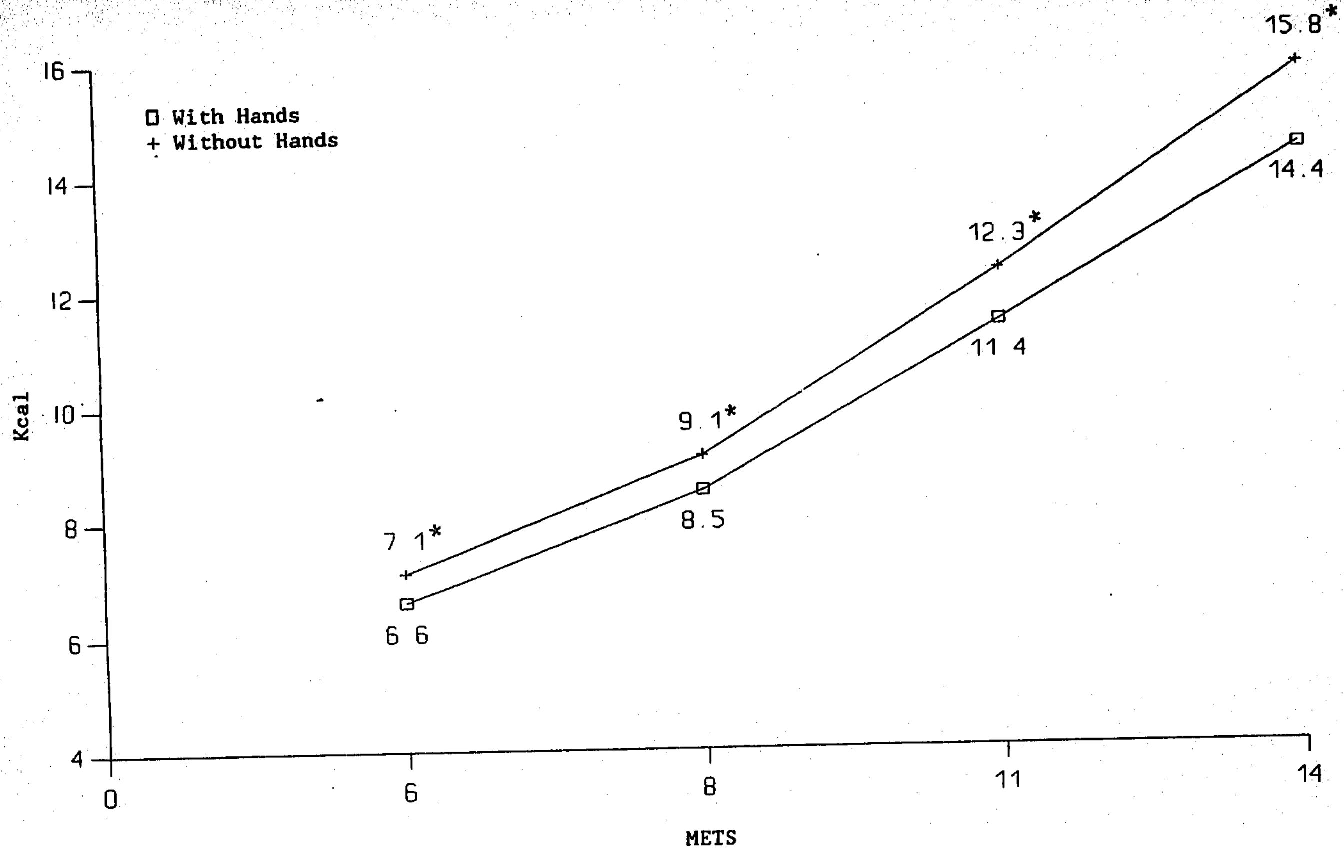

Figure 5. Comparison of Kcals at each MET level with and without hands.
* Without hands significantly higher ($p<.01$).

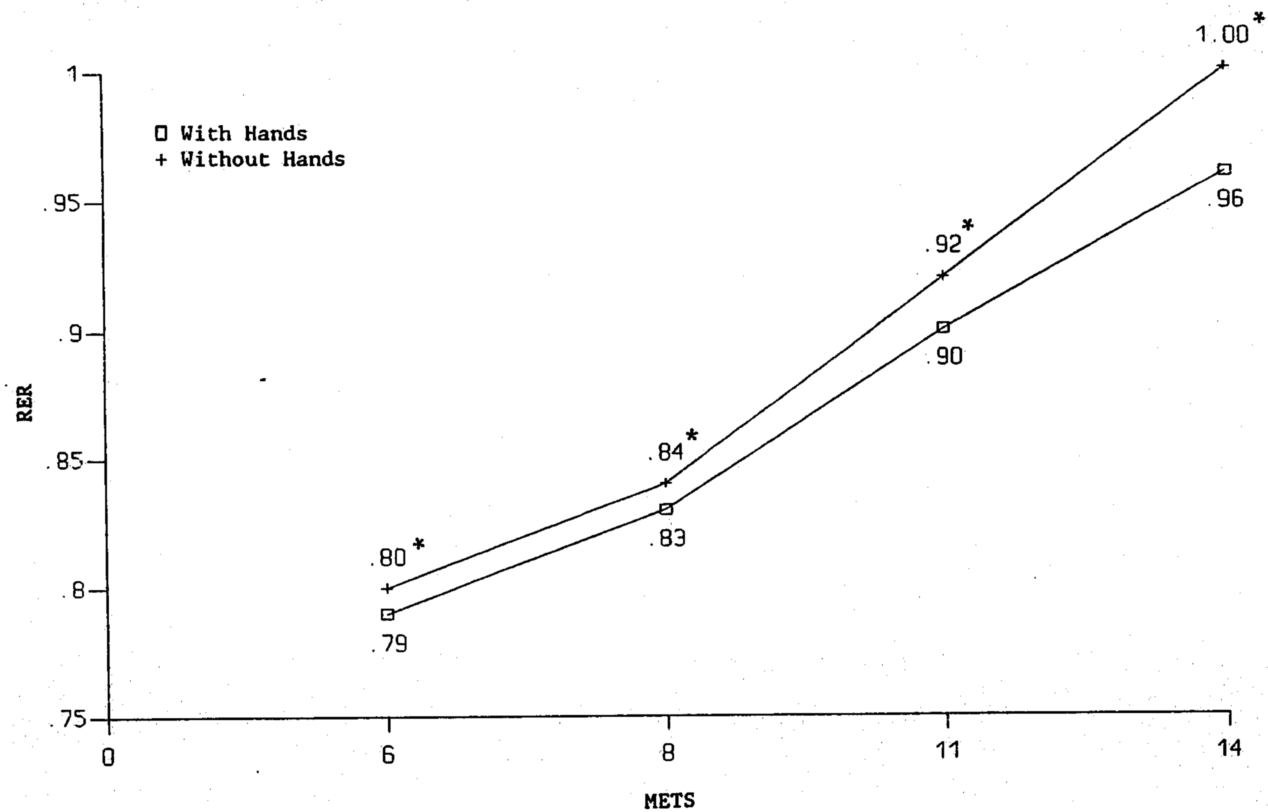

Figure 6. Comparison of RER at each MET level with and without hands.
* Without hands significantly higher (p<.01).

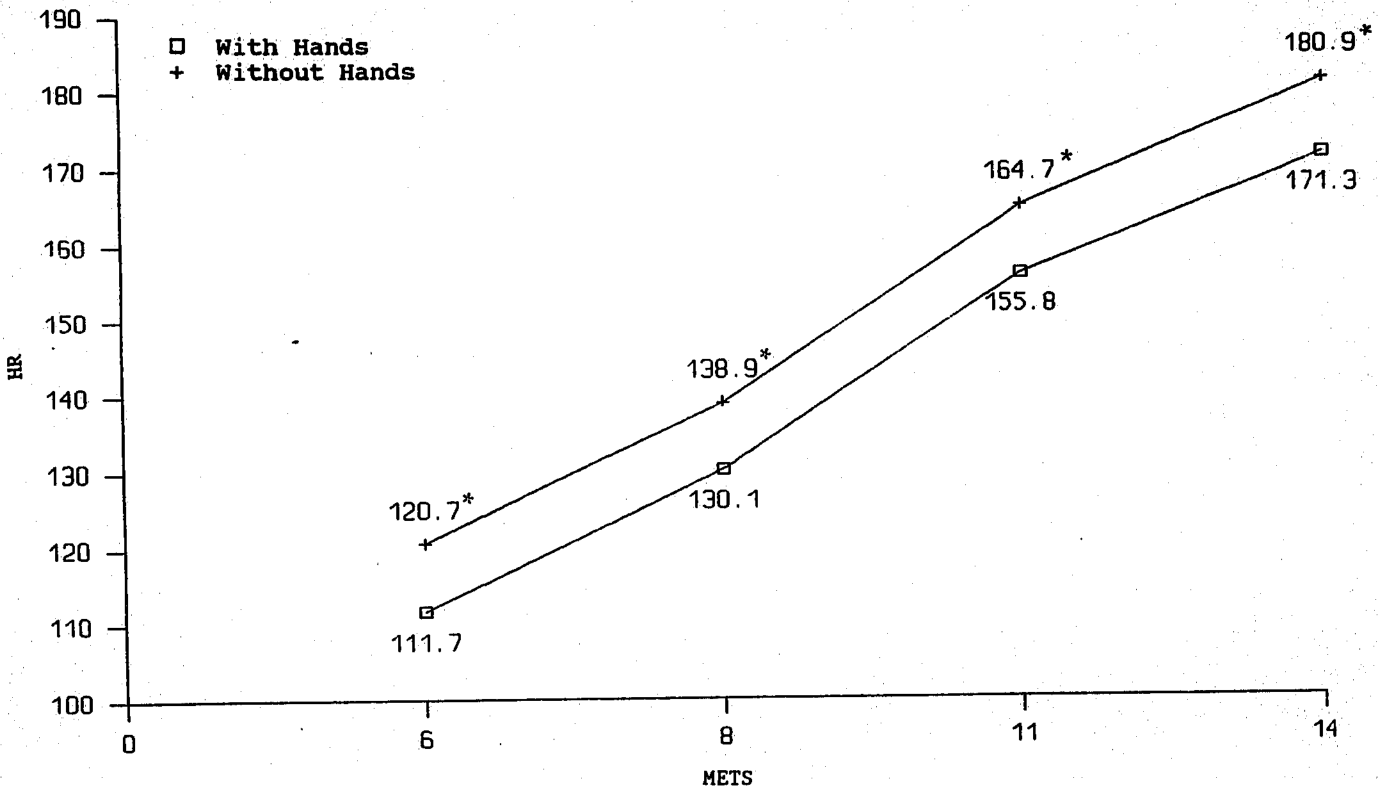

Figure 7. Comparison of heart rate at each MET level with and without hands.
* Without hands significantly higher ($p<.01$).

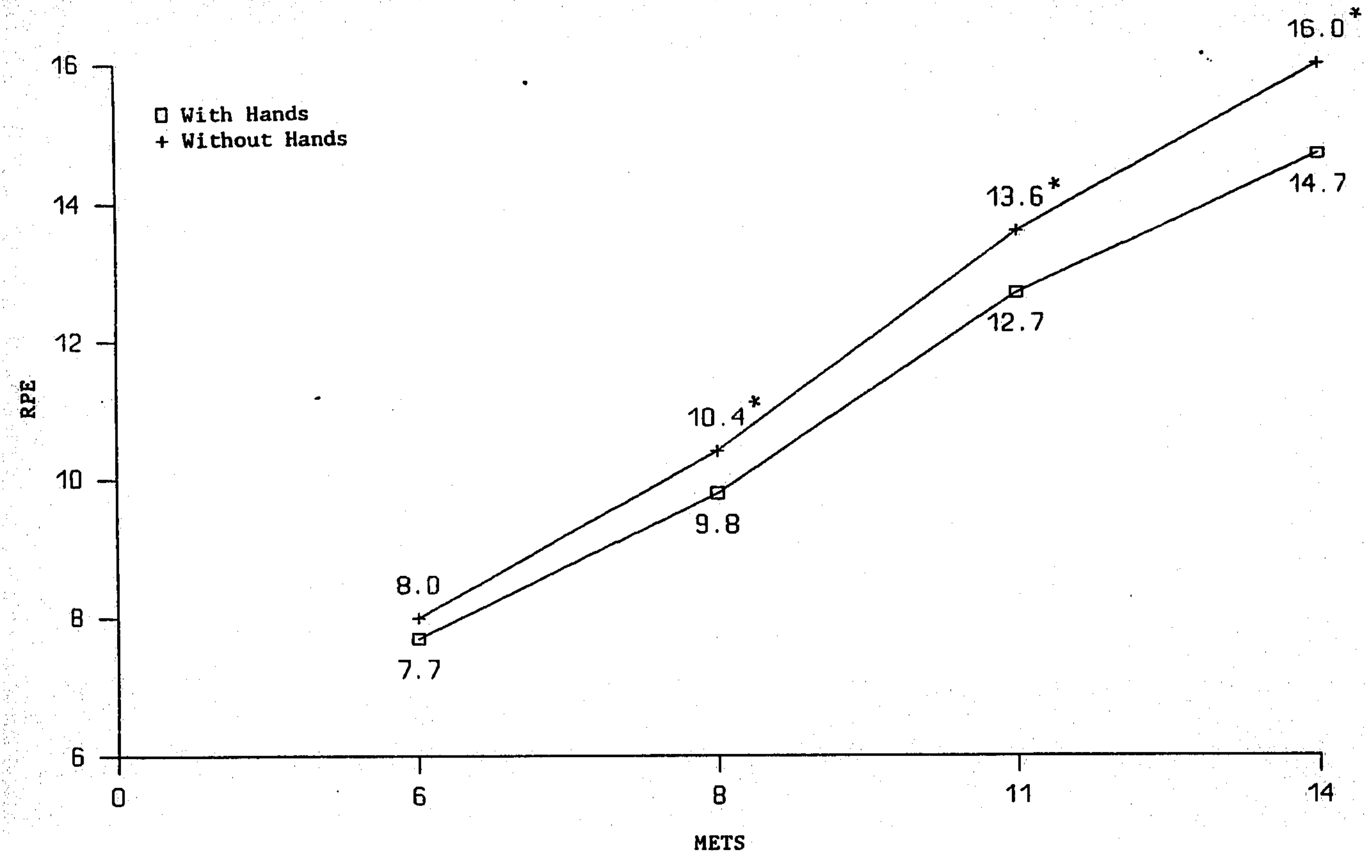

Figure 8. Comparison of RPE at each MET level with and without hands.
* Without hands significantly higher (p<.01).

actual MET levels without the use of hands was accepted only at 14 METS. The MET levels of 6, 8, and 11 were found to be significantly ($p < .01$) higher than predicted without hands resulted in an underestimation of the energy expenditure by the programmed METS. The null hypotheses indicating no difference between the programmed and actual MET levels performed on the StairMaster were rejected at the MET levels of 6, 8, and 11. As seen in Table 5 at 6 METS both methods were higher than the programmed level which underestimated the actual MET level preformed. At 11 and 14 METS the MET levels with hands overestimated the actual METS performed. The null hypotheses was accepted at 8 METS with hands and 14 METS without hands.

Even though the length of time on the StairMaster was not statistically analyzed, the number of subjects completing each stage was meaningful. Table 6 indicates that more subjects completed higher intensities when they could use their hands.

Discussion

The purpose of this investigation was to determine if the physiological responses were altered with and without the use of hands on the StairMaster Gauntlet during various exercise intensities on 20 healthy college females.

Table 5. Programmed MET values and actual MET values performed

Actual METS With Hands	Actual METS Mean Difference	Programmed METS	Actual METS Without Hands	Actual METS Mean Difference
6.3[a] 0.3[b]	0.3*	6.0	6.8 0.4	0.8*
8.0 0.4	0.0	8.0	8.5 0.4	0.5*
10.6 0.5	-0.6*	11.0	11.3 0.4	0.3*
13.1 0.3	-0.9*	14.0	14.4 0.7	0.4

* = significant difference ($p < .01$)
a = mean
b = standard deviation

Table 6. The number of subjects completing each stage of the protocol comparing with and without hands

MET Level	With Hands	Without Hands
6	20	20
8	20	20
11	20	20
14	20	15
17	11	1

The present investigation found that when the overall values were compared the use of hands significantly reduced VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$ and $l \cdot min^{-1}$), ventilation ($l \cdot min^{-1}$), METS, kcal, and heart rate. These variables represented energy expenditure or the metabolic cost of exercise. As exercise intensity increased, the metabolic requirements did not increase to the same extent with hands as it did without hands on the StairMaster. The MET levels, as well as kcals, were also reduced with the use of hands. As exercise intensity increased, the differences between methods for VO_2, V_E, METS, and kcal also increased. This may possibly be due to the greater amount of hand usage especially at higher exercising rates. However, it is unknown why the mean difference of heart rates at each stage remained consistent as the intensity increased.

Barrett's (1989) study comparing no hand support (NS), moderate hand support (MS), and heavy hand support (HS) found that at higher intensities hand usage also influenced the physiological responses to the exercise. Her overall results found a significant difference between the NS and MS groups for VO_2, V_E, and RPE while VO_2, V_E, HR, RPE, SBP (systolic blood pressure), and DBP (diastolic blood pressure) were found significantly different between the NS and HS groups. The variables VO_2 and DBP were found to be significantly different between MS and HS support groups.

The differences between the methods in both these studies may be the result of the excessive usage of hands that occurred at the higher intensities.

The present investigation was designed for balance and not for support on the StairMaster in a clinical setting. Since there are no pressure gauges on the StairMaster, an individual does not know how much pressure is being applied to the handrails during a workout. The tendency to increase hand usage as exercise intensity increases is normal. Individuals who use their hands also find that exercise can be maintained longer and the intensity of work becomes less fatiguing. As seen with VO_2, V_E, METS, kcal, and RPE, the energy demand is decreased with hand usage. The RER at all stages was found to be lower with hands than without hands, however they were only significantly lower at the 11 and 14 MET levels.

In the present investigation, relative ($ml \cdot kg^{-1} \cdot min^{-1}$) and absolute ($l \cdot min^{-1}$) oxygen consumption were found to be significantly lower when the hands were used at all comparative MET levels. Although Barrett's (1989) study only looked at relative oxygen consumption, she also reported significant decreases in values with hand usage. Hanson et al. (1989) compared oxygen consumption on the StairMaster with actual stair climbing and found that actual stair climbing required more oxygen per kg of body weight to perform the activity. However, Hanson et al. (1989) did not define the hand usage in their study.

Although Barrett's study was the only research that compared hand usage on a step ergometer, several authors (ACSM, 1991; Beadle et al., 1990; McConnell & Clark, 1987; Zeimetz et al., 1985) previously demonstrated the use of handrails overestimated oxygen consumption by about 10-30% during treadmill exercise. For example Zeimetz et al. (1985) measured oxygen consumption of five different handrail methods of varying positions and amount of support on the treadmill. They reported as much as a 30% difference in oxygen consumption with and without hands.

Doherty (1989), Holland et al. (1990), and Holland et al. (1988) all compared maximal exercise responses on the treadmill with the StairMaster. These authors found no significant difference in maximal oxygen consumption, but found that hand usage allowed longer time on the treadmill. Von Duvillard and Pivirotto (1991) investigated hand usage on the treadmill and reported no significant difference in VO_2max but a significantly longer time on the treadmill. Von Duvillard and Pivirotto (1991) also reported a higher VO_2 response during submaximal exercise when no hands were allowed. The results of the present study have shown that the use of hands also allowed longer time on the StairMaster. As can be seen in Table 6 more subjects completed the stages at the higher intensities when hands were allowed to be used. Since energy costs were also found to be significantly lower at these stages, this provides a good indication that the hands were used for support at the higher intensities rather than just providing balance.

Minute ventilation (V_E) was found to be significantly lower with the use of hands at all stages. A mean difference of 7.1 $l \cdot min^{-1}$ was found when combing all stages, and a significant difference was found between methods at all stages. These results also agree with Barrett (1989) who reported a significantly lower V_E with increasing use of hands. When comparing methods at each stage, Barrett (1989) found significant differences between NS and MS groups and NS and HS groups but no significant difference between MS and HS. Zeimetz et al. (1985) found a significant difference in V_E comparing gripping intensities of 4.5 kg horizontal resistance, 6.3 kg horizontal resistance, and front hand rail balance to no hands on the treadmill. Results of all three studies showed that using hands decreased the V_E requirements and that the differences in V_E were magnified with increasing exercise intensities.

The mean difference of actual METS performed in this investigation ranged from .5-1.4 METS with and without hands on the StairMaster resulting in a 7% difference. Although hands were only to be used for balance rather than support in this investigation, a significant difference was found between methods at each stage. As the intensity increased (i.e., increased MET level), the difference between the methods increased indicating that greater hand support apparently was being used and not just for balance at the higher intensities. These results are comparable to a health club situation where individuals tend to use a greater amount of hand support as the intensity increases thus creating incorrect energy readings on the StairMaster. These readings can result in an overestimation of the actual work being performed with the use of hands.

Zeimetz et al. (1985) compared five hand usages to no hands and found the mean differences in MET values ranged from 0.8-3.4 METS which directly effects energy expenditure at any given workload. Von Duvillard and Pivirotto (1991) reported an overestimation of 1 MET when hands were used at submaximal exercise to predict VO_2max. The results of the present study for step ergometry support Von Duvillard and Pivirotto's (1991) and Zeimetz et al. (1985) treadmill findings. As found with oxygen consumption and METS, increasing workloads increase the difference in energy expenditures between exercising with or without hands.

Calories or kcals were found to be significantly lower with hands at all MET levels. This was anticipated since kcals are computed from the resulting VO_2 values. The subject burned more calories when not using her hands which indicated that the programmed kcal in the StairMaster may overestimate the calories burned if hands are being used. Individuals who are trying to lose weight would have to work longer to burn the same amount of calories if they used their hands. At a difference of 0.8 kcals per minute, a 30 minute workout 5 days a week could make a 120 calorie difference. For individuals who are trying to lose weight, the hand condition they choose could make an overall difference between losing weight and maintaining weight. Those who choose to use their hands to make it easier can maintain exercise longer thus possibly expending more energy. Those who choose not to use their hands at the same intensity can burn the same amount of kcals in a shorter amount of time, however, they can not exercise as long. Looking at the raw data, there may be a possible error in the calculation of kcals at 14 METS, due to the number of individuals who reached RER > 1.0. The kcals are determined by the RER value that is reached. Any value > 1.0 will burn more kcals than what is interpreted.

The differences in methods for RER were not found to be statistically different at the lower two levels but were significantly different at the higher two workloads (11 and 14 METS). A lower percent of VO_2max was obtained at the lower stages of RER which could explain why a significant difference was not found. With increasing MET levels the subjects approached their maximal work load which was reflected in the higher RER value. At 14 METS without the use of hands, an RER of 1.00 indicated that the subjects had reached maximal effort. The mean value of 0.95 with the use of hands at 14 METS indicated that the subjects had not reached maximal effort.

Barrett (1989) reported a significant difference in the RERs between NS and MS groups and NS and HS groups, while no significant difference was found between MS and HS groups. The highest RER in her study occurred at 7 and 8.5 METS for the HS group. Barrett suggested these differences were the result of the restricted blood flow while supporting approximately 30-40% of the body weight resulting in greater lactic acid production than in the NS and MS groups.

As expected heart rates were found to be lower with the use of hands, however it is unknown why the mean differences in hearts rates did not increase as intensity increased. The use of hands lowered the heart rates needed to perform on the StairMaster. When determining exercise prescriptions, HR and MET levels are used to determine the level of intensity to be used (ACSM, 1991). In the present study the use of hands resulted in lowering the heart rates by an average of 9 beats•min^{-1} lower which would make a difference in the exercise prescription calculated for some individuals, especially cardiac patients. It would appear that individuals who exercise on the StairMaster should decide whether they wish to exercise with or without the use of hands and adjust their exercise prescription accordingly. According to the ACSM (1991) and McConnell and Clark (1987), if a subject's VO_2 is to be estimated from a treadmill test it is essential that the equations used specify with or without hand usage. This also appears to be appropriate for the StairMaster exercise.

The rating of perceived exertion (RPE) is based on the individual's perception of intensity. The comparison of methods at each stage found no significant difference in RPE at 6 METS possibly because the intensity level was light. At the lower intensities both methods were perceived to be easier, therefore, there was very little variability between methods. With increasing workloads the differences between the methods also increased which indicated greater variability among subjects. As seen in VO_2, with increasing intensities the subjects are achieving a higher percentage of VO_2max which also increases their perception of intensity at the higher workloads. The difference between methods indicates that the use of hands is perceived to be easier. Barrett (1989) found her results showed significant differences in RPE between NS and HS during 10-14.5 METS and between NS and MS during 13.1-14.5.

The second purpose of this investigation was to determine if there was a significant difference between the actual METS measured and the programmed METS on the StairMaster (see Table 5). At 6 METS, the measured values were greater then the estimated programmed MET values. If no hands were used, the programmed energy expenditures were underestimated at 6-11 METS and the ranges became closer to the programmed levels as intensity increased. When exercising with hands on the StairMaster, the average MET level achieved was accurate at 8 METS and declined below the programmed MET level as intensity increases thus the programmed value overestimated the actual energy expenditure. Riddle and Orringer (1990) using the StairMaster 4000 PT with the same computerized console as the Gauntlet, found that the console significantly underestimated all MET values from 5 to 17 METS. If the programmed MET values underestimated the true MET values achieved, the energy cost is greater than what is predicted thus energy expenditure is actually higher than what the computerized console is recording.

Summary

Analysis of the data revealed significantly lower values in VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$ and $l \cdot min^{-1}$), V_E ($l \cdot min^{-1}$), METS, RER, kcal, HR, and RPE when hands were allowed to be used on the StairMaster compared to no hand usage. The methods, stages, and interactions were analyzed separately. Overall, both the methods and stages were found significantly different with hands resulting in significantly lower values for all variables. Comparing each method at each stage the RER at 6 and 8 METS, along with RPE at 6 METS, were the only variables that did not reach significance. In comparison of method at each stage, RER at 11 and 14 METS, RPE at 8, 11, and 14 METS, and all stages of oxygen consumption ($ml \cdot kg^{-1} \cdot min^{-1}$ and $l \cdot min^{-1}$), ventilation ($l \cdot min^{-1}$), METS, kcal, heart rate ($beats \cdot min^{-1}$) were found to be significantly lower with the use of hands.

There was a significant difference between the programmed MET levels and the MET levels actually obtained with or without the use of hands. No significant difference was found between the programmed MET level at 8 METS with hands and at 14 METS without hands. A significantly higher value was found at 6 METS with hands and 6, 8, and 11 METS without hands when compared to the corresponding programmed MET values. The corresponding MET values for 11 and 14 METS with hands were found to be significantly lower.

The data from this investigation and other related investigations clearly indicate that using the handrails during exercise will decrease VO_2, V_E, METS, RER, kcal, HR, and RPE which can grossly overestimate the metabolic values. More research needs to be done in the areas of step ergometry. A few studies (Doherty, 1989; Hanson et al., 1989; Holland et al., 1990; Holland et al., 1988; Riddle & Orringer, 1990;) have compared the various modes of exercise with the StairMaster. Ben-Ezra and Verstraete (1988) and Verstraete and Bassett (1989) studied training specificity of the StairMaster. Zeimetz et al. (1985) compared five hand usages to no hands on the treadmill, however at this writing Barrett's (1989) study was the only work that addressed the effect of using hands during exercise on the StairMaster. Therefore, more research is needed with this new "hot" machine.

CHAPTER V

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

Summary

Twenty female volunteers from University of Wisconsin-La Crosse each performed two discontinuous StairMaster tests: with and without hands. Workloads increased 2-3 METS per stage with a 2 minute rest period between each stage. The subject proceeded until she grasped the handrails during the no hands protocol, could no longer continue, or completed 17 METS.

All respiratory responses were analyzed by the Quinton (Q-Plex I). Heart rates were determined by a UNIQ-CIC heart rate watch and entered into the Q-Plex at the end of each minute. The RPE was taken the last 20 seconds of each stage. Only the last minute values of each stage were analyzed.

The SAS program was used to analyze the overall results. The alpha level was adjusted using the Bonferroni method to identify the significant differences.

The following findings were reached on the StairMaster Gauntlet based on the results of this investigation.

1. The ANOVA revealed significantly ($p < .05$) lower VO_2, V_E, MET, RER, kcal, HR, and RPE when the hands were allowed, regardless of stages.

2. The ANOVA revealed significantly ($p < .05$) higher VO_2, V_E, MET, RER, kcal, HR, and RPE as the stages increased, regardless of method.

3. The Bonferroni method revealed significantly ($p < .01$) lower responses at each stage for VO_2, V_E, METS, kcal, and HR when hands were allowed to be used.

4. The Bonferroni method revealed no significant ($p > .01$) difference at MET levels 6 and 8 for RER and 6 for RPE in comparison of methods.

5. The StairMaster Gauntlet was found to overestimate the actual VO_2 values at the higher levels with hand usage and underestimate the actual values when hands were not used.

Conclusion

This investigation compared the physiological responses of submaximal and maximal exercise responses with and without the use of hands on the StairMaster. The use of hands resulted in significantly lower VO_2, V_E, METS, kcals, and HR at each stage/MET level. As the intensity increased the differences between the methods also increased.

No significant difference was found between methods at MET levels 6 and 8 for RER and 6 METS for RPE. However, a significant difference was found between methods at MET levels 11 and 14 for RER and 8, 11, and 14 for RPE also resulting in lower energy expenditure with the use of hands.

Even though length of time on the StairMaster was not analyzed, the data indicated that individuals extended their StairMaster time when hands were being used. Along with the previous findings, this also indicates that energy expenditure is lower with the use of hands. Therefore in conclusion, there is a significant difference in physiological responses with or without the use of hands while exercising on the StairMaster.

Clinical Implication

In a clinical setting technicians need to be aware of the physiological effects of handrail usage. As intensity increases it is common for individuals to use greater amounts of hand usage. This greater amount of hand usage extends the length of time on the StairMaster overestimating the amount of energy that is being used.

Employers and instructors at fitness clubs need to instruct individuals of the importance of balance on the handrails. Support of the body weight on the handrails decreases the physiological demands, thus overestimating the energy requirements that are used during that time period.

Suggestions for Further Research

The following suggestions have been made for future research:

1. Future research comparing the physiological responses of the StairMaster Gauntlet to the StairMaster 4000 PT.

2. Continue research to design a standard protocol for VO_2max testing comparable to the treadmill.

3. Future research on the biomechanical effects of the StairMaster Gauntlet and the StairMaster 4000 PT.

4. Future research of the long term implications (benefits and injuries) of the StairMaster.

5. Future research on the effects of the StairMaster on hypertensive individuals.

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APPENDIX A

RAW DATA

Individual characteristics

Subject	Age yrs	Weight kgs	Height cms
01	22	65.0	172.7
02	22	59.5	170.2
03	20	64.5	170.2
04	21	59.1	170.2
05	22	49.5	165.1
06	25	71.8	172.7
07	19	58.6	160.0
08	24	60.5	160.0
09	23	68.6	175.3
10	24	59.5	160.0
11	21	56.8	157.5
12	24	75.5	170.2
13	21	61.4	162.6
14	22	69.5	175.3
15	23	53.6	160.0
16	22	68.2	162.6
17	27	64.5	172.7
18	27	67.3	172.7
19	27	54.5	152.4
20	20	63.6	162.6
Mean	22.8	59.6	166.3

Individual data for VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	21.7	26.6	37.1	48.2
02	23.1	28.7	39.0	
03	22.4	28.3	37.2	
04	20.1	26.3	35.4	45.1
05	19.4	24.9	33.8	34.2
06	23.7	29.0	38.2	45.2
07	23.6	30.3	39.6	49.3
08	22.6	29.0	38.0	47.6
09	22.9	29.7	37.0	47.1
10	22.2	29.8	36.4	45.5
11	21.7	27.3	36.4	
12	21.5	27.1	32.9	44.3
13	21.5	27.6	36.2	
14	20.9	27.4	36.1	45.0
15	23.9	29.3	39.0	45.4
16	20.4	26.4	35.6	
17	22.6	28.2	35.9	46.0
18	22.5	28.6	39.8	48.6
19	22.8	29.0	38.9	49.5
20	21.9	28.0	36.4	44.6
Mean	22.1	28.1	36.9	45.7

Individual data for VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	23.8	28.8	38.6	50.6
02	22.5	28.9	38.6	
03	23.7	28.8	38.2	
04	21.6	27.6	37.3	46.5
05	21.2	29.6	38.1	47.8
06	26.0	31.8	41.5	49.2
07	25.1	32.1	41.7	51.2
08	24.4	31.7	41.2	54.1
09	22.9	29.4	39.5	48.0
10	24.4	30.3	40.6	50.5
11	24.4	30.9	40.8	
12	23.7	30.1	40.0	52.2
13	22.8	29.1	38.2	
14	25.3	30.0	37.1	47.1
15	25.8	31.0	41.1	52.1
16	21.7	28.6	40.0	
17	22.7	28.0	38.7	48.4
18	23.3	30.5	38.8	50.8
19	25.3	31.0	42.2	54.9
20	23.1	30.1	40.8	53.1
Mean	23.7	29.9	39.7	49.8

Individual data for VO_2 ($l \cdot min^{-1}$) with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	1.545	1.865	2.506	3.282
02	1.360	1.691	2.297	
03	1.443	1.823	2.395	
04	1.175	1.540	2.072	2.636
05	0.959	1.231	1.669	1.691
06	1.708	2.088	2.754	3.262
07	1.392	1.785	2.334	2.904
08	1.373	1.760	2.309	2.894
09	1.568	2.034	2.534	3.227
10	1.310	1.755	2.144	2.664
11	1.238	1.562	2.079	
12	1.648	2.080	2.521	3.392
13	1.314	1.690	2.219	
14	1.450	1.904	2.508	3.120
15	1.288	1.579	2.107	2.452
16	1.381	1.787	2.407	
17	1.453	1.813	2.311	2.961
18	1.528	1.948	2.706	3.304
19	1.241	1.578	2.119	2.695
20	1.392	1.778	2.313	2.829
Mean	1.388	1.765	2.315	2.888

Individual data for VO_2 ($l \cdot min^{-1}$) without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	1.408	1.724	2.403	3.126
02	1.345	1.728	2.311	
03	1.524	1.853	2.458	
04	1.286	1.638	2.214	2.762
05	1.038	1.449	1.865	2.343
06	1.861	2.279	2.973	3.522
07	1.457	1.865	2.423	2.972
08	1.451	1.883	2.447	3.211
09	1.570	2.015	2.702	3.287
10	1.450	1.802	2.413	3.002
11	1.371	1.737	2.297	
12	1.762	2.242	2.972	3.882
13	1.393	1.782	2.340	
14	1.754	2.079	2.572	3.269
15	1.379	1.660	2.198	2.790
16	1.486	1.959	2.737	
17	1.461	1.804	2.490	3.118
18	1.563	2.046	2.607	3.411
19	1.388	1.702	2.314	3.010
20	1.466	1.910	2.593	3.371
Mean	1.471	1.858	2.466	3.138

Individual data for V_E ($l \cdot min^{-1}$) with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	35.8	43.9	63.9	101.1
02	31.6	40.8	61.8	
03	34.7	47.0	72.7	
04	29.2	38.0	54.7	86.0
05	23.9	31.8	45.7	47.5
06	39.2	49.6	81.3	115.9
07	34.2	45.9	64.1	91.5
08	29.5	37.5	54.2	80.3
09	34.4	44.2	54.6	74.8
10	34.1	43.1	54.5	79.0
11	28.1	32.4	44.5	
12	37.6	46.0	55.9	85.1
13	35.5	42.2	63.9	
14	30.4	39.0	53.8	77.4
15	29.8	33.5	48.7	65.9
16	30.0	41.7	67.1	
17	31.0	38.4	54.0	77.1
18	33.5	44.6	71.6	113.0
19	29.3	38.5	54.6	73.8
20	29.4	37.8	55.7	80.1
Mean	32.1	40.8	58.9	83.2

Individual data for V_E ($l \cdot min^{-1}$) without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	39.6	46.3	66.4	116.4
02	32.4	47.5	73.8	
03	40.7	52.4	82.9	
04	32.2	39.1	57.7	89.0
05	25.9	35.6	55.0	79.6
06	47.2	62.4	96.5	129.9
07	37.2	48.5	70.6	105.0
08	31.1	42.4	60.5	100.8
09	32.4	45.6	60.7	83.4
10	33.1	44.3	66.2	96.7
11	28.0	35.1	52.1	
12	42.3	50.7	66.0	98.9
13	35.6	46.8	73.6	
14	34.7	39.2	55.0	83.3
15	33.3	36.6	56.4	97.5
16	36.9	50.1	81.7	
17	32.9	38.5	56.7	84.3
18	34.7	47.4	64.9	122.9
19	33.5	42.7	62.0	88.1
20	33.9	45.5	72.1	115.3
Mean	34.9	44.8	66.5	99.4

Individual data for METS with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	6.20	7.60	10.59	13.77
02	6.59	8.20	11.13	
03	6.40	8.09	10.62	
04	5.74	7.52	10.12	12.87
05	5.54	7.12	9.65	9.77
06	6.77	8.27	10.91	12.93
07	6.75	8.65	11.31	14.07
08	6.46	8.27	10.86	13.60
09	6.54	8.48	10.57	13.46
10	6.34	8.50	10.38	12.91
11	6.19	7.81	10.39	
12	6.14	7.75	9.40	12.64
13	6.13	7.89	10.36	
14	5.97	7.84	10.33	12.85
15	6.82	8.36	11.15	12.98
16	5.84	7.56	10.18	
17	6.45	8.05	10.25	13.14
18	6.42	8.18	11.37	13.88
19	6.52	8.29	11.13	14.15
20	6.27	8.00	10.41	12.73
Mean	6.30	8.02	10.56	13.05

Individual data for METS without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	6.81	8.22	11.04	14.46
02	6.42	8.25	11.03	
03	6.76	8.22	10.90	
04	6.18	7.88	10.65	13.28
05	6.06	8.45	10.88	13.67
06	7.42	9.09	11.85	14.04
07	7.17	9.18	11.93	14.63
08	6.98	9.05	11.77	15.44
09	6.55	8.41	11.27	13.72
10	6.97	8.67	11.60	14.43
11	6.96	8.82	11.67	
12	6.77	8.61	11.42	14.91
13	6.50	8.32	10.92	
14	7.22	8.56	10.59	13.46
15	7.36	8.86	11.73	14.90
16	6.20	8.17	11.42	
17	6.48	8.01	11.05	13.84
18	6.65	8.71	11.10	14.52
19	7.23	8.86	12.05	15.67
20	6.59	8.60	11.67	15.17
Mean	6.76	8.54	11.33	14.41

Individual data for RER with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	0.79	0.83	0.89	1.00
02	0.76	0.81	0.91	
03	0.79	0.86	0.98	
04	0.79	0.80	0.83	0.91
05	0.79	0.84	0.90	0.89
06	0.74	0.79	0.92	1.00
07	0.80	0.84	0.90	0.97
08	0.80	0.83	0.91	0.96
09	0.81	0.86	0.89	0.94
10	0.76	0.78	0.82	0.89
11	0.84	0.86	0.94	
12	0.77	0.80	0.83	0.92
13	0.84	0.86	0.95	
14	0.81	0.85	0.93	1.04
15	0.79	0.79	0.85	0.90
16	0.73	0.81	0.92	
17	0.78	0.84	0.91	0.96
18	0.76	0.83	0.94	1.01
19	0.77	0.84	0.90	0.95
20	0.81	0.85	0.93	1.01
Mean	0.79	0.83	0.90	0.96

Individual data for RER without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	0.83	0.85	0.91	1.09
02	0.82	0.90	0.99	
03	0.77	0.83	0.96	
04	0.84	0.82	0.87	0.97
05	0.77	0.82	0.93	1.01
06	0.82	0.87	0.97	1.03
07	0.82	0.84	0.93	1.02
08	0.74	0.81	0.88	0.99
09	0.76	0.82	0.87	0.99
10	0.67	0.73	0.82	0.90
11	0.79	0.85	0.97	
12	0.83	0.84	0.86	0.95
13	0.80	0.85	0.95	
14	0.81	0.83	0.95	1.07
15	0.81	0.81	0.91	1.02
16	0.82	0.88	0.96	
17	0.81	0.85	0.92	0.99
18	0.85	0.88	0.97	1.05
19	0.79	0.84	0.90	0.98
20	0.78	0.82	0.93	1.00
Mean	0.80	0.84	0.92	1.00

Individual data for kcal with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	6.78	8.38	11.84	15.78
02	6.50	8.19	11.37	
03	6.95	8.92	12.03	
04	5.65	7.44	10.07	13.03
05	4.62	6.00	8.24	8.32
06	8.13	10.04	13.64	16.48
07	6.71	8.69	11.52	14.56
08	6.63	8.55	11.42	14.47
09	7.59	9.96	12.50	16.06
10	6.27	8.43	10.39	13.11
11	6.03	7.64	10.36	
12	7.89	10.03	12.24	16.81
13	6.39	8.27	11.07	
14	7.02	9.29	12.46	15.89
15	6.20	7.60	10.29	12.11
16	6.56	8.64	11.92	
17	6.99	8.83	11.43	14.82
18	7.31	9.47	13.47	16.72
19	5.95	7.68	10.46	13.44
20	6.73	8.68	11.50	14.30
Mean	6.65	8.54	11.41	14.39

Individual data for kcal without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	7.51	9.10	12.40	16.89
02	6.52	8.53	11.63	
03	7.29	9.00	12.29	
04	6.26	7.95	10.87	13.84
05	4.98	7.02	9.27	11.85
06	9.02	11.18	14.90	17.91
07	7.06	9.09	12.05	15.08
08	6.91	9.11	12.02	16.18
09	7.51	9.78	13.25	16.56
10	6.79	8.56	11.68	14.82
11	6.60	8.47	11.50	
12	8.56	10.92	14.55	19.37
13	6.72	8.70	11.68	
14	8.48	10.10	12.85	16.74
15	6.68	8.03	10.87	14.15
16	7.20	9.62	13.70	
17	7.07	8.81	12.36	15.72
18	7.62	10.07	13.06	17.40
19	6.69	8.28	11.42	15.12
20	7.03	9.27	12.88	17.01
Mean	7.13	9.08	12.26	15.81

Individual data for heart rate with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	108	124	158	187
02	122	147	179	
03	135	157	179	
04	101	116	144	173
05	90	112	136	142
06	124	146	173	186
07	111	135	162	181
08	101	116	146	167
09	107	131	151	174
10	118	136	155	174
11	130	150	177	
12	107	120	141	162
13	113	137	166	
14	99	112	141	174
15	111	125	144	161
16	116	138	163	
17	99	112	136	160
18	110	125	154	179
19	109	123	154	177
20	123	139	156	172
Mean	111.7	130.1	155.8	171.3

Individual data for heart rate without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	129	144	174	194
02	132	161	181	
03	158	174	188	
04	110	125	155	176
05	101	121	150	170
06	132	148	174	185
07	116	139	168	186
08	107	131	157	182
09	112	137	165	189
10	123	137	166	182
11	133	154	179	
12	118	131	150	169
13	124	145	173	
14	112	128	146	179
15	115	124	155	176
16	129	155	180	
17	117	131	154	172
18	111	127	156	187
19	107	123	156	184
20	128	143	166	183
Mean	120.7	138.9	164.7	180.9

Individual data for RPE with the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	09	10	13	15
02	10	11	16	
03	07	11	15	
04	09	10	14	17
05	07	09	11	13
06	07	10	13	15
07	09	11	13	15
08	07	09	11	12
09	07	08	11	13
10	07	09	10	15
11	08	12	15	
12	09	11	13	15
13	07	10	14	
14	07	10	13	16
15	07	09	11	15
16	06	07	11	
17	07	09	12	14
18	07	09	13	18
19	07	09	12	13
20	10	11	13	15
Mean	07.7	09.8	12.7	14.7

Individual data for RPE without the use of hands

Subject	6 METS	8 METS	11 METS	14 METS
01	09	11	14	19
02	09	12	17	
03	07	12	17	
04	10	12	13	17
05	07	12	14	16
06	07	09	13	16
07	11	12	15	17
08	06	08	11	12
09	07	09	12	15
10	08	12	14	16
11	07	12	15	
12	09	10	12	14
13	07	09	15	
14	11	11	13	14
15	07	09	11	17
16	07	09	13	
17	09	10	12	14
18	07	10	14	19
19	06	09	13	15
20	09	11	14	19
Mean	08.0	10.4	13.6	16.0

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT
FOR STAIRMASTER STUDY

I ________________________, volunteer to be a subject in a study to determine what effect hand support has on various physiological parameters during exercise on the StairMaster Gauntlet, which is a step-treadmill ergometer. I understand that participation in this study requires that I complete two maximal VO_2 tests on the StairMaster Gauntlet, one test without the use of hand support and the other with hand support. The time span between the two tests will be one to two weeks.

Prior to the actual tests, I will be required to attend two practice sessions in an attempt to familiarize myself with StairMaster exercise. When I am able to demonstrate competency in StairMaster exercise, the practice sessions will be terminated. I also understand that these practice sessions will be scheduled at my convenience.

The StairMaster maximal VO_2 tests will consist of an initial warm-up for five minutes at a relatively low climbing speed. Three stages will follow the warm-up. Each stage, consisting of four minutes, will increase in climbing speed. The test will last approximately 20 minutes. During the test my exhaled air will be collected and heart rate monitored. I understand that I can stop the test at any time. I also understand that there exists the possibility that adverse changes (extreme shortness of breath, chest pain, dizziness) may occur during the tests. If any abnormal situations arise, the test will be immediately terminated.

I consider myself in good health and do not have any physically limited condition or disability, especially in regard to my cardiorespiratory system, that would preclude my participation in the study.

I have read the foregoing and completely understand what is expected of me. Any questions that may have occurred to me have been answered to my complete satisfaction. I have been fully advised of the nature of the study and the possible risks which may be involved. I, therefore, voluntarily consent to participate as a subject in the study. I also may withdraw from the study at any time.

Signed:____
Date:___________

Witnessed: ____________________________________
Date:___________

APPENDIX C

PRETEST INSTRUCTIONS

Please follow the instructions given to you to prevent any outside factors influencing the tests.

1. Do not exercise 24 hours prior to testing.
2. Do not do any strenuous exercise 3 days prior to testing.
3. Refrain from alcohol, tobacco, and caffeine 8 hours prior to testing.
4. Most important be consistent with your sleeping and eating habits before each test.

APPENDIX D

BORG'S RATING OF PERCEIVED EXERTION

Borg's Rating of Perceived exertion

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