ABSTRACT

ZYWICKI, S.S. The energy cost of women walking with and without hand weights while performing rhythmic arm movements. MS in Adult Fitness/Cardiac Rehabilitation, 1992, 83pp. (N. Butts)

Sixteen female Ss (30-59 yrs) volunteered to walk at 3.0 mph, normal walk (NW), while performing arm movements to the shoulder level of excursion (SLE) and head level of excursion (HLE), with no weight (0-), 1 lb (1-), and 2 lb (2-) hand weights: 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, and 2-HLE, respectively. After successfully completing a practice session, the Ss randomly performed the exercises on 3 separate days with no more than 3 exercises per session. Exercise variables measured were HR, V_E, VO_2, ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$), METS, RER, RPE general, and RPE arms. A one-way and two-way ANOVA with a Scheffe post hoc analysis indicated that walking with HEAVYHANDS (HH) sig ($p<.05$) increased HR, V_E, VO_2 ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$), RPEg, RER and MET responses over the NW. HR responses sig ($p<.05$) increased from 86.5 NW to 119.3 (2-HLE), respectively. Sig ($p<.05$) RER values were obtained for all 6 exercises with the exception of 0-SLE. The average energy costs for the NW and 6 exercises were 3.1, 3.7, 4.0, 4.3, 4.0, 4.5, 5.0 METS, respectively. The addition of weight to 0-SLE increased the MET level by 0.5 METS per lb added. Caloric expenditures ranged from 3.9 to 5.3 k·cal for the 6 exercises which were sig ($p<.05$) higher than the NW. Sig ($p<.05$) diff were also found between weight and level of excursion for all variables except RPEg and RPEa. Sig ($p<.05$) increases were observed in VO_2 for 0-lbs to 1-lb, and from 1-lb to 2-lbs. RPEg and RPEa responses did not sig ($>.05$) differ from each other and accurately assessed increased workload. The findings indicate that hand weighted exercises could be used to assist in weight reduction programs. The MET levels obtained in this study were appropriate for persons with a 10 MET capacity or below. The HR response in 2-SLE, 1-HLE, and 2-HLE were sufficient to produce a training effect at or above 60% in the Ss tested using the age prediction formula: 220-age.

THE ENERGY COST OF WOMEN WALKING WITH AND
WITHOUT HAND WEIGHTS WHILE PERFORMING
RHYTHMIC ARM MOVEMENTS

A THESIS PRESENTED

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TABLE OF CONTENTS

CHAPTER

CHAPTER

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Background

More and more Americans are trying to achieve and maintain optimal fitness levels. Levine, Wells, and Kopf (1986) reported that jogging and walking have gained unparalleled popularity as a means of achieving this optimal fitness. They estimated that 73 million Americans walk or jog on a regular basis. In 1986, the United States Public Health Service indicated 60% of the American public were currently involved in some form of exercise (Levine et al., 1986). Thus, it should not be surprising that women are becoming increasingly active in sports and aerobic exercise programs.

There are numerous reasons why individuals exercise. Long term exercise can increase cardiovascular endurance, muscle tone, flexibility, maximal oxygen uptake, cardiac output, total blood volume, and hemoglobin as well as reduce total body fat (Astrand & Rodahl, 1986; Fox & Mathews, 1981). To many, the most important aspect of physical fitness is its effects on body composition. According to Burke and Humphreys (1982), weight control is consistently ranked as one of the primary reasons for exercise by women.

It is important that two essential facts be known about a person's capacity for physical exercise so an exercise program can be safely implemented reducing the risk of over exercising. One is the probable energy cost of the activity and the other is the person's maximum capacity for aerobic exercise. An indirect measurement of the energy expenditure of an activity can be determined by measuring the oxygen cost while performing the exercise. The amount of oxygen consumed when expressed in heat equivalents is termed "kilocalories" or kcal (Fox & Mathews, 1981). Another unit has been used to express the energy or oxygen cost of a given activity called a MET or Metabolic Equivalent. Fox and Mathews (1981) defined a MET "as the amount of oxygen required per minute under quiet resting conditions" (p. 66). It is generally accepted that one MET represents on oxygen consumption of 3.5 mls of oxygen per kg of body weight each minute (American College of Sports Medicine, 1990; Fox & Mathews, 1981).

A person's maximal aerobic capacity can be obtained by performing a maximal exercise test. However, since this is often time consuming and special equipment is necessary to administer the test, exercise prescription is often based upon heart rate. A person's maximal heart rate can be calculated by using the age prediction formula: 220-age.

Any information derived from either of these methods may be useful in establishing effective and safe exercise prescription.

Physicians consider walking to be an excellent form of exercise for individuals over the age of 50. Porcari et al. (1987) found that fast walking could provide a sufficient stimulus to produce an aerobic training effect in most adults. Although the costs of many types of work are well known, the energy costs of walking exercises that include extraneous arm movements, such as using hand held weights, have yet to be established. In recent years, a new device called HEAVYHANDS has been introduced to the American public. However, much of the available information relative to the energy cost and training effects of HEAVYHANDS is anecdotal and lacks scientific reliability. In addition, what limited research information presently available has been obtained on males. There is little research concerning the physiological responses to using HEAVYHANDS by females.

Purpose

The purpose of this study was twofold. The first purpose was to determine if the use of HEAVYHANDS significantly increases caloric expenditure while walking on a treadmill at 3.0 miles per hour. The second purpose was what arm movements, if any, would produce the greatest caloric expenditure?

There are several reasons why this study is needed. If the claims of increased caloric expenditure are unfounded, then the public would be wasting money and time on an exercise that may be more harmful than helpful in the long-run. The benefits of using hand-held weights must be weighed against the increased risk of injury. Merhar, of the American Running and Fitness Association, was quoted by Findlay (1984) suggesting the use of handheld weights could lead to an increased risk of injury because the weights can throw a person off balance.

Stamford (1984) concluded that there is also the chance that an individual could possibly do damage to the upper extremities (i.e., shoulder, upper back, and arm) due to improper muscle movements or an out-of-conditioned upper body. Stamford (1984) also concluded that adding hand-held weights to a running or walking program may decrease the energy expenditure because the individual is more likely to use a slower gait, thus reducing the total energy demand of the activity. He also concluded there may be a trade-off between a decreased aerobic capacity and an increase in strength development while exercising with hand-held weights.

Hypothesis

For this study the null hypothesis was assumed: there will be no significant differences among the caloric expenditures of walking at 3 mph while performing vigorous arm movements, with and without various hand weights. The basis for acceptance or rejection of the hypothesis was set at the .05 level of confidence.

Assumptions

The following assumptions were made for this study.

1. The Beckman Metabolic Measurement Cart was calibrated appropriately and the information was accurately recorded by the tester.
2. The subjects were untrained, normal healthy adult females.
3. The daily living habits of the subjects did not change between tests to any significant level that would influence the outcome of the study.
4. The subjects performed the arm movements to the best of their abilities during the exercise sessions.
5. The practice sessions provided sufficient experience with the testing procedure.
6. A steady state level was achieved in 5 minutes.

Delimitations

The following were accepted as delimitations to this study.

1. The subjects were female volunteers from the University of Wisconsin-La Crosse academic community.
2. The mode of exercise under study was limited to one walking speed on the treadmill (3 mph) at 0% grade.
3. Arm movements were performed with no weight, one pound weights, and two pound weights.
4. The order of testing was randomly selected for each subject.
5. The arm movements were performed to the shoulder level of excursion and to the head level of excursion.

Limitations

The following is a list of limitations for this study.

1. The subjects were untrained with varying fitness levels.
2. Time necessitated that the test be completed on three separate days.
3. Several of the subjects had never been on a treadmill prior to the study.

Definition of Terms

The following terms were used in this study:

Arm Rating of Perceived Exertion (RPEa) - is the subjective value which best represents the level of difficulty of the activity being performed by the subject with special reference to the arms or shoulders. The value is chosen from the Borg Scale of Perceived Exertion (Borg & Noble, 1974).

Beckman Metabolic Measurement Cart (MMC) - is an automated open circuit system for assessing metabolic and respiratory functions that incorporates the use of the OM-11 and LB-2 gas analyzers to determine the amount of oxygen consumed and carbon dioxide produced by the subject (Wilmore, Davis, & Norton, 1976).

General Rating of Perceived Exertion (RPEg) - is a subjective rating scale from 6 to 20 developed by Borg (1970) to determine how hard an individual perceives they are performing physical work.

Head Level of Excursion (HLE) - is the movement of the hand through the sagittal plane from the hip to the shoulder and back to the hip while walking. The axis of motion is through the elbow joint.

HEAVYHANDS (HH) - is a hand weight produced by the AMF American Company. The weight is designed with a knuckle guard that helps reduce the strain of gripping the weight while exercising.

Level of Excursion (LE) - is the specific distance and movement pattern the arm traverses while walking.

Shoulder Level of Excursion (SLE) - is the movement of the hand through the sagittal plane from the hip to the shoulder level and back to the hip while walking. The axis of motion is through the elbow joint.

Steady-State - is the physiological state where oxygen supply and demand are in balance. The oxygen consumption rises to a given level and then plateaus for the exercise session. In this study, steady-state was assumed to occur in 5 minutes when oxygen consumption did not vary more than 150 ml per minute during collection of respiratory gases.

Walking Pattern - is a movement pattern in which the performed arm motion is synchronized with the swing phase of the contralateral leg. The peak of the arm movement corresponds to the heel strike with the contralateral leg.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Over the last century the methods of work in industry and agriculture have shifted from manual labor to mechanical work. The resulting increase in efficiency and productivity have decreased the working week and lessened physical work thus leading to more leisure time. People no longer receive physical exercise by simply going to work and they are looking for new and exciting methods of exercise that would encompass all areas of fitness.

Current participation in exercise to develop cardiovascular fitness has created a need to know the relative stress of different exercise modalities. Exercise prescription requires a precise knowledge of the physiological demands of an activity. These demands should be known before the sedentary healthy individual, or those with compromised cardiovascular functions, participates in these activities.

Numerous exercise modalities have been thoroughly studied but a relatively new form of exercise has gained popularity without proper study. The use of HEAVYHANDS as a method of exercise has been a topic of controversy and the research in this area is still inconclusive. It was the intention of this investigator to utilize this study as a means of adding new and relevant information to the area of hand held weights (HEAVYHANDS) and energy expenditure. Following is a review of the research related to this study and includes studies of energy assessment.

Energy Assessment

Calorimetry

Knowledge of energy expenditure in various physical activities is very important for the precise prescription of exercise in weight control programs, heart disease patients, and for sensible systematic training programs for normal subjects and athletes.

As early as 1899, Atwater and Benedict determined that it was possible to measure and record the amount of energy produced by an object through a process called direct calorimetry. This procedure determines the amount of heat gained or lost in an enclosed chamber called a calorimeter. Although this method is quite accurate it is impractical due to cost and the need for an enlarged chamber with walls specifically designed to absorb and measure the heat produced by the subject (Lamb, 1978). The easiest way to measure metabolic cost of any given activity is through indirect calorimetry which uses computer technology and electronics for the collection, measurement, and computation of respiratory and metabolic data (Kannagi et al., 1983; Wilmore et al., 1976). Since oxygen is utilized during energy-yielding reactions and carbon dioxide is produced, the exhaled air contains less oxygen and more carbon dioxide than the inhaled air. Thus the analysis of the difference in composition between the exhaled air and the ambient air brought into the lungs reflects the body's constant release of energy.

Since the metabolic processes of the body utilize oxygen and produce carbon dioxide as a by-product, the quantity of these respiratory gases are directly related to energy expenditure (de Vries, 1980). These gases can then be collected and measured electronically. There is growing evidence that there is a high correlation between indirect calorimetry for estimating energy metabolism and the direct methods of calorimetry (Kannagi et al., 1983; Snellen, 1980; Wilmore et al., 1976).

Kannagi et al. (1983) evaluated the reproducibility and the accuracy of measurements by the Beckman Metabolic Measurement Cart (MMC) and a manual method of the ventilatory responses at rest and during symptom-limited exercise in eight subjects. The MMC showed excellent reproducibility of minute ventilation, oxygen uptake (VO_2), carbon dioxide production (VCO_2), and respiratory exchange ratio (RER). The reliability correlations for the MMC were r = .99, .99, .99, .93, respectively. Comparing the two methods of measurement showed excellent agreement for minute ventilation, VO_2, VCO_2, and RER. The authors concluded the MMC provides reproducible and accurate measurements of respiratory variables and on-line results that are an advantage over manual methods due to the amount of time saved for the technician.

Respiratory Exchange Ratio

Scientists can now indirectly observe energy metabolism, since there is a direct correlation between the amount of oxygen present and the metabolic foodstuff being oxidized. As oxygen is consumed by the mitochondria in the process of catabolizing foods (fats, carbohydrates, and proteins), the oxygen consumption is associated with a certain amount of carbon dioxide production. Each type of food that is broken down gives a particular ratio of volume of carbon dioxide produced to the oxygen consumed, due to the different amounts of oxygen required to oxidize each food. This ratio is known as the respiratory exchange ratio (RER) or the respiratory quotient [RQ] (Shaver, 1981). It is then possible to determine the amount of energy metabolized as well as the foodstuff used to form ATP by measuring and analyzing the expired gases (McArdle, Katch, & Katch, 1986). In most cases it is assumed that carbohydrates and fats are being metabolized when RER values are used to calculate kilocalories (kcals) with small amounts of energy provided by non-proteins.

The RER ratio serves as a convenient guide to the nutrient mixture being catabolized for energy. One must know the RER and the amount of oxygen consumed to estimate the body's heat production during an activity (McArdle et al., 1986). Once this information is obtained it is possible to determine the energy cost of an activity in $kcal \cdot min^{-1}$ by knowing the oxygen consumption in $l \cdot min^{-1}$ and the thermal equivalent that corresponds to the proper RER value which ranges from .70 for fats to 1.00 for carbohydrates.

MET

As mentioned earlier, there is another unit of measurement used to express the energy or oxygen cost of a given activity that is easily understood. This unit of measurement is referred to as a MET or Metabolic Equivalent. A MET can be defined as "the amount of oxygen required per minute under quiet resting conditions" (Fox & Mathews, 1981; p. 66). A MET is equal to 3.5 ml of oxygen per kilogram of body weight each minute. For the average 70 kg man and 60 kg woman, this would represent an oxygen consumption of approximately 250 and 210 ml per minute, respectively (McArdle et al., 1986). The unit of measurement referred to as a MET can be easily understood as a reference point. Thus, one MET is equivalent to the oxygen consumption at rest for the average man or woman. If a person were to exercise at 10 METS, he/she would be exercising at a rate that would require approximately 35 $ml \cdot kg^{-1} \cdot min^{-1}$ or 10 times his/her resting oxygen requirements. A MET, then, is seen as a multiple of one's resting metabolic rate or basal metabolic rate (McArdle et al., 1986).

In summary, the understanding of energy expenditure is essential for precise exercise prescription. The knowledge of how much energy is produced through each activity is of paramount importance to coaches, teachers, doctors, and exercise physiologists.

Steady State Activity

Physiological efficiency can be expressed by the total caloric output of certain muscular activities. Oxygen uptake increases during the first minutes of exercise to a steady-state. "A steady-state condition denotes an exercise situation where oxygen uptake equals the oxygen requirements of the tissue" (Astrand & Rodahl, 1986; p. 295). A true steady-state could not occur if any significant part of the energy was obtained through the anaerobic processes. Therefore, during a true steady-state there would be no accumulation of lactic acid (Astrand & Rodahl, 1986).

During steady-state exercise there is little fluctuation in cardiac output, heart rate, pulmonary ventilation, and blood lactate levels because the body is capable of meeting the necessary oxygen requirements. In order to maintain a steady-state a person must work aerobically. If the work is such that a steady-state cannot be maintained then anaerobic metabolism will be activated.

When the average individual's exercise intensity exceeds about 50 to 60% of maximal aerobic capacity, steady-state is almost impossible to maintain (Costill, 1973; Hagberg, Mullin, & Nagle, 1978; McArdle et al., 1986). As work intensity increases, there will also be increases in oxygen intake due to higher body temperature, decreasing carbohydrate oxidation, fatigue, and eventually for the removal of lactic acid rather than direct muscle functions. If oxygen consumption continues to increase, it would indicate that an individual has exceeded a steady-state. For this reason it is advisable to use a workload of less than 50% of maximal capacity when conducting tests that assume a steady-state condition. Astrand and Saltin (1961) found that a 5 minute measurement period would accurately reflect a true steady-state allowing for necessary respiratory and circulatory changes to occur during activity.

In summary, when measuring the energy cost of an activity in steady-state it is necessary to maintain a workload of below 50% of a person's maximal aerobic capacity. This allows the body to meet its energy requirements through aerobic processes. It is then possible to measure the energy cost of an activity without having to take into consideration oxygen debt, since there is little fluctuation in cardiac output, heart rate, pulmonary ventilation, and blood lactate levels during steady-state activity.

Physiological Benefits of Exercise

Intensity of training sessions is of paramount importance to guarantee maximal fitness gains (ACSM, 1990). To bring about the desired physiological benefits of exercise, a person needs to exercise at a level above that of their everyday activity. This is known as the "overload" principle (McArdle et al., 1986). To obtain an overload, an individual may manipulate either the frequency, intensity, or the duration of an activity.

Frequency

Shaver (1981) believed that a sedentary person could improve endurance levels by working out between 2 and 4 days per week. Conversely, the ACSM (1990) recommends 3 to 5 exercise sessions per week. It is important to note that exercising more than 5 days per week may lead to an increased risk of injury. In research conducted on army recruits, Jones (1983) found that in an 8 to 12 week basic training program approximately 60% of the women and 40% of the men were injured in an aerobic exercise program. It should also be noted that exercising less than the recommended number of days per week could lead to insufficient overload thus the individual would not receive an adequate training effect. When exercising with proper care and adherence to the ACSM (1990) guidelines, a person can minimize the risk of injury and receive the desired aerobic benefits of endurance exercise.

Intensity

Maintaining proper intensity levels during exercise sessions will insure maximal fitness gains. The intensity of activity is usually assigned as some percentage of a person's maximal capacity for aerobic exercise. The training intensity of an activity may be calculated by the heart rate response to exercise, by anaerobic threshold, or by the MET level of the activity (ACSM, 1990).

One of the easiest methods to ascertain exercise intensity is through heart rate. A heart rate intensity of between 60 and 90% of maximum capacity should be maintained for endurance training (ACSM, 1990; Shaver, 1981). Maximal capacity percentages may be obtained by direct measurement during maximal exercise sessions but may be difficult to obtain because of the need for expensive laboratory equipment. A relatively simple calculation for maximal heart rate may be obtained by using the following equation: maximal heart rate = 220 - age.

Once maximal heart rate response is obtained through either a direct test or by using the formula presented, a training intensity may now be calculated. For people with sedentary lifestyles, an exercise intensity of about 60% of maximal heart rate may be sufficient to induce a training effect, whereas in a trained athlete it may be necessary to train at about 90% of maximal heart rate capacity (Shaver, 1981).

As stated earlier, it is also possible to calculate exercise intensity by using a proper MET value. A person's maximal MET capacity must first be obtained and then a training intensity between 50 and 85% of maximum capacity should be used to receive the desired cardiovascular improvements (ACSM, 1990). However this method requires the use of expensive and sophisticated equipment for measurement.

When assessing the initial fitness level of an individual prior to an exercise program, the expertise of qualified individuals and the facilities available and the training goals should be taken into consideration. Since using an exercise intensity of 60 to 90% of an individual's maximal heart rate capacity is practical and effective, it is one of the most commonly used methods for exercise prescription.

Duration

The optimal duration of an activity is dependent upon several factors including exercise intensity, training frequency, initial fitness levels, and total amount of work done. In general, the duration of an activity should be between 20 minutes to 60 minutes of aerobic work (ACSM, 1990). Endurance activities with lower intensities should be conducted over longer periods of time. Conversely, those activities of high intensity should be conducted for shorter periods of time.

Zochert (1974) stated that in order for a person to elicit a training effect it would be necessary to expend approximately 300 kcals during a given activity. Exercise regimes requiring 300 to 500 kcals of work produce optimal results in weight reduction and cardiovascular fitness if performed three to five times per week (Cureton, 1969). This is equivalent to walking on level ground for 1 hour at 3.5 miles per hour. Pollock et al. (1971) believed that walking could be considered a moderate-intensity exercise.

Exercise sessions of 20 to 30 minutes are often practical and can produce optimal results as long as the exercise intensity remains at 70% of maximal heart rate (McArdle et al., 1986). As long as the guidelines for exercise regarding intensity and duration are adhered to, significant improvements in cardiovascular fitness will occur rapidly, possibly within 1 or 2 weeks (de Vries, 1980).

Mode

The selection of a specific activity is often made on the basis of the individual's interests, functional capacity, availability of equipment and facilities, and the objectives of the exercise program. The mode of training is immaterial as long as the activity involves large muscle groups involved in rhythmic aerobic activities (ACSM, 1990; McArdle et al., 1986). Running, swimming, rope jumping, cycling, and walking are all excellent activities which tax the aerobic system. When choosing a mode of exercise a person should take into account the reasons for exercise and then train accordingly.

Walking

Walking has gained an enormous amount of support over the years as an excellent way to stay healthy. Proponents believe walking may be the best mode of exercise for an out-of-shape adult who is just starting an exercise program because of the low rate of muscularskeletal dangers (Marchetti, 1980; Schultz, 1980).

A number of studies have demonstrated that walking programs can be effective in improving cardiovascular fitness (Flint, Drinkwater, & Horvath, 1974; Sharkey & Holleman, 1967). In addition, a number of studies have reported a reduction in body fat following a training program of walking or jogging (Frey, Doerr, Laubach, Mann, & Glueck, 1982; Gwinup, 1975; Wynne, Frey, Laubach, & Glueck, 1980).

Gwinup (1975) showed that walking may be the most practical form of exercise for overweight adults. Eleven adult women who were from 10 to 60% overweight, were given a walking program. All subjects lost weight ranging from 10 to 38 pounds. The weight loss seemed to parallel the amount of exercise each subject performed. In a similar study, Lewis et al. (1976) found that after completing a walking and exercise program, 22 obese women lost both fat and total-body weight.

The energy expenditure of walking may vary for a given individual depending upon a number of factors such as total body weight (body weight and load), walking speed, type of surface and grade, as well as the fitness level and the muscular development of the individual (Cotes & Meade, 1960; Passmore & Durnin, 1955).

Several authors (Bobbert, 1960; Mahadeva, Passmore, & Wolfe, 1953; Passmore & Durnin, 1955) studied the relationship between energy expenditure while walking and weight, height, age, race, and sex of the individuals.

Although age, sex, height, and fitness levels are important factors when calculating the energy cost of walking, the body weight of the individual is considered to be of primary importance (Bobbert, 1960). Passmore and Durnin (1955) also concluded that weight was the most important factor in determining individual energy expenditure.

Passmore and Durnin (1955) concluded that the energy cost of walking will increase proportionally when speeds increase between 1.9 and 4.0 mph or with body weight increases. The energy cost of walking 2.0 to 4.0 mph can be easily estimated because of these linear relationships. The relationship between energy expenditure and walking speed becomes curvilinear at speeds greater than 4.0 mph.

Several formulas have been devised which take into account walking speed and the weight of the individual that can accurately assess the energy cost of walking. Estimated values for walking 3.0 mph range from 3.8 to 4.0 kcals per min (Bobbert, 1960; Workman & Armstrong, 1963). Kashiwa and Rippe (1987) calculated the caloric cost of walking for the speeds of 3.0 to 4.5 mph according to body weight (see Table 1).

Table 1. Caloric cost of walking (calories per mile)

Walking pace (mph)	Body weight (lbs) 100	125	150	175	200
3.0	52	66	79	92	105
3.5	54	67	80	94	107
4.0	58	72	87	101	116
4.5	65	81	97	113	129

(Kashiwa & Rippe, 1987; p.77)

Research has shown that common forms of exercise such cycling and running, often provide a sufficient stimulus for aerobic conditioning. Much less has been known about the aerobic benefits of fast walking until recently. Porcari et al. (1987) studied 343, 30-to-60-year old men and women to determine if walking a mile as fast as possible could elicit a training heart rate (> or = to 70% of maximal heart rate). In this study 91% of the women and 83% of the men reached a training heart rate. In order to achieve the training heart rate the subjects had to walk at a minimum pace that ranged from 2.9 to 4.0 miles per hour. These same authors studied ten men with high VO_2 values to determine if the subjects could maintain a training heart rate during a 30 minute walking session. The subjects were able to maintain a training heart rate fcr an average of 25 minutes during the walk. The authors concluded that walking may provide an adequate aerobic training stimulus for most adults.

The oxygen cost for walking speeds from 1.9 to 3.7 mph are reasonably accurate and can easily translated into METs for easy readability by the average person. For activities such as running or walking the exercise intensity in METs is directly related to the speed of movement (ACSM, 1990). The ACSM (1990) presents data for common walking speeds and MET levels.

In summary walking is an excellent way to stay healthy. People that walk will receive the aerobic benefits of exercise without the added muscularskeletal risks associated with other types of aerobic activities, such as jogging. Fast walking could also produce enough of a stimulus to elicit a training effect in most adults (Porcari et al., 1987) thus making it a very effective way to maintain or increase one's fitness level.

Weighted Exercise

Walking with weights is becoming very popular as an alternative to running exercise programs for many adults. Walking with weights would appear to be a natural progression for aerobic walking, adding variety during the workout, as well as adding some progressive resistance training for individuals who do not want to run, who are limited by the speed at which they can walk, or individuals with high aerobic capacities who wish to walk.

The reactions for using handheld weights vary greatly from being extremely positive to those who believe it is an undesirable activity. The amount of literature on external loading is growing daily, with varying points of view.

Most researchers are in agreement that the use of weights will increase caloric expenditure (Astrand & Rodahl, 1986; Claremont & Hall, 1988; Makalous, Araujo & Thomas, 1988; Martin, 1985). These authors found increases in energy expenditure from 5 to 10% for each kg of weight carried. Several authors (Claremont & Hall, 1988; Francis & Hoobler, 1986) believed that these small increases in energy expenditure could be obtained by merely increasing the speed or the distance traveled without handweights. They also thought that increasing speed and distance would be a safer and more desirable alternative to carrying weights.

Graves, Pollock, Montain, Jackson, and O'Keefe (1986) found that the addition of 1- and 3-lb weights could significantly increase the metabolic cost of walking by approximately 1 MET and heart rate by 7 to 13 bpm. The authors concluded that the addition of handweights may be beneficial for healthy individuals who wish to increase the intensity of walking exercises. However, the authors found that the use of handweights may be contraindicated for individuals with diminished functional reserve or those with exaggerated blood pressure responses to exercise.

Conversely, Auble, Schwartz, and Robertson (1987) found when adding exaggerated arm movements and weights to various walking speeds, the subjects' requirements for VO_2 increased from 113 to 255% at any given speed. Subjects required greater VO_2 as the height of the arm swing increased regardless of handweight size. The VO_2 also increased as the size of the handweight increased, regardless of the height of the arm swing. Walking while pumping handweights required aerobic metabolic rates equivalent to 31 to 77% of maximal aerobic capacity. Also, heart rates were 54 to 93% of maximal heart rate potential. The authors concluded that the most likely cause for variability in the effects of handweight on energy expenditure of walking is the amount of arm movement used in this study compared to other studies (Claremont & Hall, 1988; Makalous et al., 1988; Martin, 1985). A decrease in either the range of motion or the frequency of movement may reduce the energy requirements of the activity, thus negating the increased weight. After reviewing the current literature on handweighted exercise Auble and Schwartz (1991) concluded that the energy cost of exercising with handweights is closely related to variations in the arm motion patterns.

Mayhew (1977) studied trained runners to determine the oxygen cost and energy expenditure for running. The subjects tested were allowed to select their own running speed, which may have minimized the amount of energy expenditure when compared to arbitrary impositions of pace. Claremont and Hall (1988) found similar results when allowing the subjects to self-determine their own pace while carrying 1 and 2 lb weights on various parts of the body. After reviewing the current literature on handweighted exercise Auble and Schwartz (1991) concluded that leg stride frequency may be an important factor in energy cost for handweighted exercise.

It appears that exercising with weights can benefit individuals involved in programs with weight loss goals. The amount of energy expended will depend upon several factors, including size of the weight carried, speed of locomotion, and the pumping height and frequency. Subjects that were allowed to arbitrarily choose their own speed or pumping height showed minimal energy expenditure increases ranging from 5 to 10%. Reduction in either the range of motion, the frequency of the activity, or the amount of weight used may reduce the energy requirements of an activity. Auble et al. (1987) concluded that walking with weights could produce a sufficient stimulus to produce endurance training effects for persons with poor to excellent levels of aerobic fitness. Auble and Schwartz (1991) also concluded that handweighted exercises which limited VO_2 to 25 $ml \cdot kg^{-1} \cdot min^{-1}$ or less were appropriate for individuals with low to modest levels of aerobic fitness. Cigala (1985) concluded that walking with HEAVYHANDS could produce a training effect in males with poor health or those individuals in a phase II cardiac rehabilitation program.

In Cigala's study (1985), the 15 males (mean = 48.9 yrs) performed vigorous arm movements to the shoulder or the head level carrying no handweights or carrying 1 and 2 lb. handweights while walking at 3.0 mph. Cigala reported increases in oxygen consumption, heart rate, perceived exertion, RER, and METs when exercising with weights. However, it should be noted that the increases in oxygen consumption, heart rate, and MET values were not significant at the ($p>.05$) level. The addition of weight increased the MET level of the activity by approximately 0.5 METs per pound of weight added. In the study conducted by Cigala (1985) the MET values of 3.8, 4.1, and 4.5 were recorded for 0-lbs to the shoulder level of excursion, 1-lbs to the shoulder level of excursion, and 2-lbs to the shoulder level of excursion, respectively. In addition, performing 0-lb to the head level of excursion, 1-lbs to the head level of excursion, and 2-lbs to the head level of excursion at 3.0 mph required 4.1, 4.8, and 5.1 METs, respectively.

According to the ACSM (1990), 50% of the maximum MET capacity must be reached during exercise in order for a subject to obtain a training effect. Therefore, trained individuals with maximal MET capacities of greater than 10 METs would not be able to receive a training effect from walking with HEAVYHANDS at 3.0 mph.

Summary

It is apparent that if women adhere to the ACSM (1990) guidelines for exercise, they will receive the same physiological benefits as do their male counterparts. Any mode of exercise that is safe and uses large muscle groups can be used. One of the controversial methods of exercise is the use of handheld weights (HH). There is little agreement regarding the energy requirements of this activity. The increase in energy requirements due to walking with handweights have ranged from 5 to 8% (Claremont & Hall, 1988) to as high as 225% (Auble et al., 1987). Also, the studies that have been conducted with handweights have dealt primarily with men (Auble et al., 1987; Cigala, 1985; Zarandona, Nelson, Conlee, & Fischer, 1986). There is a need to determine the energy cost of this activity for women.

CHAPTER III

METHODS

Introduction

The purpose of this study was twofold: to determine if the use of HEAVYHANDS would significantly increase caloric expenditure while walking on a treadmill at 3.0 mph; and to determine what arm movements, if any, would produce the greatest caloric expenditures.

Subject Selection

A total of 16 females volunteered to participate in this study from the University of Wisconsin-La Crosse. These subjects were presumed to be healthy and free from disabling disease which might preclude participation in this study. The volunteers were enlisted by personal communication from the Physical Education faculty and staff, as well as by graduate students in the Adult Fitness/Cardiac Rehabilitation Program. An informal meeting was held to answer any questions regarding testing procedures, time, and other requirements. Those individuals who still wished to participate in the study were then asked to choose suitable times for practice and experimental sessions.

Three experimental sessions were necessary for the subjects to complete the required seven exercises. The subjects performed a maximum of three exercises per session. The number and order of exercises completed at each session were randomly assigned by drawing the exercise and the number of exercises (up to three) to be performed out of a hat. The following is a list of the seven exercises:

1) 3.0 mph, normal walk (NW)
2) 3.0 mph, no hand weights (O-SLE)
3) 3.0 mph, HLE with no hand weights (O-HLE)
4) 3.0 mph, SLE with one pound hand weights (1-SLE)
5) 3.0 mph, HLE with one pound hand weights (1-HLE)
6) 3.0 mph, SLE with two pound hand weights (2-SLE)
7) 3.0 mph, HLE with two pound hand weights (2-HLE)

Practice Session

The subjects reported to the Human Performance Laboratory at their scheduled times. Upon their arrival the subjects read and signed the informed consent (see Appendix A) which explained the testing procedures and listed possible health risks involved with the participation in the experiment. The subjects were encouraged to ask questions at this time regarding any aspect of the experiment. After answering all questions, the researcher showed the HEAVYHANDS and demonstrated how to hold and walk with the hand weights.

The first movement demonstrated to the subject was the shoulder level of excursion (SLE). This movement had its focal point at the elbow joint. The subject was instructed to flex the arm to bring the weight up to the shoulder level and then extend the arm down to the side. They were to avoid any unnecessary movements by keeping the upper arm as close to the body as possible. During the arm swing phase the contralateral leg should also be moving so that at the peak of the arm swing, the opposite foot would contact the ground. This action helped the subjects maintain adequate balance throughout the movement.

The second arm movement demonstrated was the head level of excursion (HLE). This movement occurs through flexion and extension of the arm from the shoulder. The subject raised the weight to the head level and then extended the arm back down to the side. During this movement, the elbow joint remained fixed at approximately a 30 degree angle. The contralateral foot should again contact the ground while the hand is at its peak (top of the head).

The subjects were given ample practice time to work on coordinating the arm and leg movements of SLE and HLE exercises. Once the researcher was satisfied with the ability of the subject to perform the coordinated movement in the hallway, the subject was taken into the Human Performance Laboratory to practice walking on the treadmill and to help the subject become more at ease with the testing procedures.

During this part of the practice session, the subjects practiced getting on and off the treadmill safely and practiced both arm movements while walking on the treadmill. To simulate testing conditions, the subjects wore the headgear with a mouthpiece and two-way breathing valve. After the subject and the researcher were satisfied with this portion of the practice session, the Borg scale (1970) was explained (see Appendix B). The subjects were asked to give two ratings of perceived exertion: a general rating of exertion (RPEg); and, an arm rating of perceived exertion (RPEa). Upon completion of this task, all remaining questions were answered and three appointments were made which would enable the subject to complete the testing.

Equipment and Calibration

To insure accuracy, each piece of testing equipment was calibrated and checked prior to each testing session. The Quinton pit treadmill was calibrated by measuring one revolution of the treadmill belt (535 cm) and adding the number of revolutions per minute at 3.0 mph. The number of belt revolutions was calculated to be 16 per minute. The control panel counter recorded the number of revolutions the drive barrel made during that minute. For each mile per hour of speed the drive barrel of the treadmill revolved 21 times. When the treadmill was operating properly the control panel counter would register 63 revolutions per minute at 3.0 mph.

During each testing session heart rates were determined using a Burdick Electrocardiographic (ECG) Recorder. Each subject had three electrodes (Medi-Trace Offset-disposable) placed on their chest in the CM5 position. The first electrode was placed just below the ribs in line with the right leg. The second electrode was placed approximately in the middle of the sternum and the third electrode was placed in the fifth intercostal space on the left chest wall. The color-coated wires were connected to the electrodes on the subject and the ECG recorder after the subject was seated on a chair on the treadmill. A sample recording was then taken for 15 seconds to insure a proper readout.

To determine VO_2 ($L \cdot min^{-1}$,& $ml \cdot kg^{-1} \cdot min^{-1}$), and the respiratory exchange ratio (RER), the MMC was used during the testing sessions (Wilmore et al., 1976). The MMC was calibrated using a known gas sample previously verified by the micro-Scholander technique. Oxygen and carbon dioxide percentages were calibrated within .01% prior to each testing session. Barometric pressure and room temperature were recorded from a barometer in the Human Performance Laboratory. The thermometer in the MMC was then adjusted so that it would correspond to that of the room barometer. Air was injected into a spirometer from a 1 L syringe to calibrate volume. Ten, 1 L syringes were injected into the MMC and the volume meter was adjusted until it read 10 L of air.

Expiratory gases were collected through a plastic tube which was attached to the MMC at one end and a Hans Rudolf nonbreathing valve (model 2700) which was supported by an adjustable headpiece snugly around the head. The plastic tubing was attached to a pole that was anchored to the treadmill handrail. A velcro strap was used to support the weight of the tubing. A nose clip was worn by each subject to ensure that all expired gases were passed through the plastic tube to the MMC.

The handweights (HEAVYHANDS) used during the exercise session are produced by the AMF American Corporation (Schwartz, 1982). The weights require the assembly of two parts: the handle, which weighs one pound, and the screw-on weights that come in various sizes. For the purpose of this study only 1-2 pound weights were used.

Exercise Session

Each subject reported to the Human Performance Laboratory at the appointed time. Prior to each test the subjects were weighed on a Continental Health-O-Meter scale (No. 400 DKL) while wearing the appropriate exercise clothing and shoes. Body weight was taken to the nearest 0.25 of a pound.

Upon completion of the weigh-in, the subject was prepared for electrode placement. In order to insure good electrical conduction, the skin was rubbed with rubbing alcohol and gauze until the skin became reddened. Electrodes were then placed in the CM-5 position. Heart rate was monitored by the Burdick 200 M model EKG machine. The subjects were then seated on a chair on the treadmill and fitted with a headset that supported a low resistance breathing valve and mouthpiece. Respiratory gas values and heart rates were taken during each minute of the 5 minute rest and exercise sessions.

Expired air was collected so the respiratory gas values of minute ventilation (V_E), VO_2 ($L \cdot min^{-1}$ & $ml \cdot kg^{-1} \cdot min^{-1}$) and respiratory exchange ratio (RER) could be analyzed by the MMC.

After the 5 minute resting values were recorded, the first exercise began. The subject was told which exercise sequence they were to perform and given the proper hand weight, if necessary. The chair was then removed from the treadmill, while the subject straddled the belt and held on to the hand railing. The treadmill was then started. Each subject began by placing one foot on the moving treadmill to get used to the speed (3.0 mph). When the subject felt comfortable with speed, she stepped on the treadmill with both feet and began walking. Once she felt comfortable with the walking speed, the subject began the coordinated arm movements. The designated exercise was performed for a minimum of 5 minutes or until steady-state had been obtained. Steady-state was defined as an oxygen variance of less than 150 ml, for 3 consecutive minutes. The average of these 3 minutes was used in the actual data analysis. Heart rates were recorded for 15 seconds during each minute of the exercise session. That number was then multiplied by four, and the total was then recorded on the subject's chart in beats per minute. Walking and arm form corrections were also made by the experimenter when necessary.

The subject was asked to rate her level of perceived exertion during the 4th minute of each exercise session. Two ratings were taken during each exercise: a general rating of perceived exertion (RPEg) and an arm rating of perceived exertion (RPEa). During the normal walk an arm rating was not taken because this rating was assumed to be the same as the general rating of perceived exertion. The experimenter held up the Borg scale so the subject could point to the number that best described her feelings of perceived exertion. The experimenter verified the choice by repeating the number back to the subject. Upon completion of the 5 minutes of steady-state activity, the treadmill was stopped and the rest period began. The subject was seated on a chair on the treadmill while the headset, breathing apparatus, and handweights were removed. The subject was given a minimum of 5 minutes of rest until her heart rate was equal to or below the baseline value. The baseline values were determined by averaging the heart rate, then taken for 15 seconds to insure a proper readout.

Statistical Treatment of Data

Standard descriptive techniques (means, standard deviations, and ranges) were calculated for age, weight, and height of the subjects as well as the steady-state variables of V_E, VO_2 ($L \cdot min^{-1}$, and $ml \cdot kg^{-1} \cdot min^{-1}$) heart rate, (bpm), RER, RPE, and MET level responses to walking 3.0 miles per hour by averaging the values obtained during the last 3 minutes of the steady-state period. MET values were obtained by dividing VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$ by 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. To determine if a significant difference existed between the seven exercises, a one-way ANOVA with repeated measures was calculated for each physiological parameter tested. A two-way mixed design ANOVA with repeated measures was calculated to determine the main effects for handweights and levels of excursion. If the F ratio obtained was significant, a Scheffe' post-hoc analysis was conducted to determine where the difference in the one- and two-way

ANOVAs occurred. For this experiment, the level of confidence was set at .05.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to determine the energy cost of walking with and without hand weights in women. Normal walking (NW) at 3.0 mph was performed with no weight, one, and two pound hand held weights combined with arm movements to the shoulder, and head level of excursion. This chapter contains the statistical analyses of the data, and discusses the possible factors that affect the variables when performing the exercises. Guidelines for prescribing hand held weight walking exercises will also be attempted in this chapter.

Subjects

Sixteen female subjects volunteered to participate in this study at the University of Wisconsin-La Crosse. All the subjects were either graduate students or women employed by the University. The fitness levels of the subjects varied greatly as did the recreational activities of the participants. The subjects' mean age, weight, and height are presented in Table 2 along with the ranges and standard deviations.

Table 2. Subjects' descriptive information.

Variable	Mean	Standard Deviation	Range
Age (yrs)	41.0	9.78	30.0-59.0
Weight (kg)	64.0	6.47	52.0-74.0
Height (cm)	166.7	6.32	157.5-176.5

Results

Means and standard deviations for heart rate (HR), minute ventilation V_E ($L \cdot min^{-1}$), oxygen uptake VO_2 ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$), metabolic equivalents (METS), respiratory exchange ratio (RER), general rating of perceived exertion (RPEg), and arm rating of perceived exertion (RPEa) are presented in Table 3.

Normal Walk

One-way analysis of variance was computed to determine if there was significant differences in the above variables among the normal walk, and the six other exercises (0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, and 2-HLE). The results of the ANOVA are presented in Appendix C. Normal Walk (NW) compared to the other six exercises showed significantly ($p<.05$) lower values for HR, V_E ($L \cdot min^{-1}$), VO_2 ($L \cdot min^{-1}$), VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$), METS, RER, and RER. It should be noted the

Table 3. Means and standard deviations of exercise variables for each exercise mode

Variables	NW	0-SLE	1-SLE	2-SLE	0-HLE	1-HLE	2-HLE
HR	86.5[a]	96.1	100.9	108.0	99.8	109.1	119.3
($b \cdot min^{-1}$)	10.5[b]	11.1	13.1	14.7	11.4	13.6	10.6
VO_2	0.701	0.820	0.892	0.964	0.884	1.014	1.129
($L \cdot min^{-1}$)	0.082	0.111	0.142	0.149	0.098	0.133	0.175
VO_2	10.8	12.8	14.0	15.1	13.9	15.9	17.8
($ml \cdot kg^{-1} \cdot min^{-1}$)	0.9	1.5	2.4	2.2	1.7	2.2	3.2
V_E	17.8	21.8	24.2	26.7	23.2	27.1	31.3
($L \cdot min^{-1}$)	2.1	3.4	4.4	4.9	3.0	3.7	6.0
METs	3.1	3.7	4.0	4.3	4.0	4.5	5.0
	0.2	0.4	0.7	0.4	0.5	0.6	0.9
RER	.75	.78	.83	.83	.80	.84	.86
	.06	.05	.05	.06	.07	.08	.06
RPEg	7.6	8.2	9.4	10.8	8.6	10.3	12.1
	1.6	1.7	1.7	2.0	1.7	2.1	1.8
RPEa		8.1	9.9	12.5	8.9	11.5	16.5
		1.8	2.1	1.9	1.9	2.5	2.1

a= mean
b= standard deviation

NW= Normal Walk
0-SLE= 0 lb, shoulder level of excursion
1-SLE= 1 lb, shoulder level of excursion
2-SLE= 2 lb, shoulder level of excursion
0-HLE= 0 lb, head level of excursion
1-HLE= 1 lb, head level of excursion
2-HLE= 2 lb, head level of excursion

subjects were not asked to give a RPEa for the NW, thus a comparison could not be made with the other six exercises. A Scheffe' post-hoc analysis was performed to determine where the significance existed between (NW) and the six other exercises (see Appendix D).

The HR, V_E, VO_2 ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$), METs, and RPEg responses to a normal walk were significantly ($p<.05$) lower than any other exercises. It should be noted that the RER for the normal walk was not significantly ($p>.05$) different than 0-SLE; however, it was significantly ($p<.05$) lower for all other comparisons.

Weight versus Level of Excursion

A two-way analysis of covariance comparing the weight carried and the level of excursion performed was calculated for all exercises (see Appendix E for specific results).

Since a significant F ratio was obtained for all exercise variables (weight and height) a Scheffe' post-hoc analysis was performed for each variable. The results are presented in Appendix F. Significant ($p<.05$) differences were found between weight and level of excursion for all of the variables. In addition, significant results for interaction were noted for all exercise variables. The results are presented in Appendix G. As the weight and level increased the physiological responses also increased.

Overall the no-weight condition produced significantly ($p<.05$) lower values compared to the 1- and 2-lb weights. As the weight increased from 0-lb to 1-lb and from 1-lb to 2-lbs a significant ($p<.05$) increase in VO_2 ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$) was found. A significant ($p<.05$) increase in VO_2 ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$) was noted when the level of excursion increased from shoulder to head level condition with the exception of 2-SLE vs 0-HLE, and 2-SLE vs 1-HLE. The increase in weight seemed to offset the increase in height in both cases. The V_E values were significantly ($p<.05$) higher for all comparisons with the exception of 1-SLE vs 0-HLE, 2-SLE vs 2-HLE, and SLE vs HLE conditions, respectively. This may indicate that the weight had a greater influence on ventilation than the height of excursion. This may be indicative of a lack of upper body strength on the part of the female subjects in this study.

The RER values were significantly ($p<.05$) greater when comparisons were made by weight, with the exception of 1- and 2-lb weights. By increasing the weight from 1- to 2-lbs, higher RER values were obtained but these increases were not significant ($p>.05$). When comparisons were made by height, no significance ($p>.05$) existed between the SLE and HLE levels of excursion.

Discussion

HR Response

Significant increases in HR were found when adding arm movements and/or weights to an NW. The greatest increase in HR occurred when the level of excursion increased from NW to HLE, and when 2-lb weights were added to the no weight condition. Also, significant ($p<.05$) increases in HR were produced by 2-HLE when compared to all other exercise conditions. Significant ($p<.05$) increases in HR were also found in 2-SLE and 1-HLE over 0-SLE, 1-SLE and 1-HLE, respectively. The increase in HR was expected due to the increase in workload. However, the changes from 1-SLE to 0-HLE, and 2-SLE to 1-HLE were not significant. Apparently the increase in level of excursion was not great enough to offset the decrease in the amount of weight used for these exercise conditions.

Borysyk et al. (1981) reported increases in HR response of 6.7, 10.5, and 10.1 bpm with the addition of arm swings, and a 12 ounce hand weight at walking speeds of 2.0, 3.0, and 3.5 mph, respectively. Borysyk et al. (1981) concluded that the increase in HR was sufficient to produce a training effect in sedentary and cardiac populations. In the present study the average maximal HR response increased from 86.5 (NW) to 108.1 (2-SLE), 109.1 (1-HLE), and 119.3 bpm (2-HLE), respectively. These three exercise conditions produced a HR response sufficient enough to produce a training effect at or above 60% of the age-predicted maximal HR in the subjects tested. The maximal HR method was not used to calculate a target HR because the subjects were not maximally tested on the treadmill. The average age predicted maximal HR (220-age) response for these subjects was calculated to be 179 bpm thus 60% would equal 107.6 bpm.

This heart rate intensity was produced during the 2-SLE, 1-HLE, and 2-HLE exercises. In order to maintain a workload sufficient enough to produce a training effect, the subjects would have to use one of the following exercise conditions: 2-SLE, 1-HLE, or 2-HLE. An increase in exercise intensity could be enhanced by increasing the speed of walking or by increasing the load carried.

The increase in HR can be attributed to both the level of excursion and/or the amount of weight carried by the female subjects. The amount of weight carried appears to have a greater impact on HR response than the level of excursion. This was concluded because a training effect could not be obtained by merely changing the level of excursion from NW to 0-HLE.

V_E Response

A significant ($p<.05$) difference in V_E existed between the NW and all other exercise conditions. Increases in V_E also occurred with changes in level of excursion from SLE to

HLE and/or by adding hand weights. A significant ($p<.05$) increase in V_E was noted in 2-HLE over all other exercises. Increases in V_E were also significant ($p<.05$) for 2-SLE and 1-HLE over 0-SLE, 1-SLE, and 0-HLE, respectively. Such increases in the ventilation ensure that the body has sufficient air for extracting oxygen which is necessary when the body is called upon to perform exercises of increasing intensity. This is supported by Graves et al. (1986) who reported significantly greater increases in V_E when adding handweights to walking exercises performed on a treadmill at a constant speed and grade. The addition of weight to any exercise will increase the load carried, and thus increase the metabolic demands on the body.

Energy Expenditure

When comparing NW to the other six exercise conditions, energy expenditure was significantly ($p<.05$) lower for the NW than all other exercises no matter which measurement was used to express the energy expenditure ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$, and METS).

According to the ACSM (1990), normal walking at 3.0 mph requires approximately 3.28 METS. In the present study, walking on a treadmill at 3.0 mph was found to be equal to approximately 3.1 METS. Increasing the level of excursion to SLE or HLE resulted in greater energy expenditure as did adding 1- and 2-lb weights.

Energy expenditure was significantly ($p<.05$) higher for 2-HLE than all other exercises no matter which measurement was used to express the energy expenditure ($L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$ and METs). Increases in energy expenditure were also noted in 2-SLE and 1-HLE over 0-SLE, 1-SLE, and 0-HLE, respectively. Energy expenditure increases paralleled those indicators for exercise intensity (HR and oxygen consumption) which rose significantly for 2-SLE, 1-HLE, and 2-HLE over 0-SLE, 1-SLE, and 0-HLE, respectively.

Increases in energy expenditure were also observed by Auble et al. (1987), Zarandona et al. (1986), and Makalous et al. (1988) who found that by adding weights to various arm movements they could significantly increase oxygen consumption.

Schwartz (1982) indicated that by adding weight to a walking speed of 150 paces per minute, a one MET increase could be expected with each pound of weight added. A similar study conducted by Cigala (1985) reported an increase of approximately .5 METS with each pound of weight added for men. In the present study the addition of weight increased the MET level of the activity by an average of .5 METS per pound of weight added to 0-SLE. In the present study MET values of 3.7, 4.0, and 4.3 were obtained for 0-SLE, 1-SLE, and 2-SLE, respectively, while walking at 3.0 mph. These values are slightly below those reported by

Cigala (1985) who reported values of 3.8, 4.1, and 4.5 METS, respectively. In addition performing 0-HLE, 1-HLE, and 2-HLE at 3.0 mph required 4.1, 4.8, and 5.1 METS, respectively, for Cigala's study (1985) as compared to 4.0, 4.5, and 5.0 METS for the present study. These differences may have occurred because a number of women in this study exercised on a regular basis, and were in very good physical condition, and thus were able to utilize oxygen more efficiently.

The MET values obtained during this study are appropriate for Phase II cardiac rehabilitation patients which require between 3 to 6 METs, respectively (Porter, 1984). In this study MET values between 3.7 and 5.0 were recorded. As shown in Table 4, changing the weight and/or the level of excursion makes it possible to alter the MET intensity of HH exercises.

Calories

When converting the energy cost of walking to kcals, a 3.3 $kcal \cdot min^{-1}$ was reported in this study. The caloric costs were calculated by determining the product of the specific RER thermal equivalent, and the oxygen consumption in $L \cdot min^{-1}$ (McArdle et al., 1986).

The kcal and MET cost with the RER values for all seven exercises are presented in Table 4. Caloric values of 3.9, 4.0, and 3.8 $kcal \cdot min^{-1}$ were reported by ACSM (1990),

Table 4. The energy cost and RER values for the seven exercises.

Variable	NW	0-SLE	1-SLE	2-SLE	0-HLE	0-HLE	2-HLE
$kcal \cdot min^{-1}$	3.3[a]	3.9	4.3	4.6	4.3	4.5	5.3
	0.5[b]	0.6	0.7	0.7	0.7	0.7	0.8
RER	.75	.78	.83	.83	.80	.84	.86
	.06	.05	.05	.06	.07	.08	.06
METs							
Present study	3.1	3.7	4.0	4.3	4.0	4.5	5.0
Cigala (1985)	3.2	3.8	4.1	4.5	4.1	4.1	5.1
Past research	3.28[c]	8.0[d]	9.0[d]	10.0[d]			

a= means

b= standard deviations

c= ACSM (1990)

d= Schwartz (1982). Subject walking 150 paces per minute.

Bobbert (1960), and Workman and Armstrong (1963), respectively, for walking at 3.0 mph.

The findings of this study demonstrate that pumping HH while walking at 3.0 mph can substantially increase the aerobic metabolic requirements above those of the NW. The energy cost values of the HH exercise all exceeded the 3.3 $kcal \cdot min^{-1}$ cost of walking at 3.0 mph.

The addition of weight and/or the change in the level of excursion increased the caloric expenditure from 28 to 63% above that of the NW. Furthermore, the addition of 1-lb and 2-lb weights increased the caloric expenditure from 8 to 35% above 0-SLE, as well as 12.5 to 25% above the 0-HLE condition. The increase in energy expenditure appears to be consistent with previous investigations (Auble et al., 1987) who reported increases that ranged from 30 to 300% above that of exercising without weights. In contrast Claremont and Hall (1988) found only minimal caloric increases that ranged from 5 to 10% for a kg of weight added to the feet or hands during walking or running.

The differing data in this study compared to other investigations are most likely due to different speeds of walking/or running, and the amount of arm movement used by the subjects. In Claremont and Hall's (1988) study the subjects were allowed to use a self-selected pace as well as self-selected excursion heights. Thus, increases in energy expenditure ranged from only 5 to 8%. In contrast, Auble et al. (1987) found increases in energy expenditure which ranged from 113 to 225% above normal walking. These large increases are due in part because of large ranges of motion as well as faster walking speeds. ACSM (1990), and Passmore and Durnin (1955) reported curvilinear increases in energy expenditure when walking faster than 3.7 and 4.0 mph, respectively. Furthermore, an increase in walking speed is directly related to the pumping rate of the arms. Since the speed of walking was held constant at 3.0 mph, the increases in energy cost can be directly related to the arm movements, and/or the addition of hand weights.

RER

Significant ($p<.05$) increases in RER values were obtained for all six exercises over the NW with the exception of 0-SLE. By increasing the level of excursion from SLE to HLE, higher RER values were obtained but these increases were not significant ($p>.05$). It should be noted that significantly ($p<.05$) higher RER values were found for 2-HLE over all other exercises. Also, 1-SLE, 2-SLE, and 1-HLE produced significantly ($p<.05$) higher RER values than 0-SLE and 0-HLE, respectively.

The significant increases in the RER values indicate a change from predominantly fat utilization for the NW, towards carbohydrate utilization for the 2-HLE. According to McArdle et al. (1986), this shift in substrate allows the body to produce energy more efficiently. The increase in the RER was due to greater increases in carbon dioxide production over relatively small increases in oxygen consumption. The RER values were significantly ($p<.05$) greater when comparisons were made by weight but were not significant ($p>.05$) when comparing the levels of excursion.

RPE

The rate of perceived exertion (RPE) is a subjective rating system devised by Borg (1970) which grades the difficulty of the physical task being performed (see Appendix B). In this investigation two rates of perceived exertion are presented: RPEg, which represents a general rating of perceived exertion; and RPEa, which reflects the amount of exertion required for the arm work.

Comparing the RPEg responses of the NW with the other six exercise responses revealed increases in all six RPEg values. However, only the RPEg responses for 1-SLE, 2-SLE, 1-HLE, and 2-HLE were significantly ($p<.05$) higher than the NW response. These findings are similar to those reported by Cigala (1985) who found significant differences in 2-SLE, 0-HLE, 1-HLE, and 2-HLE, respectively, when compared to the NW. The addition of 1- and 2-lb weights to 0-SLE and 0-HLE also significantly increased the RPEg responses. Significantly ($p<.05$) higher RPEg values were obtained for

1-SLE, 2-SLE, and 1-HLE over 0-SLE and 0-HLE, respectively. In addition 2-HLE produced significantly ($p<.05$) greater RPEg values than all other exercise conditions. These findings parallel those indicators for exercise intensity (HR and oxygen uptake) which also rose significantly for 1-SLE, 2-SLE, and all HLE exercises. However, significant increases in HR and oxygen uptake were also noted in 0-SLE when compared to NW. This may indicate that using RPEg values to determine workload increases may be accurate in most instances but needs to be used with caution when gauging the low intensity exercises.

The addition of weight and the change in level of excursion from SLE to HLE produced similar RPEg and RPEa results. The addition of 2 lbs to the no weight condition produced a significant increase in RPEg and RPEa values. Significant ($p<.05$) RPEa values were obtained for 2-HLE over all other exercise conditions. Significant ($p<.05$) increases were also noted in 2-SLE and 1-HLE over 1-SLE, respectively. Also, 1-SLE produced significantly ($p<.05$) higher values than 0-SLE and 0-HLE, respectively. Increasing the level of excursion from SLE to HLE produced significant increases in both HR and energy expenditure, which were accurately ascertained by the subjects when rating RPEg and RPEa.

There was little difference between the average RPEg and RPEa values for the no weight, and 1 lb weight conditions as well as the 2-SLE exercise. This would indicate that using either an arm or general RPE measure may be employed to assess the intensity level for most HH exercises. It should be noted that the average RPEa value for the 2-HLE exercise was almost four whole numbers higher than the RPEg value (12 RPEg and 16 RPEa, respectively) representing a significant ($p<.05$) increase in the RPEa response. This indicates that the subjects' ratings for RPEa were much higher than using the indicators for exercise intensity (HR and oxygen expenditure). This situation would make it difficult to get an accurate assessment of exercise intensity for the 2-HLE by using the RPEa ratings alone.

Significant ($p<.05$) increases in both RPEa and RPEg responses were found in 2-SLE and 2-HLE over 0-SLE, 1-SLE, 0-HLE, and 1-SLE, respectively. This may also suggest that the subjects would be unable to maintain the 2-SLE and 2-HLE exercises over an extended period of time due to muscle fatigue in the arms and shoulders. It should be noted that several of the subjects complained of stiffness or soreness in the shoulders and arms after several of the testing sessions. This would indicate that several of the subjects were exercising at an intensity that was to high or the strain on the arms was too much.

In summary, the RPE rating for HH exercise intensity corresponds closely to HR and energy expenditure increases for the higher intensity exercises. The lone exception is the RPEa rating for 2-HLE which overstated the intensity level of this exercise, but was indicative of the muscle strain in the shoulder and arms.

Summary

The findings in the present study indicate that walking with HH increased the aerobic metabolic requirements above those for NW. The increases ranged from 19 to 61% when the level of excursion was increased and/or 1- or 2-lb weights were added to NW. There were also significant increases in all exercise variables as the intensity of the exercise increased.

Significant RER values were obtained for all six exercises over the NW with the exception of the 0-SLE. Increasing the level of excursion from SLE to HLE produced higher RER values although these values were not significant.

Comparing the RPEg responses of the NW with the six other exercises produced significant increases for 1-SLE, 2-SLE, 1-HLE, and 2-HLE, respectively. RPEa values were not taken for the NW so a comparison could not be made with the other six exercise conditions. The addition of 1- and 2-lb weights also significantly increased the RPEg responses.

The addition of weight and the change in level of excursion from SLE to HLE produce similar RPEg and RPEa findings. Since the RPEg and RPEa produced similar results either measure may be used to assess the intensity level for most HH exercises. These findings parallel those indicators for exercise intensity (HR and oxygen uptake) which also rose significantly with HH exercise.

When comparing the NW to the six exercise conditions energy expenditure was significantly lower for the NW than all other exercises no matter which measurements was used to express the energy expenditure (i.e., VO_2 and METS). The MET values obtained in this study ranged from 3.1 for the NW to

5.0 for the 2-HLE. These MET levels would be appropriate for individuals in a Phase II cardiac rehabilitation program. In addition, when converting the energy cost of walking to kcals, a 3.3 $kcal \cdot min^{-1}$ was found for the NW. The energy cost values of the HH exercises all exceeded the 3.3 $kcal \cdot min^{-1}$ cost of walking at 3.0 mph, which may be of benefit in weight reduction programs.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the energy cost of walking at 3.0 mph with and without hand weights while performing vigorous arm movements to the SLE and HLE. The energy cost of NW was calculated and all exercise variables were compared to those found for NW. The following exercise variables were measured for each exercise condition HR, V_E, RER, RPEg, and RPEa along with the energy consumption measurements of VO_2 ($L \cdot min^{-1}$), VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$), and METS. After analyzing the information an attempt was made to provide guidelines for hand-weighted exercise prescription.

Each subject was tested in an identical manner. The sequence and number of exercises to be performed were randomly assigned. Statistical analyses of the data were performed to determine if significant differences existed among the variables obtained for each of the seven exercises (NW, 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, and 2-HLE). For this experiment the level of confidence was set at .05.

When compared to the NW, the HR responses for all arm exercises were greater. A significant ($p<.05$) difference existed between the NW and all other exercise conditions.

Increases in V_E also were noted with changes in the level of excursion from SLE to HLE and/or adding hand weights. The RER values were significantly ($p<.05$) higher than the NW for all exercise conditions with the exception of 0-SLE. Comparing the RPEg responses of the NW with the other six exercise responses revealed increases in all six RPEg values although only the RPEg responses for 1-SLE, 2-SLE, 1-HLE, and 2-HLE were significantly ($p<.05$) greater than the NW. Increasing the arm movements from SLE to HLE significantly ($p<.05$) increased the following exercise variables: HR, V_E, VO_2, METS, RPEg, and RPEa.

Conclusions

The HH exercises in this study could produce a training effect sufficient for utilization in Phase II cardiac rehabilitation, and for those individuals with low aerobic capacities. In order to produce a training effect an individual would have to workout at an intensity estimated at 40 to 85% of their functional capacity (ACSM, 1990). In this study the MET levels ranged from 3.3 to 5.3, respectively. The MET levels reported in this study would be sufficient to produce a training effect in individuals with low fitness levels or cardiac patients in Phase II (ACSM, 1990; Porter, 1984).

The three exercise conditions (2-SLE, 1-HLE, and 2-HLE) produced a HR response sufficient enough to produce a training effect at or above 60% of the age predicted maximal HR in the subjects tested. These results indicate that the intensity for these conditions meet the ACSM (1990) guidelines for training intensity.

For those individuals with greater than a 10-12 MET maximal capacity, the HH exercises performed at 3.0 mph would not be sufficient to produce a training effect. For sedentary individuals, exercise sessions of moderate duration (20-30 minutes), and a moderate intensity (40 to 60% of functional capacity) are recommended (ACSM, 1990). For anyone with a maximal MET capacity of greater than 10-12, the heavyhand exercises in this study would not be sufficient to keep the exercise intensity at or above 40 to 60% required to elicit a training effect.

By increasing the level of excursion from SLE to HLE and/or by adding 1- and 2-lb weights the caloric cost of NW can be significantly increased. By adding weight, and changing the level of excursion the MET levels increased from 3.3 for the normal walk to 5.3 for the 2-HLE exercise condition. By changing the level of excursion or by adding weight to the normal walk the MET levels increased by an average of 0.5 METs for each exercise condition. A training regimen may be established by observing the following guidelines.

Guidelines for a HEAVYHANDS Training Program

1. To receive a training effect from the HH exercises while walking at 3.0 mph, the exerciser must have a MET capacity of less than 10.

2. The frequency of training with HH should be 3 to 5 days per week in accordance with ACSM guidelines (1990). It is recommended that a person who wishes to use HH as a means of exercise should start out with the least amount of weight available, and gradually increase the weight and/or the level of excursion as the person's functional capacity increases.

3. Participants should set a intensity level that is suitable to individual fitness levels. The initial stage of HH exercise should include low levels of walking in which the participant experiences a minimum of muscle soreness, and avoids debilitating injuries or discomfort. Asymptomatic adults could exercise at an intensity between 60 and 90% of the functional capacity while individuals with low functional capacities should initiate the conditioning program at 40 to 60% of their functional capacity (ACSM, 1990). The intensity of the exercise may be prescribed by METS or HR.

4. The duration of the HH exercises should begin with sessions of 5 to 10 minutes to reduce the risk of injury to the upper body. This would allow the individual the

opportunity to acclimatize themselves to the HH exercises. Modification of duration should be individualized on the basis of toleration of the activity. Total time of the activity should range between 15 and 60 minutes for optimum effect (ACSM, 1990).

5. The progression for HH exercise should follow a slow and safe sequence which corresponds to an appropriate MET level. The sequence should be 0-SLE, 1-SLE, or 0-HLE, 2-SLE, 1-HLE, and then 2-HLE.

6. To insure that the proper exercise intensity is maintained the exerciser should monitor the HR response closely. The individual should also use a walking speed that is comfortable, and follow the progressions for weight and arm technique as suggested in guideline number five.

Recommendations for Future Study

1. A longitudinal study should be conducted to determine the effectiveness of HH training on cardiovascular fitness levels as well as strength increases.

2. To determine the safety of HH exercise, a study should be undertaken to determine what types of injuries are common with this form of exercise.

3. Since 1- and 2-lb weights were utilized in this investigation, a similar study using various weights should be undertaken.

4. Since only 3.0 mph was evaluated in this investigation, similar studies using various speeds should be attempted.

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APPENDIX A

INFORMED CONSENT FORM

Informed Consent Form
The Energy Cost Of
Walking With and Without Hand Weights
While Performing Rhythmic Movements

I, ____________________________, volunteer to participate in a study to determine the energy cost of walking with various arm movements utilizing hand held weights. I will have my weight and height determined prior to each of the three test sessions. I will then have three electrodes applied to my chest for electrocardiographic monitoring and heart rate determination. I will be required to wear a headset which will support a low resistance breathing valve and mouthpiece for collection of expired air during testing. I will attend an instruction and practice session where I will practice the exercises to be performed during the test sessions. After a five minute rest period (sitting), I will begin walking at 3.0 miles per hour (mph) on the treadmill with and without an exaggerated arm swing. In some cases, I will be required to hold a hand weight of no more than two pounds during the walk. I will be required to perform a total of seven exercises which will include:

1) 3.0 mph, with normal arm swing

2) 3.0 mph, moving the arms to the shoulder level of excursion with no hand weights

3) 3.0 mph, moving the arms to the head level of excursion with no hand weights

4) 3.0 mph, moving the arms to the shoulder level of excursion with one pound weights

5) 3.0 mph, moving the arms to the head level of excursion with one pound weights

6) 3.0 mph, moving the arms to the shoulder level of excursion with two pound weights

7) 3.0 mph, moving the arms to the head level of excursion with two pound weights

No more than three exercises will be performed per session and the sequence of exercises will be randomized.

I may experience unsteadiness while walking on the treadmill and performing the arm exercises. Due to this unsteadiness, I may slip or fall while walking on the treadmill. The practice session will give me time to walk on the treadmill and become familiar with the exercises to be performed. The treadmill handrails will be in place to hold for balance if I should fall. Wearing the breathing apparatus may cause some discomfort, but should not produce any injuries. The arm exercises may produce muscular soreness due to the unique motion and added weight that I will be carrying in my hands. My heart rate and electrocardiogram will be monitored during the entire test session. If any abnormal physiological response is observed, the test will be stopped. I understand that I may withdraw form the study at any time.

In signing this consent form, I acknowledge that I am physically capable of performing the tests described above. I have read the foregoing and understand it; any questions regarding my participation have been satisfactorily explained to me and I understand their implications. I hereby acknowledge that no representations, warranties, guarantees, or assurances of any kind pertaining to the testing procedures have been made to me by the University of Wisconsin-La Crosse, the officers, the administration, employees, or by anyone acting on the behalf of any of them.

________________________________ (Subject)   ____________ (date)

________________________________ (Witness)

APPENDIX B

BORG SCALE OF PERCEIVED EXERTION

BORG SCALE 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
20	

APPENDIX C

ONE WAY ANALYSIS OF VARIANCE FOR THE EXERCISE VARIABLES

One way analysis of variance for the exercise variables.

Variable	F ratio	df	Level of significance
HR ($b \cdot min^{-1}$)	11.05	6, 105	.001
V_E ($L \cdot min^{-1}$)	17.70	6, 105	.001
VO_2 ($L \cdot min^{-1}$)	17.74	6, 105	.001
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	17.54	6, 105	.001
METS	17.64	6, 105	.001
RER	6.00	6, 105	.001
RPEg	11.65	6, 105	.001

APPENDIX D

SIGNIFICANT POST HOC RESULTS OF ONE WAY ANALYSIS OF VARIANCE

Significant post hoc results of one way analysis of variance.

Variable	Exercise Comparison	Level of Significance
HR	NW < 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE	.05
V_E	NW < 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE	.05
VO_2 *	NW < 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE	.05
RER	NW < 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE	.05
RPEg	NW < 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE	.05

* Expressed in $ml \cdot kg^{-1} \cdot min^{-1}$, and METS.

APPENDIX E

LEVEL OF SIGNIFICANCE FOR WEIGHT AND LEVEL OF EXCURSION

Level of significance for weight and level of excursion.

Variable	Comparison	Level of Significance
HR	Level of Excursion	.05
	Weight	.05
V_E	Level of Excursion	.05
	Weight	.05
VO_2 *	Level of Excursion	.05
	Weight	.05
RER	Level of Excursion	.05
	Weight	.05
RPEg	Level of Excursion	.05
	Weight	.05
RPEa	Level of Excursion	.05
	Weight	.05

* Expressed in $L \cdot min^{-1}$, $ml \cdot kg^{-1} min^{-1}$ and METS.

APPENDIX F

SIGNIFICANT POST HOC RESULTS OF TWO WAY ANALYSIS OF VARIANCE FOR WEIGHT

Significant post hoc results of two way analysis of variance for weight

Variable	Comparison	Level of Significance
HR	0 wt < 1 lb wt, 2 lb wt	.05
V_E	0 wt < 1 lb wt, 2 lb wt	.05
VO_2 *	0 wt < 1 lb wt, 2 lb wt	.05
RPEg	0 wt < 2 lb wt	.05
RPEa	0 wt < 2 lb wt	.05

* Expressed in $L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$ and METS.

APPENDIX G

SIGNIFICANT POST HOC RESULTS OF TWO WAY ANALYSIS OF VARIANCE FOR INTERACTION

Significant post hoc results of two way analysis of variance for interaction

Variable	Comparison	Level of Significance
HR	0-SLE, 1-SLE, 0-HLE < 2-SLE, 1-HLE < 2-HLE	.05
V_E	0-SLE, 1-SLE, 0-HLE < 2-SLE, 1-HLE < 2-HLE	.05
VO_2*	0-SLE, 1-SLE, 0-HLE < 2-SLE, 1-HLE < 2-HLE	.05
RPEg	0-SLE, 0-HLE < 1-SLE, 2-SLE, 1-HLE < 2-HLE	.05
RPEa	0-SLE, 0-HLE < 1-SLE < 2-SLE, 1-HLE < 2-HLE	.05
RER	0-SLE, 0-HLE < 1-SLE, 2-SLE, 1-HLE < 2-HLE	.05

* Expressed in $L \cdot min^{-1}$, $ml \cdot kg^{-1} \cdot min^{-1}$ and METs.