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

A Thesis Presented
to
The Graduate Faculty
University of Wisconsin - La Crosse

In Partial Fulfillment
of the Requirements for the
Master of Science Degree

by
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ABSTRACT

CIGALA, Jr., Kenneth E. The energy cost of walking with and without hand weights while performing rhythmic arm movements. M.S. in Adult Fitness/Cardiac Rehabilitation, 1985. 78 p. (Dr. N. K. Butts)

The purpose of this study was to determine the energy cost of walking while performing hand-weighted exercises. Ss, 15 active healthy males ($\bar{x}$=48.9 yrs), walked at 3.0 mph performing the following: normal walk (NW), and rhythmic 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. The 7 exercises were NW, 0-SLE, 1-SLE, 2-SLE, 0-HLE, 1-HLE, and 2-HLE. Following a practice session, the Ss participated in 3 test sessions where the exercises were randomly performed on 3 different days, with no more than 3 exercises per session. Variables measured were HR, $V_{E}$, $V_{O_{2}}$ ($1 \cdot \text{min}^{-1}, \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), METS, RER, RPE general, and RPE arms. A 1 and 2 way ANOVA with a Scheffe post hoc analysis revealed several sig (p<.05) differences. The average energy cost for the 6 arm exercises were 3.8, 4.1, 4.5, 4.1, 4.8, and 5.1 METS, respectively. These and the other energy cost values were sig (p<.05) higher than NW energy cost, except for 0-SLE. HLE produced sig (p<.05) greater energy cost and HR values than SLE. A sig (p<.05) increase was noted for adding 1 and 2 lb weights to the no weight exercise, and a sig (p<.05) increase for adding 1 lb to the 1 lb exercise. HR sig (p<.05) increased with the addition of 2 lb to the no weight exercise. The RPE values were not greatly different from each other and accurately reflected increases in exercise intensity at the relatively higher workloads. These findings suggest that the hand-weighted exercises evaluated would assist in reducing body weight because of the increased energy cost when compared to NW. The intensity level of the hand-weighted exercises could not produce a training effect for the subjects tested, however, the MET level was appropriate for persons with a maximal MET capacity below 10 METS.
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We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

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Finally, I would like to thank my family for their unconditional love, support, and understanding.
DEDICATION

This work is lovingly dedicated to Gina, for without her there would not have been a project.
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CHAPTER I
INTRODUCTION

Background

Physical activity has become an integral facet in the daily lives of many individuals. As the interest in exercise has grown, so has the need for information describing its physiological effects on the body. As with all things, man needs to measure an object or action before he can fully describe it, and this is also true of exercise. One area of interest concerning physical activity is the ability to measure the energy needed to perform an activity. Since beginning this inquiry in the late 1800's, several methods have been developed which can accurately assess the energy cost of physical activity. Along with these methods, several terms describing the values obtained have been created to define energy cost. One such term is metabolic equivalents (METS).

The MET is a standard measure of workload or energy consumption. One MET is an estimation of energy consumption when an individual is at rest, and is expressed as oxygen consumption in milliliters per kilogram per minute (ml·kg⁻¹·min⁻¹). "Resting metabolic rate is approximately 3.5 ml of O₂ consumption per minute/per kilogram body weight" (deVries, 1980, p. 201).
The MET value of a given workload can be determined directly by measuring oxygen consumption or indirectly by calculating the amount of work done while exercising. The indirect measurement of the energy cost of an activity can be obtained by comparing the workload achieved during exercise with its estimated MET level. Standardized workload charts have been developed which indirectly estimate the oxygen cost of an activity. These charts include several activities such as stair stepping, bicycling, and walking which have MET values assigned to them (American College of Sports Medicine [ACSM], 1980). These MET activity levels are helpful when determining appropriate activities for individualized exercise prescriptions.

Since 1982, HEAVYHANDS (HH) have been popularized in the media and "fitness world" as a simple means to increase the workload of specific exercises. These hand-held weights have been reported to increase the caloric cost of walking, running, and aerobic dance (Findlay, 1984; Schwartz, 1982). It has also been claimed that HH "double performance and endurance in half the time it takes without weights for those just starting an exercise program" (Findlay, 1984, p. 3).

An abstract by Borysyk, Dressendorfer, Smith, Goodfliesh, Franklin, Gordon, and Timmis (1981) indicated that the addition of 12 ounces in each hand increased oxygen consumption significantly while walking at speeds of 2.0, 3.0,
and 3.5 miles per hour (mph). The MET level of moving the arms to the shoulder level of excursion (SLE) while walking with no weight has been reported to be seven METS with an increase of "close to 1 MET for each additional pound of weight. As weights increase past 3 pounds, the workload increases by almost 2 METS per pound of weight added" (Schwartz, 1982, p. 128). The cadence of walking for the above exercise was 150 paces per minute which was determined by counting the number of heel strikes per minute. Soule and Goldman (1969) reported that oxygen consumption will increase with the addition of weight to the hands, feet, head, and trunk of an exercising individual. An abstract by Raab, Smith, Smith, and Gilligan (1985) reported increased energy requirements for walking and jogging with the addition of weighted bands to the limbs and trunk. No other measurements of oxygen consumption for hand-weighted exercise, except for the investigations mentioned above, have been documented to this author's knowledge.

Purpose

The purpose of this investigation was to ascertain the metabolic cost of normal walking and normal walking with no weight, one, and two pound HH while performing arm movements to the shoulder and head level of excursion. The determination of these energy costs can then be used as a standard when prescribing HH exercise.
Need for the Study

HEAVYHANDS and other types of hand weights are being used by the "healthy" population and cardiac patients when exercising to improve fitness levels (Pesman, 1984). Presently, there is little information describing the metabolic cost and physiological effects of hand-weighted exercise. A study evaluating these parameters would be helpful to determine the benefits of hand-weighted exercise and to provide guidelines for exercise prescription.

Hypotheses

It was hypothesized that there would be no significant difference between normal walking and the arm exercises performed at 3.0 mph.

It was hypothesized that there would be no significant difference in oxygen consumption when walking 3.0 mph while performing arm exercises to the shoulder and head level of excursion, with no weight, one pound HH, and two pound HH.

Assumptions

It was assumed that one instructional practice session would be sufficient to teach the subjects proper arm motions while walking on the treadmill, familiarize the subjects with the test procedures, and to relieve test anxiety.

It was assumed that the average oxygen consumption during the last three minutes of each exercise session represented a steady-state level.
It was assumed that all subjects did not smoke or ingest food, with the exception of water, within two hours prior to each test session.

It was assumed that all subjects were in good health.

**Delimitations**

The sample consisted of 15 healthy male adult volunteers who were participating in an organized aerobic exercise program.

The testing was completed within two weeks of the instructional session.

The treadmill speed was set at 3.0 mph for all subjects.

Only the arm movements of shoulder level of excursion (SLE) and head level of excursion (HLE) were selected to be evaluated. These arm movements were described by Schwartz (1982).

The three weight conditions examined were no weight, one pound HH, and two pound HH.

**Limitations**

The subjects' arms did not traverse the same distance while performing the arm motions due to the variation of individual arm length.

The subjects did not consume identical diets prior to each test session.

**Definition of Terms**

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 (BMMC) is a programmable automated open circuit system which analyzes expired air with the OM-11 and LB-2 to determine oxygen and carbon dioxide concentrations, respectively. The calculations of oxygen consumption, respiratory exchange ratio, and minute ventilation are determined via the calculator which coordinates operation of the measurement system.

Energy Cost is the amount of energy required by the body to perform an activity. Energy cost was estimated from the oxygen requirements of the exercise in this study. This value was expressed in l·min⁻¹ or ml·kg⁻¹·min⁻¹ of oxygen consumed, or in METS.

General Rating of Perceived Exertion (RPEg) is the subjective value which best represents the overall level of difficulty of the activity being performed by the subject. The value is chosen from the Borg Scale of Perceived Exertion (Borg & Noble, 1974).

Head Level of Excursion (HLE) is the movement of the hand through the sagittal plane from the hip to the head level and back to the hip. The axis of motion is through the shoulder joint.
HEAVYHANDS (HH) are hand weights manufactured by AMF American. The weights are designed with a knuckle guard that slips around the back of the hand. This guard helps reduce the strain of gripping the weights while exercising. (HEAVYHANDS is a trademark of Leonard Schwartz, M.D.).

Level of Excursion is the specific distance and movement pattern the arm traverses.

Metabolic Equivalent (MET) is the amount of oxygen required by the average individual when at rest. One MET is equal to 3.5 ml·kg⁻¹·min⁻¹ (deVries, 1980).

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. 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 attained when oxygen consumption did not vary more than 150 ml per minute during collection of respiratory gases.

Walking Pattern is a pattern of movement in which the performed arm motion is synchronized with the swing phase of the contralateral leg. Consequently, the peak of the arm excursion corresponds to heel strike with the contralateral leg.
CHAPTER II
REVIEW OF THE LITERATURE

Introduction

Since the early 1980's, HEAVYHANDS (HH) have been included in regular aerobic exercises, performed by healthy and cardiac-diseased individuals (Pesman, 1984). Although HH are often included in exercise prescriptions, the research literature contains very little information describing the physiological effects of hand-weighted exercise.

This chapter presents information relative to the factors regarding the use of HH. This review summarizes the effectiveness of indirectly measuring energy cost by determining oxygen consumption, the theory of indirect measurement of energy consumption, and the effects of aerobic exercise as it pertains to the upper body. Most of the literature evaluating upper body exercise used arm ergometry as the mode of exercise. The scientific literature contained little information which looked at the effect of hand-weighted aerobic exercise. This lack of information was the reason for this investigation.

Energy Measurement

The assessment of energy cost has intrigued scientists since the late 1800's. The classical experiments by Atwater
and Benedict (1899) began to establish a link between the physical laws which act in the observable world and those not observable in the human body. Atwater and Benedict tried to show that "the chemical and physical changes which take place within the body and to which the general term 'metabolism' is applied, occur in obedience to the laws of the conservation of matter and energy" (Atwater & Benedict, 1899, p. 5). Their experiments were performed in a chamber in which all heat changes were recorded and used to calculate energy output. The chamber was called a calorimeter and this method of determining energy production was called direct calorimetry. Direct calorimetry determines the gains or losses of heat in a closed system. The heat energy is usually expressed in kilocalories (kcal) (McArdle, Katch, & Katch, 1981). Because of the large chamber needed for human experimentation, this method is cumbersome, expensive, and impractical when evaluating exercise (deVries, 1980).

The more commonly used method for measuring energy production in the human is indirect calorimetry. "Because all the body's metabolic processes utilize oxygen and produce carbon dioxide . . . the energy output is directly related to the quantity of these respiratory gases. The gases can be collected from the expired air and measured" (deVries, 1980, p. 206). The measurement of oxygen and carbon dioxide concentrations is made by sampling a portion
of the expired air collected and analyzing it electronically (deVries, 1980). Over the years indirect calorimetry has been widely accepted as a method to determine the energy cost of human activity (Hill, 1927; Passmore & Durnin, 1955; Wilmore, Davis, & Norton, 1976). Recognizing the link between body metabolism, oxygen consumption, and the production of carbon dioxide requires an understanding of how the potential energy of food is transferred into the energy expended during daily activities.

When foodstuffs such as carbohydrates, proteins, and fats are catabolized aerobically, their stored energy can be transferred via aerobic metabolism into adenosine triphosphate (ATP). This high-energy phosphate is an important fuel which powers the human body (Whitney & Hamilton, 1981). The contraction of muscles, construction of new cells, and the maintenance of existing cells require ATP energy to function properly. This energy is stored in the bonds between adenosine diphosphate (ADP) and the terminal phosphate. When both are linked together, they form ATP. The energy for this bond is obtained from the breakdown of foodstuffs and when the bond is split, usable energy is released. It is this energy that powers the mechanism of muscle contraction and other cellular activities. During this transfer of energy, several complicated biochemical reactions occur with or without the presence of oxygen. The formation of ATP with oxygen present is called aerobic metabolism.
The function of aerobic metabolism is to break down foodstuffs into useful energy. Carbohydrates and fats are transformed into acetyl coenzyme A, while proteins are converted into keto acid. Both acetyl coenzyme A and keto acid are then passed into the Kreb Cycle. When moving through the Kreb Cycle, hydrogen ions are removed. These hydrogen ions are transferred to the final step of aerobic metabolism, oxidative phosphorylation (McArdle et al., 1981).

During oxidative phosphorylation, ATP is generated by transferring the hydrogen ions via a group of hydrogen carriers, the cytochromes. Small quantities of energy are also forwarded with the hydrogen ions. This energy is used to form the bonds between ADP and free phosphates to produce ATP. In summary, the transfer of energy begins with the catabolism of foodstuffs into acetyl coenzyme A and keto acid. Both of these substances are funneled into oxidative phosphorylation and ATP is produced (deVries, 1980; Whitney & Hamilton, 1981).

Both the Kreb Cycle and oxidative phosphorylation are cyclic processes. A cyclic process requires that energy be passed along a chain of biochemical reactions. Aerobic formation of ATP is highly efficient if all the steps in the cycle occur uninterrupted. Once the chain of reactions is disrupted, the aerobic formation of ATP comes to a halt.

Hydrogen ions are a by-product of aerobic metabolism and combine with oxygen to produce water. The combining of
hydrogen ions with molecular oxygen becomes critical in the last step of oxidative phosphorylation. Oxygen plays a key role in the removal of hydrogen ions from the cell during aerobic metabolism (Whitney & Hamilton, 1981). Oxygen and glucose react to produce carbon dioxide, water, and energy. The hydrogen ions are formed during glucose \( \text{C}_6\text{H}_{12}\text{O}_6 \) breakdown. If oxygen is present in sufficient quantities, the resulting hydrogen ions are removed and the biochemical steps of the Kreb Cycle and oxidative phosphorylation occur uninterrupted. However, if insufficient quantities of oxygen are available, a build up of hydrogen ions occurs and aerobic metabolism can come to a halt (McArdle et al., 1981).

Hence, a direct relationship exists between the presence of oxygen and the ability to aerobically oxidize foodstuffs. This relationship allows scientists to indirectly observe energy metabolism.

Not only is the level of energy metabolism revealed, but the foodstuff used to form ATP can also be disclosed from the analysis of expired gases (McArdle et al., 1981). The foodstuff can be determined by calculating an individual's respiratory exchange ratio (RER). The RER is the ratio of carbon dioxide produced to the oxygen consumed. The chemical composition of carbohydrates, fats, and proteins differ, and, therefore, require different amounts of oxygen to oxidize the respective foodstuffs. Because of this inherent difference in oxygen usage for these three substrates,
the substrate being used to perform an activity can be identified from the RER. This is not entirely true when protein is catabolized, since the protein RERs vary substantially from one type of protein to another. Therefore, when kcals are calculated with the RER value, it is assumed that carbohydrate and/or fat is being metabolized.

With knowledge of these RER values, body heat production, and, therefore, energy expenditure can be calculated in kcals. The RERs for carbohydrates and fats are 1.00 and 0.70, respectively. To assess the energy cost of an activity in kcal·1·min⁻¹ of oxygen, the exact RER must be known (McArdle et al., 1981). These values are presented in Table 1. By knowing the oxygen consumption in 1·min⁻¹ and the thermal equivalent corresponding to the RER value, the energy cost of an activity can be computed. The product of these two values is equal to the energy cost in kcal·min⁻¹.

Although the energy cost of a physical activity may be expressed in kcals, it may also be expressed in METS. The MET represents the average resting metabolic rate and is equal to approximately 250 ml of oxygen consumed per minute for the average male. When expressed with regard to body weight, one MET is equal to 3.5 ml·kg⁻¹·min⁻¹ (devries, 1980; McArdle et al. 1981). The presentation of energy consumption in this manner is easily understood by the lay person, since the energy cost of an activity can be expressed in multiples of resting metabolic rate. Thus, the MET.
Table 1. Thermal equivalents of oxygen for nonprotein respiratory exchange ratio.

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<th>RER</th>
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provides a point of reference common to all individuals when referring to the workload of an activity. The average workload of a great number of activities have had their MET levels assessed (ACSM, 1980; McArdle et al., 1981).

In order to calculate the MET level of an activity, the oxygen consumption in ml·kg⁻¹·min⁻¹ must be known. This amount is then divided by one MET, and the result is a value with no units. Thus, the MET level of an activity becomes a ratio of exercising energy cost to resting energy cost.(deVries, 1980).

Although the measurement of oxygen consumption can be procured by direct or indirect calorimetry, the indirect method is the easiest and most commonly used. The information provided by the technique of indirect calorimetry addresses one specific question: How much energy (i.e., oxygen) will be required to perform a specific task?

Throughout the years, various methods have been developed to answer that question. Currently, automated systems accurately assess the consumption and production of oxygen and carbon dioxide, respectively. The reliability of these automated systems has been established by Wilmore et al. (1976).

**Steady-State Exercise**

"A steady-state condition denotes a work situation where oxygen uptake equals the oxygen requirement of the tissues; consequently, there is no accumulation of lactic
acid in the body" (Astrand & Rodahl, 1977, p. 295). Astrand and Rodahl (1977) and Hill (1927) reported that heart rate, cardiac output, ventilation, core temperature, and lactic acid concentration in the blood have little variability during steady-state exercise. This steady-state condition exists because the body is meeting the demand for oxygen uptake, waste product removal, and temperature regulation while performing an activity. To maintain steady-state, the level of activity must not be increased greatly or anaerobic metabolism will be activated.

An increasing lactic acid concentration indicates that energy is being manufactured anaerobically. Even though the anaerobic formation of ATP does not immediately require oxygen, eventually oxygen is needed to remove lactic acid from the body. Once the activity stops or the body achieves steady-state again, the lactic acid must be reconstituted into pyruvic acid so the it may enter the Kreb Cycyle. Like most physiologic reactions, oxygen is essential for this reformation (McArdle et al., 1981).

The amount of oxygen needed to eliminate the lactic acid build-up incurred is often termed oxygen debt. When ascertaining the energy cost of an activity, if anaerobic metabolism is activated to supply energy, the added oxygen required to repay the oxygen debt must also be considered part of the energy cost of that activity (McArdle et al., 1981). By maintaining exercise at a constant level of
exertion, only small amounts of lactic acid are formed and no significant oxygen debt is incurred. Therefore, the measurement of oxygen consumption during steady-state exercise allows for the calculation of energy cost without having to consider oxygen debt. According to Astrand and Saltin (1961) a measurement period of five minutes for respiratory and circulatory changes during submaximal workloads will accurately reflect steady-state levels of activity.

Maintaining steady-state exercise at workloads of greater than 50 percent of maximum oxygen uptake is difficult. Hagberg, Mullin, and Nagle (1978) evaluated oxygen consumption at workloads of 65 and 85 percent of maximal oxygen uptake on bicycle ergometers. Oxygen uptake increased significantly from the fifth to the twentieth minute of exercise in 81 percent of the tests they conducted. Increases in oxygen uptake were attributed to increased respiration and core temperature. The increased oxygen consumption indicated that steady-state had not yet been obtained because of the high level of physical exertion required to perform the tests. Tests that assume steady-state has been achieved must keep the workload below 50 percent of maximal capacity.

When attempting to measure steady-state energy cost, it is imperative that steady-state is reached and maintained. This reduces the variability in oxygen consumption observed
during the first few minutes of any submaximal exercise and also the need to calculate oxygen debt to determine energy cost. Once steady-state has been achieved, the oxygen consumption, heart rate, and ventilation remain relatively stable.

Achieving the Benefits of Exercise

Numerous benefits of aerobic exercise have been demonstrated in the literature. Walking and running exercise programs have been shown to increase maximal oxygen consumption and decrease percent body fat in middle-aged men (Pollock, Miller, Janeway, Linnerud, Robertson, & Valentino, 1971). The men in this study also had a decreased heart rate response to a submaximal workload when compared to pre-training response. Some other benefits of aerobic exercise are a decrease in resting heart rate, greater stroke volume of the heart, a reduction in blood pressure, and an improved respiratory function (McArdle et al., 1981). These benefits can be attained by merely following the recommendations made by the ACSM (1978) regarding the alteration of frequency, intensity, duration, and mode of exercise in an aerobic workout.

Frequency

Frequency refers to the number of days per week an individual exercises. ACSM (1978) advocates three to five periods of exercise per week depending on the capacity of the individual. The individual who participates less than
The heart rate response is the most common means of gauging exercise intensity. The percent of maximal capacity can be ascertained directly from the heart rate response during maximal exercise. In addition, the maximum heart rate response can also be estimated from a prediction formula. The formula is:

\[ 220 - \text{subject's age} = \text{maximum heart rate response} \]

By using either of these methods, the desired percent of heart rate training intensity (60-90% of heart rate reserve) can be calculated. Once this value is determined, it can be used as the training heart rate. When the individual

This will not receive an adequate training effect. On the other hand, by exercising more than five days per week, the individual increases his potential for injuries. Exercising at the recommended frequency provides the greatest benefit of aerobic exercise while protecting the exerciser from overuse injuries.

Intensity

The intensity of a workout is related to the percent of functional capacity needed to overload the physical system being exercised. The system in this case is aerobic metabolism. Intensities between 60-90 percent of maximum heart rate reserve will produce a training effect. The desired intensity level of exercise can be calculated from the heart rate response or by the MET level of the activity (ACSM, 1978).

The heart rate response is the most common means of gauging exercise intensity. The percent of maximal capacity can be ascertained directly from the heart rate response during maximal exercise. In addition, the maximum heart rate response can also be estimated from a prediction formula. The formula is:

\[ 220 - \text{subject's age} = \text{maximum heart rate response} \]

By using either of these methods, the desired percent of heart rate training intensity (60-90% of heart rate reserve) can be calculated. Once this value is determined, it can be used as the training heart rate. When the individual
counts his heart rate during exercise, he can adjust the workload so that the prescribed heart rate is achieved and maintained during the exercise session.

The workout intensity can also be calculated by first assessing an individual's maximum MET capacity. Then the desired percent of training intensity (50-85% of maximum MET level) to achieve a training effect is chosen. The values of various activities' MET levels have been established and these assigned values provide a means to determine the activities which are within the individual's training intensity. If the exercise is at an appropriate MET level, the individual can participate with little worry of sustaining an overuse injury and will receive a training effect (ACSM, 1978).

**Duration**

The duration of participation must also be regulated if an effective exercise prescription is desired. The recommended time of participation varies from 15 to 60 minutes and can vary inversely with exercise intensity. That is, lower intensity activities should be performed for longer periods of time, and higher intensity activities should be of shorter duration. If the total energy costs of the two relationships just mentioned are equal, then similar training effects can be expected, provided that a minimal level of intensity has been achieved (ACSM, 1978).
Finally, the mode of exercise can be any rhythmic activity which uses large muscle groups. The use of rhythmic movements is essential since this type of movement produces a large number of submaximal muscle contractions when aerobically exercising. These repeated movements can create large energy expenditures over time, and assist in maintaining the intensity required to produce an improved fitness level (ACSM, 1978). Some examples of these rhythmic activities include walking, jogging, swimming, and bicycling.

By following the guidelines established by the ACSM (1978), not only can a physiological training effect be achieved, but a decrease in percent body fat can also occur. ACSM (1978), Fox, Naughton, and Gorman (1972), and Pollock et al. (1971) stated that a caloric expenditure of approximately 300 kcal per session, three times per week, was beneficial in reducing percent body fat. The expenditure of 200 kcal per exercise session, four days per week, can also produce a reduction in percent body fat (ACSM, 1978). These energy expenditures will not produce a physiological training effect unless the minimal levels of frequency, intensity, and duration are satisfied for the exercising individual. Pollock et al. (1971) found that caloric expenditures of 241-357 kcal per exercise session produced both a physiological training effect and a decrease in
percent body fat in the middle-aged men studied.

By adhering to ACSM (1978) guidelines regarding frequency, intensity, duration, and mode of exercise, it is possible to develop safe and effective exercise prescriptions for most individuals. Although numerous modes of exercise have established exercise guidelines, none are currently available for HM.

Walking Exercises

One of the most commonly chosen modes for exercise is walking and there are many reasons for this choice. Walking is inexpensive, can be done anywhere, and by almost anyone (McArdle et al., 1981). Walking has also been shown to provide physiological training effects for untrained individuals and is beneficial in reducing percent body fat (ACSM, 1978; Astrand & Rodahl, 1977; Pollock et al., 1971). The physiological effects of walking have been investigated with emphasis on the caloric cost.

Pollock et al. (1971) demonstrated that a 20 week walking program produced a training effect for the sedentary middle-aged men they studied. These men showed increases in maximal oxygen uptake and pulmonary ventilation. In addition to decreases in resting heart rate, diastolic blood pressure, and percent body fat, their heart rate responses were lower for submaximal workloads. McArdle et al. (1981) suggested that walking not only produces a training effect for untrained persons at a tolerable workload,
but also has a reduced injury rate when compared to running. In 1982 Cooper stated that although walking was an excellent activity to improve physical work capacity, excessive amounts of time were required to achieve training benefits. This increase in duration was needed because of the relatively low work intensity of walking.

Passmore and Durnin (1955), in their summary of human energy expenditure, related three basic conclusions with regard to the energy cost of walking. First, the variability between individuals' caloric cost of walking at the same speed was only 15 percent. Second, the energy cost of walking increased proportionally with an increase in speed, between 1.9 and 4.0 mph. At speeds greater than 4.0 mph, the relationship between walking speed and caloric cost becomes curvilinear. Third, as body weight increased, the energy expenditure rose proportionally. Because of these linear relationships, the caloric cost of walking can be estimated for speeds between 2.0 and 4.0 mph.

Several formulas have been developed to accurately predict the energy cost of walking. These formulas take into account the speed of walking and the weight of the individual. The estimated values found for walking 3.0 mph by ACSM (1980), Bobbert (1960), Passmore and Durnin (1955), and Workman and Armstrong (1963) were 3.9, 4.0, 4.0, and 3.8 kcal·min⁻¹, respectively. Although the age, gender, training level, and morphological type of the individual
are important when calculating the energy cost of walking, the body weight of the exerciser is considered to be of primary importance (Bobbert, 1960).

The addition of weight to increase the energy expenditure of walking was not restricted to only body weight. Bobbert (1960) noted a rise in energy cost during walking with increases in shoe weight. Regardless of where the additional weight was carried (feet, wrists, head, or trunk), Borysyk et al. (1981), Goldman and Iampietro (1962), Raab et al. (1985), and Soule and Goldman (1969) all reported increases in caloric cost during walking. Specifically, the studies by Borysyk et al. (1981), Raab et al. (1985), and Soule and Goldman (1969) looked at the carriage of weight on the arms. This will be discussed more extensively in the following section.

Since walking and most forms of aerobic exercise rely primarily on the legs to perform the work, the upper body is usually neglected. This is not to say that the benefits of physical training cannot be achieved in the upper body. Many researchers have shown positive physiological changes with upper body training modes.

**Upper Body Exercise**

The benefits and guidelines which apply to rhythmic, aerobic exercise of the lower body also apply to upper body rhythmic exercise. Extensive research into the area of upper body exercise has established that a training effect
also occurs in the upper body. The studies involving upper body aerobic exercise have relied heavily on arm cycling and has been thoroughly investigated. However, hand-weighted exercise has not been amply researched and little information exists regarding the effects of HH exercise. A comparison of HH exercise with arm cycling is impractical since the two exercises have little in common, except for the use of the arms during exercise.

Arm Cycling

The benefits of aerobic exercise have been demonstrated in activities which use the arms to perform the exercise. When evaluating arm cycling after 10 weeks of training, 20 minutes per day, for three days per week, Magel, McArdle, Toner, and Delio (1978) noted increases in peak oxygen uptake, minute ventilation, and arteriovenous oxygen difference while performing maximal exercise. The maximal values for cardiac output, stroke volume, heart rate, and respiratory exchange ratio remained the same. Significantly lower heart rate responses to submaximal workloads have been found after arm training (Clausen, Klausen, Rasmussen, & Trap-Jensen, 1973; Lewis, Thompson, Areskog, Vodak, Marconyak, DeBusk, Mellen, & Haskell, 1980; Magel et al., 1978). Magel et al. (1978) suggested that the arm musculature has a relatively large potential for improvement in physical work capacity possibly because the arms are not taxed as the legs are in daily activities.
The work by Toner, Sawka, Leveine, and Pandolf (1983) demonstrated that combined arm and leg cycling did not overstress the heart by increasing its rate. These researchers concluded that leg exercise in conjunction with arm cycling decreased myocardial afterload and facilitated venous return to the heart. This reduction in stress on the heart lends credence to the notion that incorporating arm work with leg work can be beneficial. Mostardi, Gandee, and Norris (1981) also showed that combined arm and leg training enabled their subjects to perform more work at a lower heart rate. The lower heart rate suggests that a reduced stress load was placed on the heart during the combined work.

Work by Stenberg, Astrand, Ekblom, Royce, and Saltin (1967) reported that at a given submaximal oxygen uptake, the heart rate, intra-arterial blood pressure, and pulmonary ventilation were equal when comparing combined arm and leg work with leg work alone. Arm work alone produced higher values for heart rate, intra-arterial blood pressure, and pulmonary ventilation than combined arm and leg work and leg alone work at similar submaximal oxygen uptakes. Stenberg et al. (1967) were convinced that the increased values demonstrated during arm work were due to increased static arm work and a smaller exercising muscle mass.

The previously mentioned studies were investigations into the physiological effects of arm cycling. In all cases
the mode of arm exercise was arm ergometry. The combination of arm and leg exercise was shown to be beneficial because of the reduced stress on the cardiovascular system.

Hand Weights

In the literature, the number of studies investigating hand-weighted aerobic exercise is limited. In all studies that did look at hand-weighted exercise, the weights were either held in the hands or worn on the wrists. An abstract by Raab et al. (1985) indicated that the addition of weight to the wrists, ankles, and waist increased the energy cost of walking 3.0 mph at 0, 5, 10, and 15 percent grades. They also found no consistent difference in energy cost between the 1.5 and 2 kg weights when carried on the wrists. Unfortunately, no actual energy cost values were presented in the abstract. Soule and Goldman (1969) also reported increases in energy expenditure with the addition of weight to the extremities while walking. These researchers also discovered that the addition of "loads carried in the hands cost nearly twice as much per kilogram as loads carried on the torso" (Soule & Goldman, 1969, p. 689).

In a study by Borysyk et al. (1981), not only did their subjects carry 12 ounce hand weights, but they also performed vigorous arm movements. Borysyk et al. (1981) reported increases in oxygen consumption, heart rate, and systolic blood pressure when exercising with the weights. The increases in oxygen consumption were 161.1, 192.2, and
205.6 ml of oxygen above the oxygen consumption calculated when walking without the weights at speeds of 2.0, 3.0, and 3.5 mph, respectively. When expressed in METS, these increases were equal to 0.52, 0.64, and 0.61, respectively. The increases in heart rates were 6.7, 10.5, and 10.1 b·min⁻¹ when compared to exercising without the weights at the same respective speeds. Borysyk et al. (1981) concluded that these physiologic alterations while walking with hand weights occurred at an intensity that could produce a training effect in sedentary and cardiac populations.

The three studies cited above were the only related scientific literature which discussed the effects of hand-weighted aerobic exercise. Although there are no scientific studies regarding the use of HH, there are a few anecdotal remarks in both scientific and general media publications supporting the possibility of their use in an aerobic exercise program. These remarks advocate HH as an effective means of increasing the energy expenditure of walking, running, and aerobic dance.

When using HH in aerobic exercise, they are pumped rhythmically to the pace of the activity being performed. As previously mentioned, HH have and are being used to train healthy and cardiac-diseased persons (Pesman, 1984). Caution in the use of hand weights has been given by Stamford (1984) who stated that injuries occur in poorly conditioned individuals using hand weights while exercising.
Stamford (1984) advised walking with hand weights since running with hand weights can increase the incidence of injury. He added that walkers should begin with one pound hand weights and should try to maintain their speed of walking. Schwartz (1982) advocated the use of HH while walking, running, and performing aerobic dance to increase the energy cost of the aerobic workout. He found that the energy cost of performing 0-SLE, 1-SLE, and 2-SLE when walking 150 paces per minute was 8, 9, and 10 METS, respectively. Workman and Armstrong (1963) stated that walking at 150 paces per minute is equal to a walking speed of over 4.0 mph. Schwartz (1982), the inventor of HH, stated:

Heavyhands is a new kind of exercise. Its claims are explicit: a higher level of fitness than that produced by any known aerobic exercise, and a new kind of fitness. Heavyhands brings strength plus endurance to all of the muscles. No muscle group is neglected; muscles already well trained by other exercise and sports are even further upgraded by Heavyhands. Most exciting of all, the simultaneous movement of many muscles is a superlative way to train the heart. Hard Heavyhands actually feels surprisingly easy. The Heavyhander can become as strong as most lifters, as swift as most runners, and outwork both on a smaller investment of time and with far fewer injuries. (p. 3)

The claims for HH exercise vary from extremely positive to guarded caution and little information is available concerning the use of HH in an aerobic exercise program. Thus, it is difficult to determine the appropriate combination of frequency, duration, and intensity to safely produce
a training effect.

Summary

Since the late 1800's, energy expenditure has fascinated scientists. Through their investigations, a basic description of energy input and output has been developed. Energy output has been directly related to oxygen consumption. When the activity level increases, so does oxygen consumption. By following ACSM (1978) guidelines regarding frequency, intensity, duration, and mode of exercise, safe and effective exercise prescriptions can be developed for most individuals. Most training regimens used to improve fitness levels have been lower leg activities, yet arm cycling has produced training effects and has been proven a safe activity for physical training. HEAVYHANDS have become popular over the past five to seven years and there is little information predicting the energy cost with these hand weights. Knowledge of the energy cost of hand-weighted exercise would provide information on which to base safe and effective exercise prescription.
CHAPTER III

METHODS

Introduction

The methods in this chapter were developed to determine the energy cost of males walking with various arm movements with and without hand-held weights. The equipment used to perform the study and its calibration are discussed in this chapter. Along with this information, a description of the pilot study conducted prior to the final investigation is presented. Finally, the exact operational procedures of the study are outlined including subject selection, practice sessions, experimental sessions, and statistical treatment of the data.

Equipment and Calibration

Prior to each test session, the Quinton pit treadmill was calibrated. Calibration was done by first measuring one revolution of the treadmill belt. The number of revolutions min⁻¹ at 3.0 mph, with a belt length of 535 cm, was calculated to be 16. The treadmill was set at the required speed and checked for its accuracy. Then, the speed calibration was double checked with a subject actually walking on the treadmill. For each mph of speed, the drive barrel of the treadmill revolved 21 times and the number of revolutions were recorded on the control panel counter.
which is part of the Quinton treadmill. When the treadmill was set at 3.0 mph and 63 barrel revolutions were recorded on the revolution counter, the treadmill was assumed to be calibrated.

The Beckman Metabolic Measurement Cart (BMMC) described by Wilmore et al. (1976) was used to determine oxygen uptake and other respiratory gas values during the test sessions. The subjects were fitted with an adjustable headpiece which supported a Hans Rudolf nonrebreathing valve (model 2700) and mouthpiece. The valve was connected to the BMMC by plastic tubing which was anchored to a pole. The pole was attached to the treadmill handrail and supported the weight of the tubing. Calibration of the BMMC was done by using a known gas sample which had been previously verified by the Micro-Scholander technique. The BMMC was calibrated prior to each test session within .01 for oxygen and carbon dioxide percentages. Temperature and barometric pressure were adjusted according to a thermometer in the BMMC and a barometer in the testing laboratory, respectively. The volume calibration of the BMMC was performed by injecting air into the spirometer from a one liter syringe. Ten full syringes were injected into the BMMC and the volume meter was adjusted until 10 liters of air registered on the volume meter.

Heart rate was determined on the Burdick Electrocardiographic (ECG) Recorder using a modified three lead system
(CM$_5$). The subjects had three electrodes (Medi-Trace Offset disposable) placed on their chests. The electrodes were placed at the inferior angle of the ribs above the right leg, the mid-portion of the sternum, and the fifth intercostal space on the left chest wall, anterior to the axilla. The lead wires were attached to the subject and then connected to the ECG recorder after the subject was resting in a seated position on the treadmill.

The hand weights used were HEAVYHANDS, which are manufactured by AMF American. The weights can be disassembled into a handle, which weighs one pound, and add-on weights to increase the mass of the hand weight. The HEAVYHANDS weight can be increased up to 10 pounds, but only one and two-pound weights were used for this investigation.

**Pilot Study**

A pilot study was conducted to determine the exact testing procedures. Five males between the ages of 30 and 64 years of age were tested. The three exercises of two pounds at the head level of excursion (2-HLE), one pound at the shoulder level of excursion (1-SLE), and two pounds at the shoulder level of excursion (2-SLE) were each performed for five minutes. Before the test session, the subject rested for five minutes while resting heart rate and respiratory gas values were obtained. Between each test, the subject rested for ten minutes and again resting heart rate
and respiratory gas values were determined. After each test session, the mouthpiece was removed to allow the subject to talk to the experimenter and to rest.

As a result of the pilot study, changes in the testing procedures were made where needed by the experimenter and the thesis chairperson. These changes consisted of a reduced test speed from 3.5 mph to 3.0 mph, a shortened rest stage lasting five minutes, and no collection of resting respiratory data after each test session. The data collected from the pilot study were not analyzed statistically, and have not been presented in this paper.

**Subject Selection**

A total of 15 males volunteered to participate in this study. The subjects were assumed to be in good health and free of any disease which would hinder them from participating in the study, since they regularly took part in an aerobic exercise program. The participants were contacted through verbal announcements and personal discussions with the experimenter during their exercise sessions. All questions were answered with respect to the practice and testing sessions by the experimenter. Those individuals who wished to participate in the study were then scheduled for a practice session.

**Practice Session**

When the subject arrived at the Human Performance Laboratory, he was required to read and sign an informed
consent form (see Appendix A) which described the risks and procedures to be followed for testing. After all questions were answered, the experimenter explained and demonstrated the two arm exercises the subject was required to perform.

The first arm movement demonstrated was the shoulder level of excursion (SLE). This movement required repeated flexion and extension of the elbow joint, while the upper arm was held at the side of the body. Performing SLE also required synchronized arm and leg action when walking. During SLE, when a hand was raised to a height level with the shoulder, the contralateral foot contacted the ground.

The second arm movement demonstrated was the head level of excursion (HLE). Performing HLE required repeated flexion and extension of the arm, with the elbow fixed at approximately 30 degrees of flexion. The hand was moved to a height level with the top of the subject's head. The weight was then lowered until the hand reached a position by the subject's hip. Performing HLE also required the same synchronized movement as SLE, except the hand should be at the top of the head when the contralateral foot contacted the ground.

Once the HLE and SLE movements could be performed while walking on the ground, the exercises were practiced while walking at 3.0 mph on the treadmill. After demonstrating he could perform the arm exercises, the subject
practiced the arm exercises on the treadmill while wearing the breathing apparatus. This was done to allow the subject to practice under simulated test conditions and reduce anxiety during the test sessions. Each subject practiced until the experimenter was satisfied with the subject's performance of the exercises. Once the subject could perform the exercises on the treadmill correctly, the three experimental sessions were arranged.

**Experimental Sessions**

The subject arrived at the Human Performance Laboratory and had his weight determined while wearing running shorts and shoes on a Continental Health-O-Meter (No. 400 DKL) to the nearest 0.25 pound. Three electrodes were applied in the CM$_5$ lead position. The electrode application was done by rubbing the skin until reddened with a gauze pad saturated with alcohol. After the electrodes were in place, the subject was connected to the ECG recorder while resting seated in a chair placed on the treadmill. The experimenter described the test procedure and answered all the subject's questions. Prior to adjusting the headpiece to the subject, a description of the Borg scale of Perceived Exertion (Borg & Noble, 1974) was read to the subject (see Appendix B). It was explained that two levels of perceived exertion, the general rating of perceived exertion (RPE$_g$) and arm rating of perceived exertion (RPE$_a$) would be determined during the exercises.
The test started when the headpiece and breathing apparatus were fitted to the subject. The subject rested for five minutes while seated on the treadmill. Resting heart rate and respiratory gas values were obtained each minute during the rest and exercise periods. Heart rate was calculated by recording a ECG strip during the last 15 seconds of the exercise minute, and multiplying the number of R complexes by four. The respiratory gas values of minute ventilation ($\dot{V}_E$), $\dot{V}O_2$ (l·min$^{-1}$), $\dot{V}O_2$ (ml·kg$^{-1}$·min$^{-1}$), and respiratory exchange ratio (RER) were determined via the BMMC each minute.

Each subject participated in three experimental sessions to complete the required seven exercises. The order of performance and the number of exercises completed in one test session were randomly assigned. The subjects performed a maximum of three exercises per session. The seven exercises were the following:

1) 3.0 mph, normal walk (NW)
2) 3.0 mph, SLE with no hand weights (0-SLE)
3) 3.0 mph, HLE with no hand weights (0-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)

The first exercise began after the five minute rest period. The subject was told which randomly determined exercise to
perform and was given the appropriate hand weights while straddling the treadmill belt. The treadmill was started and he began walking. Once the subject became accustomed to the pace, he began to perform the assigned arm movement. During the experimental sessions, the subject's arm technique was corrected by the experimenter if indicated. The subject continued to perform the exercise for at least five minutes to establish steady-state. If steady-state was not attained within five minutes, the test was extended until oxygen consumption variance was less than 150 ml for three consecutive minutes. Each minute, both heart rate and respiratory gas values were obtained and recorded.

During the fourth minute of all exercises except the normal walk, the subject was asked to assess his perceived exertion on the Borg scale. A chart of the scale was held so that the subject could see and point to the number which represented his exertional level. The experimenter announced the number to confirm the subject's selection.

Once three minutes of steady-state values were recorded, the treadmill was stopped and the subject was seated on the treadmill. The breathing apparatus was removed and the hand weights were taken from the subject. The subject rested for at least five minutes until his heart rate returned to baseline. The baseline heart rate was determined to be equal or lower than the average heart rate response obtained during the rest period prior to the exercise.
If the subject had not achieved baseline heart rate within five minutes, the rest period was extended.

At the end of the rest period, the subject was asked to perform another exercise. The breathing apparatus was again fitted to the subject and the test procedure stated above was repeated. This procedure was followed for all seven tests.

**Statistical Treatment of the Data**

Means, standard deviations, and ranges were calculated for age, weight, height, and the steady-state variables of heart rate, $\dot{V}_E$, $\dot{VO}_2 (l.min^{-1})$, $\dot{VO}_2 (ml.kg^{-1}.min^{-1})$, RER, and MET level. The heart rate and respiratory gas values were determined by averaging the values obtained during the last three minutes of the steady-state period. The oxygen consumption values were converted to METS by dividing $\dot{VO}_2 ml.kg^{-1}.min^{-1}$ by 3.5 $ml.kg^{-1}.min^{-1}$, which is equal to one MET. A one way ANOVA was calculated for each physiological variable to determine if a significant difference existed between the seven exercises. A two way ANOVA with hand weight and level of excursion as the variables was calculated to determine if a significant difference existed between the six arm exercise conditions. If a significant F ratio was obtained, a Scheffe post hoc analysis was used to determine where the difference existed in the one and two way ANOVAS. The level of confidence was set at the .05 level.
CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this investigation was to ascertain the energy cost of normal walking (NW) and normal walking with no weight, one, and two pound HH while performing arm movements to the shoulder and head level of excursion. An attempt was also made to provide guidelines for prescribing hand-weighted exercise. This chapter includes the statistical analyses of the data collected and discusses the possible factors which influenced the variables when performing the arm exercises.

Subjects

Fifteen male subjects volunteered to participate in the investigation. All were residents of La Crosse, Wisconsin and the surrounding area. Most of the subjects regularly participated in a running aerobic conditioning program an average of three days per week, covering between 1 to 5 miles per exercise session. They also participated in a wide range of recreational activities. The subjects' mean age, weight, and height, along with standard deviations and ranges are presented in Table 2.
Table 2. Subjects' descriptive information.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>48.9</td>
<td>11.3</td>
<td>30.0 - 70.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.2</td>
<td>11.4</td>
<td>150.0 - 241.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>176.5</td>
<td>6.9</td>
<td>160.0 - 190.5</td>
</tr>
</tbody>
</table>

Results

The means and standard deviations for heart rate (HR), minute ventilation ($\dot{V}_E$ l·min$^{-1}$), oxygen uptake ($\dot{V}O_2$ l·min$^{-1}$, $\dot{V}O_2$ ml·kg$^{-1}$·min$^{-1}$), metabolic equivalents (METS), respiratory exchange ratio (RER), general rating of perceived exertion (RPEg), and arm rating of perceived exertion (RPEa), were calculated for the seven exercises. These values are presented in Table 3.

Normal Walk

One way analyses of variance were calculated to determine if there was a significant difference between responses to the NW and the other six exercises (O-SLE, 1-SLE, 2-SLE, O-HLE, 1-HLE, and 2-HLE). The results of these analyses are presented in Appendix C and revealed a significant (p<.05) difference for HR, $\dot{V}_E$ (l·min$^{-1}$), $\dot{V}O_2$ (l·min$^{-1}$), $\dot{V}O_2$ (ml·kg$^{-1}$·min$^{-1}$), METS, RER, and RPEg. A Scheffé post hoc analysis
Table 3. Means and standard deviations of exercise variables for each exercise mode.

<table>
<thead>
<tr>
<th>Variables</th>
<th>NW</th>
<th>0-SLE</th>
<th>1-SLE</th>
<th>2-SLE</th>
<th>0-HLE</th>
<th>1-HLE</th>
<th>2-HLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (b·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>82.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>91.1</td>
<td>92.3</td>
<td>96.5</td>
<td>93.9</td>
<td>99.7</td>
<td>102.5</td>
</tr>
<tr>
<td></td>
<td>8.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.6</td>
<td>11.4</td>
<td>15.3</td>
<td>14.4</td>
<td>13.7</td>
<td>15.5</td>
</tr>
<tr>
<td>VE (1·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>22.2</td>
<td>26.8</td>
<td>30.0</td>
<td>33.9</td>
<td>32.1</td>
<td>37.8</td>
<td>39.2</td>
</tr>
<tr>
<td></td>
<td>4.7</td>
<td>7.2</td>
<td>6.7</td>
<td>10.4</td>
<td>10.4</td>
<td>13.2</td>
<td>9.9</td>
</tr>
<tr>
<td>VO&lt;sub&gt;2&lt;/sub&gt; (l·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>0.944</td>
<td>1.104</td>
<td>1.187</td>
<td>1.308</td>
<td>1.197</td>
<td>1.414</td>
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<td></td>
<td>0.144</td>
<td>0.193</td>
<td>0.222</td>
<td>0.259</td>
<td>0.200</td>
<td>0.309</td>
<td>0.280</td>
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<td>VO&lt;sub&gt;2&lt;/sub&gt; (ml·kg&lt;sup&gt;-1&lt;/sup&gt;·min&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>11.3</td>
<td>13.2</td>
<td>14.2</td>
<td>15.6</td>
<td>14.3</td>
<td>16.9</td>
<td>18.0</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>1.8</td>
<td>2.5</td>
<td>2.7</td>
<td>2.1</td>
<td>2.7</td>
<td>3.0</td>
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<tr>
<td>METS</td>
<td>3.2</td>
<td>3.8</td>
<td>4.1</td>
<td>4.5</td>
<td>4.1</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.6</td>
<td>0.8</td>
<td>0.9</td>
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<tr>
<td>RER</td>
<td>0.76</td>
<td>0.79</td>
<td>0.79</td>
<td>0.81</td>
<td>0.82</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>0.03</td>
<td>0.05</td>
<td>0.06</td>
<td>0.06</td>
<td>0.04</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>RPEg</td>
<td>8.0</td>
<td>8.2</td>
<td>8.9</td>
<td>9.7</td>
<td>8.7</td>
<td>9.5</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>1.9</td>
<td>1.9</td>
<td>2.2</td>
<td>2.4</td>
<td>2.4</td>
<td>2.2</td>
<td>2.7</td>
</tr>
<tr>
<td>RPEa</td>
<td>-</td>
<td>8.5</td>
<td>9.1</td>
<td>10.1</td>
<td>8.7</td>
<td>9.6</td>
<td>10.7</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>2.2</td>
<td>2.1</td>
<td>2.3</td>
<td>2.2</td>
<td>1.7</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<sup>a</sup> = mean  
<sup>b</sup> = standard deviation
(see Appendix D for specific levels of significance) was performed to determine where the significance existed between NW and the six other exercises.

The HR response to the NW was significantly \( (p < .05) \) lower than any other exercise. Although \( \dot{V}_E \) for the NW was not significantly \( (p > .05) \) different compared to 0-SLE, it was significantly lower for all other comparisons. Regardless of the units used to express energy expenditure, NW was not significantly \( (p > .05) \) different than 0-SLE but was significantly lower when compared to all other exercises. The RER value obtained during the NW was significantly lower than the RER values for the 1-HLE and 2-HLE exercises. The RPEg values obtained for 2-SLE and all HLE exercises were significantly greater than the RPEg value measured during the NW.

**Weight versus Level of Excursion**

A two way analysis of variance comparing the weight carried and the level of excursion performed was calculated (see Appendix E for specific results). Since a significant F ratio was obtained for weight, a Scheffe post hoc analysis was performed for each variable with the results presented in Appendix F. No significant difference existed for the interaction of weight and level of excursion for any of the variables.

Similar results for HR, RPEg, and RPEa were found when performing the post hoc analyses. The no weight condition
produced significantly (p<.05) lower values compared to the two pound weights. Regardless of the units used to express energy expenditure, a significant difference was found for all three comparisons of weight. The no weight exercise resulted in significantly (p<.05) lower values than both the one and two pound weight exercises. A significantly (p<.05) lower value was also found for the one pound exercise versus the two pound exercise for all measures of energy expenditure. The $\dot{V}_{E}$ response to both the one and two pound weight exercises were significantly (p<.05) greater than those obtained in the no weight exercise. Finally, the RER value was not significantly (p>.05) different for any of the weight comparisons utilized during the exercise.

Since a significant F ratio was found when comparing the two levels of excursion, no post hoc analysis was required to determine where the significant difference lay. In all variable comparisons, HLE produced significantly (p<.05) higher values than SLE (see Appendix E).

**Discussion**

**HR Response**

The addition of arm movements and/or weights to NW increased the HR response. More specifically, HR increases were found when the level of excursion was changed from SLE to HLE and when the two pound weights were added to the no weight exercise condition. This was expected since
raising the level of excursion and weight increased the
physical workload of the activity. However, the addition
of one pound weights to the no weight condition did not
significantly increase HR response. Evidently this increase
in workload was not sufficient enough to cause a rise in HR.
Borysyk et al. (1981) reported increases in HR response of
6.7, 10.5, and 10.1 b·min\(^{-1}\) with the addition of arm swings
and 12 ounce hand weights at walking speeds of 2.0, 3.0, and
3.5 mph, respectively. Borysyk et al. (1981) concluded that
these changes in HR occurred at an intensity that could
produce a training effect in sedentary and cardiac pop-
ulations.

The average maximal HR response noted in the present
investigation was 102.5 b·min\(^{-1}\) for 2-HLE, which did not
meet the minimum HR response required to produce a training
effect in the subjects tested. When both the maximal
predicted HR response and heart rate reserve level (60%) were calculated for the subjects in this present study, it
was determined that no individual would receive a training
effect from any of the HH exercises. The average maximal
predicted HR response and heart rate reserve values with
their ranges and standard deviations are presented in
Table 4.

The average HR response for HH exercise may have been
reduced since the subjects regularly participated in aerobic
exercise. If untrained sedentary individuals were tested in
Table 4. Subjects' average maximal heart rate and heart rate reserve (60%) values.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal HR</td>
<td>171</td>
<td>10.9</td>
<td>130 - 190</td>
</tr>
<tr>
<td>60% HRR</td>
<td>135</td>
<td>8.1</td>
<td>116 - 150</td>
</tr>
</tbody>
</table>

The increases in HR noted for SLE exercise when compared to NW were solely attributed to the addition of weight to the exercise. This was concluded since increases in HR were not seen during O-SLE. With the addition of weight and/or the HLE arm movement to NW, the HR response also increased.

One additional observation was the development of ventricular trigeminy in the oldest subject while performing 2-HLE. Although he did not develop any other complex arrhythmias, there were occasional premature ventricular contractions during some of the other exercise conditions. Three other subjects also developed premature ventricular
contractions during testing, but the occurrences were infrequent. These abnormalities in heart rhythm could possibly be linked to arm exercise, since the arrhythmia noted for the oldest subject was not reproducible during a maximal treadmill graded exercise test. No cause and effect relationship could be drawn from the present study's data. Additional investigations evaluating the occurrence of arrhythmias during HH exercise would help establish if this is a safe exercise mode.

\[ V_E \] Response

There was no difference in \( V_E \) between NW and 0-SLE, but all other comparisons were significantly different. When shifting from SLE to HLE and/or adding the hand weights, increases in \( V_E \) occurred. Such increases augment the air supply; thus, providing the available oxygen for extraction, which the body needs when performing exercises of increasing intensity. This is supported by Borysyk et al. (1981) who noted significant increases in the volume of air exchanged when walking at 2.0, 3.0, and 3.5 mph while carrying hand weights, compared to walking without hand weights at the same speeds.

Oxygen Consumption

No matter which units are used to express energy expenditure (\( VO_2 \cdot \text{min}^{-1}, VO_2 \cdot \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}, \) and METS), similar results were revealed for all exercise comparisons with NW values significantly lower than all other exercise
values. According to the ACSM (1980), normal walking at 3.0 mph requires 3.28 METS. In the present study, normal walking at 3.0 mph was found to be equal to 3.2 METS.

An alteration in the level of excursion from SLE to HLE resulted in greater energy requirements. Furthermore, the addition of one and two pound hand weights to the no weight exercise condition also produced greater energy expenditure levels.

Increases in energy cost were also observed by Borysyk et al. (1981) and Soule and Goldman (1969) who found that the addition of weight to the hands while walking significantly increased oxygen consumption.

Another source of related information not found in the scientific literature indicated that performing O-SLE at a walking speed of 150 paces per minute required 8 METS, and the addition of weight increased the energy cost by one MET per pound of weight added (Schwartz, 1982). The results of the present study indicated that O-SLE at 3.0 mph required 3.8 METS, and the addition of weight increased the MET level of the activity by approximately 0.5 METS per pound of weight added. These values are below the total energy cost reported by Schwartz (1982) for O-SLE, 1-SLE, and 2-SLE which were 8, 9, and 10 METS, respectively. In the present study, MET values of 3.8, 4.1, and 4.5 were found for the same respective exercises at a walking speed of 3.0 mph. In addition, performing O-HLE, 1-HLE, and 2-HLE
at 3.0 mph required 4.1, 4.8, and 5.1 METS, respectively. Unfortunately no information relative to HLE energy expenditure was provided by Schwartz (1982); nor was the speed of 150 paces per minute expressed in miles per hour.

The differing data regarding the MET values found in this investigation and those found by Schwartz (1982) are most likely due to the different speeds of walking. Walking at 150 paces per minute is equal to a walking speed of over 4.0 mph (Workman & Armstrong, 1963). ACSM (1980) and Passmore and Durnin (1955) reported that walking faster than 3.7 and 4.0 mph, respectively, increased energy cost in a curvilinear fashion. Since the speed of walking directly alters the pumping rate of HH, a more rapid speed of walking will produce a greater rate of arm movement and an increase in energy expenditure. An increase in walking speed alone will also increase the energy expenditure of the exercising individual (Passmore & Durnin, 1955). Borysyk et al. (1981) demonstrated that the energy cost of walking with 12 ounce hand weights at 2.0 mph increased 0.1 METS when the speed was raised to 3.0 mph. Since the speed of walking in the present study was held constant, the increased energy cost can be directly related to the arm movements and/or the addition of the hand weights.

When the energy cost of walking 3.0 mph is converted to kcals, it is equal to 4.5 kcal·min⁻¹. The caloric costs are calculated by determining the product of the specific
RER thermal equivalent (Table 1) and the oxygen consumption in 1·min\(^{-1}\) (Table 3) (McArdle et al., 1981). The kcal and MET costs along with the RER values for all seven exercises are presented in Table 5. Passmore and Durnin (1955) reported the energy cost of walking at 3.0 mph for a 180 lb man to be 4.8 kcal·min\(^{-1}\). In the present study, the average energy cost for NW was 4.5 kcal·min\(^{-1}\). These subjects weighed an average of 175 lbs. Caloric cost values of 3.9, 4.0, and 3.8 kcal·min\(^{-1}\) were reported by ACSM (1980), Bobbert (1960), and Workman and Armstrong (1963), respectively, when walking 3.0 mph.

Since the addition of HH to NW increased caloric expenditure, HH can be of benefit when attempting to reduce body weight. The energy cost values of the HH exercises all exceed the 4.5 kcal·min\(^{-1}\) cost of walking 3.0 mph.

An increase in kcals expended during exercise is also essential when trying to produce a training effect. To receive a physiological training effect from aerobic exercise, a minimal intensity of 50 percent of maximal oxygen uptake or 60 percent of heart rate reserve must be maintained for 15 to 60 minutes, three days per week (ACSM, 1978). There are several modes of exercise which can produce a training effect, and walking is one of them. Cooper (1982) and Pollock et al. (1971) both stated that walking produced a training effect for the untrained, but required greater amounts of time than jogging. The increased time requirements
Table 5. The energy cost and RER values for the seven exercises.

<table>
<thead>
<tr>
<th></th>
<th>NW</th>
<th>0-SLE</th>
<th>1-SLE</th>
<th>2-SLE</th>
<th>0-HLE</th>
<th>1-HLE</th>
<th>2-HLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>kcal·min⁻¹</td>
<td>4.5</td>
<td>5.3</td>
<td>5.7</td>
<td>6.3</td>
<td>5.8</td>
<td>6.9</td>
<td>7.3</td>
</tr>
<tr>
<td>RER</td>
<td>0.76</td>
<td>0.79</td>
<td>0.79</td>
<td>0.81</td>
<td>0.82</td>
<td>0.85</td>
<td>0.86</td>
</tr>
<tr>
<td>METS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present study</td>
<td>3.2</td>
<td>3.8</td>
<td>4.1</td>
<td>4.5</td>
<td>4.1</td>
<td>4.8</td>
<td>5.1</td>
</tr>
<tr>
<td>Past research</td>
<td>3.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a</sup>ACSM, 1980.

<sup>b</sup>Schwartz, 1982. Subject walking 150 paces per minute.
for walking to produce a training effect is due to its relatively low energy expenditure, thus it does not meet the minimal intensity requirements for most trained individuals. When reviewing the subjects' most recent graded exercise test results, the average maximal MET capacity was 12.7 METS. According to the ACSM (1978), 50 percent of 12.7 METS, or 6.35 METS, must be attained during an exercise session for the subject to achieve a training effect. Therefore, trained individuals and those who participated in this study could not expect to receive a training effect from walking 3.0 mph with HH.

The MET values obtained, however, were within the acceptable range for individuals participating in Phase II cardiac rehabilitation programs. According to Porter (1984), the MET values which are appropriate and beneficial for Phase II cardiac rehabilitation patients are between 3 and 6 METS. When walking at 3.0 mph, the MET values of the HH exercises in this present study were between 3.8 and 5.1 METS. As shown in Table 5, the MET intensity of HH exercises can be altered by changing the weight or level of excursion to provide the appropriate intensity level for training.

Another benefit of HH exercise for cardiac patients is the incorporation of the upper body in the exercise program, since the arms are often neglected during aerobic exercise. Fardy, Webb, and Hellerstein (1977) stated that arm training was necessary if individuals were expected to
return to their original vocation and recreational activities. Training with the upper and lower extremities can be of benefit to the healthy exerciser as well.

**RER**

By shifting from SLE to HLE, a higher RER value was produced. Although the comparisons of the three exercise weight conditions were different from each other, no significant differences were revealed when evaluated by post hoc analysis. When compared to NW, only 1-HLE and 2-HLE produced significantly greater RER values.

The significant changes cited above reflect an alteration in energy substrate utilization from the upper end of the fat RER of 0.79, toward a carbohydrate RER of 0.84 for SLE and HLE, respectively. According to McArdle et al. (1981), the body will shift to the substrate which most efficiently allows the formation of energy. The increase in caloric expenditure was due to a large increase in carbon dioxide production over a relatively smaller increase in oxygen consumption.

**RPE**

The RPE, rate of perceived exertion, is a subjective rating system (see Appendix B) which grades the difficulty of the physical task being performed (Borg & Noble, 1974). For this investigation, two rates of perceived exertion, the RPEg, which represented the general feeling of exertion, and the RPEa, which reflected the difficulty of the arm work,
were determined.

When evaluating the RPEg responses, the comparison of the NW response with the other six exercise responses indicated an increase in the RPEg value which paralleled the increases noted in energy expenditure. However, only the RPEg responses for 2-SLE, 0-HLE, 1-HLE, and 2-HLE were significantly different from the NW response. The addition of two pounds to the no weight exercise condition and a shift from SLE to HLE produced significantly greater values for both RPE responses.

Comparing NW with the other exercises revealed that the RPEg responses of 2-SLE and all HLE exercises rose in accordance with the standard indicators of exercise intensity, HR and oxygen uptake. However, significant increases in HR were also noted for the relatively lower intensity exercises of 0-SLE and 1-SLE, when compared to NW. With regard to oxygen uptake, significant increases were found for 1-SLE. This indicates that distinguishing increases in workload from RPEg gauging may be accurate only at relatively higher intensities of HH exercise.

Similar findings were noted when comparing changes in weight and level of excursion for both RPEg and RPEa. Shifting from SLE to HLE produced significant increases in HR and energy cost, which was accurately discerned by the subjects when rating RPEg and RPEa. The addition of two pounds to the no weight condition evoked significant
increases in RPEg and RPEa, but the addition of one pound to the no weight exercise did not elicit significant changes in either perceived exertion value. It should be noted that the average values for RPEg and RPEa varied less than one whole number for the same exercises. This suggests that either measure can be used to accurately assess HH exercise intensity.

To sum up, the RPE rating of HH exercise intensity paralleled increases in HR and energy expenditure for the relatively higher intensity exercises. Since HR and energy cost are standard means of gauging exercise intensity, RPE can also be used to accurately assess HH exercise intensity.

Combined Effects

When comparing HR and oxygen consumption for the addition of one pound to the no weight and one pound exercises, there were significant increases in energy cost, but no significant increases in HR. This implies that vasodilation in the periphery along with an increase in the active muscle mass for arm exercise could have occurred. The vasodilation response would reduce the resistance of blood flow back to the heart. The increased activation of muscle mass would provide a greater muscle pumping effect which would also increase venous return to the heart, thus, increasing stroke volume. Consequently, an increased
stroke volume with a reduced heart rate can produce the same cardiac output and maintain adequate blood flow demands during exercise.

Studies of combined arm and leg cycling at submaximal workloads have been carried out by Clausen et al. (1973), Lewis et al. (1980), Magel et al. (1978), Stenberg et al. (1967), and Toner et al. (1983). These researchers noted decreased heart rates for combined arm and leg cycling when compared to leg alone exercise at the same workload. The reductions in HR were attributed to a reduced myocardial afterload and facilitation of venous return which reduced the heart's workload. Similar physiological actions may be operating when performing HH exercise while walking. With HR not increasing in direct proportion to oxygen demand during relatively lower intensity exercises, HR becomes a tenuous means of determining exercise intensity at those lower levels.

Summary

The physiological responses to HH exercise follow a similar pattern when compared to normal exercise programs. The values of HR, \( V_E \), oxygen consumption, and rate of perceived exertion rose with increases in exercise intensity. The increases in energy expenditure in the present study were not enough to produce a training effect in the subjects tested due to their level of fitness. However, the MET values were at a level which could produce a training effect
in Phase II cardiac rehabilitation patients and healthy individuals whose maximal exercise capacities were below 10 METS. With regard to all individuals, HH exercise sufficiently increased the caloric expenditure over normal walking to benefit a weight reduction program. The perceived exertion method of gauging HH exercise intensity proved accurate for the relatively higher intensity exercises. A possible drawback to using HH exercise may be the development of cardiac arrhythmias during upper body exercise which was noted in the present investigation.
CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the energy cost of walking with and without hand weights while performing the arm movements SLE and HLE. The energy cost of NW was determined and all arm exercise values were compared to those found for NW. The energy cost reflected by oxygen consumption ($\dot{V}O_2$ $l \cdot min^{-1}$, $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$, and METS) was measured for each exercise condition along with the variables HR, $\dot{V}E$, RER, RPEg, and RPEa. An attempt was made to analyze this information and provide guidelines for hand-weighted exercise prescription.

All subjects were tested in an identical manner with the sequence of exercises randomly performed. Statistical analyses 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). The level of significance was set at the 0.05 level.

It was found that the subjects had significantly higher $\dot{V}E$ and energy expenditure values for the arm exercises 1-SLE, 2-SLE, 0-HLE, 1-HLE, and 2-HLE when compared to NW. The HR responses for all arm exercises were greater than
the HR responses for NW. When performing 1-HLE and 2-HLE, the RER value was significantly elevated when compared to the NW RER value. Additionally, NW produced significantly lower RPEg values than the exercises 2-SLE, 0-HLE, 1-HLE, and 2-HLE. Shifting the arm movements from SLE to HLE resulted in statistically significant increases in HR, $\dot{V}_E$, $\dot{V}O_2$, METS, RER, RPEg, and RPEa responses. The energy cost values for all seven exercises in METS and kcal·min$^{-1}$ are presented in Table 5.

**Conclusions**

The results of this study indicated the following conclusions:

1. By altering the level of excursion from SLE to HLE and/or the addition of one or two pound hand weights, the caloric cost of NW can be significantly increased to help the exerciser reduce body weight.

2. For those individuals who have a maximal MET capacity of greater than 10 METS, the HH exercises evaluated at 3.0 mph would not produce a physiological training effect.

3. The HH exercises evaluated in this study were at an appropriate MET level (3.8 to 5.1 METS) for utilization in Phase II cardiac rehabilitation.

4. Hand-weighted exercise should be used with caution since cardiac arrhythmias were noted during this study.

5. 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 evaluated in this study walking 3.0 mph, the exerciser must have a maximal MET capacity below 10 METS.

2. The frequency of HH exercise should be 3 to 5 days per week in accordance with the guidelines established by ACSM (1978).

3. The HH exercise intensity should be adjusted to 50 to 85 percent (ACSM, 1978) of maximal MET capacity using the MET levels found for HH exercise in this investigation. Maximal RPE and HR limits should also be established to insure that the exerciser does not overtrain.

4. The duration of HH exercise should initially be only 5 to 10 minutes. This is to reduce the possibility of injuring the untrained upper body and to become accustomed to the arm movements. Increases in duration should be made according to individual toleration of the activity. Total time of participation should be between 15 and 60 minutes (ACSM, 1978).

5. The progression of exercises for all exercisers should be 0-SLE, 1-SLE or 0-HLE, 2-SLE, 1-HLE, and then 2-HLE. This sequence follows the gradual rise in MET level found for the HH exercises evaluated.

6. To insure that the intensity level of the exercise remains constant, strict attention should be given to the maintenance of proper arm technique, weights used, and speed
of walking.

7. Cardiac patients with known rhythm disturbances should initially be monitored during HH exercise.

**Recommendations**

The following suggestions are made regarding future studies:

1. Since only men were evaluated in this study, similar investigations looking at different populations would be informative.

2. A similar investigation with varying speeds of walking would be of interest since only the speed 3.0 mph was evaluated in this study.

3. Since only one and two pound hand weights were utilized in this investigation, a similar study using hand weights greater than two pounds should be attempted.

4. To help establish HH exercise as a safe exercise mode, a study evaluating electrocardiographic changes during hand-weighted exercise should be undertaken.

5. In order to test the effectiveness of HH exercise for improving fitness levels, a training study implementing the guidelines outlined should be conducted.
REFERENCES CITED


APPENDIX A
Informed Consent Form
The Energy Cost of Walking With and Without Hand Weights While Performing Rhythmic Arm 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 also wear a nose clip. Prior to the test session 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 head level of excursion with one pound hand weights
5) 3.0 mph, moving the arms to the shoulder level of excursion with one pound hand weights
6) 3.0 mph, moving the arms to the shoulder level of excursion with two pound hand weights
7) 3.0 mph, moving the arms to the head level of excursion with two pound hand 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 the 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 from 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 behalf of any of them.

(Subject)  (Date)

(Witness)
**BORG SCALE OF PERCEIVED EXERTION**

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<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<tr>
<td>9</td>
<td>Very light</td>
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<tr>
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<tr>
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<td>12</td>
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<td>13</td>
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<td>14</td>
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<td>15</td>
<td>Hard</td>
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<tr>
<td>16</td>
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<td>Very hard</td>
</tr>
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<tr>
<td>19</td>
<td>Very, very hard</td>
</tr>
<tr>
<td>20</td>
<td></td>
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</tbody>
</table>
One way analysis of variance for the exercise variables.

<table>
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<tr>
<th>Variable</th>
<th>F Ratio</th>
<th>df</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (b·min⁻¹)</td>
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<td>.001</td>
</tr>
<tr>
<td>( \dot{V}_E ) (l·min⁻¹)</td>
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<td>6,84</td>
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<td>( \dot{V}O_2 ) (l·min⁻¹)</td>
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<td>( \dot{V}O_2 ) (ml·kg⁻¹·min⁻¹)</td>
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<td>.001</td>
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<td>METS</td>
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<tr>
<td>RER</td>
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<td>.001</td>
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<tr>
<td>RPEg</td>
<td>8.49</td>
<td>6,84</td>
<td>.001</td>
</tr>
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</table>
Significant post hoc results of one way analysis of variance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise Comparison</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>NW &lt; 0-SLE</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>NW &lt; 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE</td>
<td>.01</td>
</tr>
<tr>
<td>( \dot{V}_E )</td>
<td>NW &lt; 1-SLE</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>NW &lt; 2-SLE, 0-HLE, 1-HLE, 2-HLE</td>
<td>.01</td>
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<tr>
<td>( \dot{V}O_2^* )</td>
<td>NW &lt; 1-SLE, 2-SLE, 0-HLE, 1-HLE, 2-HLE</td>
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<tr>
<td>RER</td>
<td>NW &lt; 1-HLE, 2-HLE</td>
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</tr>
<tr>
<td>RPEg</td>
<td>NW &lt; 2-SLE, 0-HLE, 1-HLE, 2-HLE</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Expressed in \( l \cdot min^{-1}, ml \cdot kg^{-1} \cdot min^{-1} \), and METS.
Levels of significance for weight and level of excursion.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Comparison</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>Level of Excursion</td>
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<tr>
<td></td>
<td>Weight</td>
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<tr>
<td>$\dot{V}$</td>
<td>Level of Excursion</td>
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<tr>
<td>$E$</td>
<td>Weight</td>
<td>.001</td>
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<tr>
<td>$\dot{V}O_2^*$</td>
<td>Level of Excursion</td>
<td>.001</td>
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<tr>
<td></td>
<td>Weight</td>
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<tr>
<td>RER</td>
<td>Level of Excursion</td>
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<tr>
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<td>Weight</td>
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<td>RPEa</td>
<td>Level of Excursion</td>
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<tr>
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<td>Weight</td>
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</tbody>
</table>

*Expressed in $l\cdot min^{-1}$, $ml\cdot kg^{-1}\cdot min^{-1}$, and METS.
Significant post hoc results of two way analysis of variance for weight.

<table>
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<tr>
<th>Variable</th>
<th>Comparison</th>
<th>Level of Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>0 wt &lt; 2 lb wt</td>
<td>.01</td>
</tr>
<tr>
<td>( \dot{V}_E )</td>
<td>0 wt &lt; 1 lb wt, 2 lb wt</td>
<td>.01</td>
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<tr>
<td>( \dot{V}O_2^* )</td>
<td>0 wt &lt; 1 lb wt &lt; 2 lb wt</td>
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<tr>
<td>RPEg</td>
<td>0 wt &lt; 2 lb wt</td>
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</tr>
<tr>
<td>RPEa</td>
<td>0 wt &lt; 2 lb wt</td>
<td>.01</td>
</tr>
</tbody>
</table>

*Expressed in l·min\(^{-1}\), ml·kg\(^{-1}\)·min\(^{-1}\), and METS.