ABSTRACT

Denny, K.L. A biomechanical analysis of the effects of hand weights on the arm-swing while walking and running. MS in Exercise and Sport Science-Human Performance, August 1995, 65pp. (M. Miller)

Ten female track runners ($\bar{X}$ age = 21.5) volunteered as subjects to determine if 4 lb hand weights would alter shoulder and elbow displacements and angular velocities under various locomotion speeds. Subjects were videotaped walking at 3.0 mph and running at 6.0 mph at a 0% grade, with and without hand weights. The ARIEL (APAS) system was used to create a 2-dimensional image of each subject while performing. A 2-way ANOVA with repeated measures ($p < .05$) was used to test the hypothesis. The F values for elbow and shoulder angular velocity with and without hand weights were 2.07 and 1.49, respectively. The values for shoulder and elbow angular velocity while walking and running were 1.87 and 3.96, respectively. The speed and condition interaction for the shoulder and elbow angular velocity during walking and running with and without hand weights were 1.55 and .99, respectively. The F values for elbow and shoulder angular displacements with and without hand weights were 2.06 and .56, respectively. The F values for walking and running were 4.03 and 1.72, which failed to meet the critical F of 18.5. The speed and condition interaction for angular displacements at the elbow and shoulder while walking and running were .96 and 1.06, respectively. All values for the elbow and shoulder angular velocities and displacements were not significant. Further investigations with a different subject population and protocol are recommended. To determine the effects of hand weights on the body, a 3-dimensional analysis is a recommended future area of study.

A BIOMECHANICAL ANALYSIS OF THE EFFECTS OF HAND WEIGHTS ON THE ARM-SWING WHILE WALKING AND RUNNING

A THESIS PRESENTED

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Finally, a very special message to my sister, Diane. Your presence, love, and spirit remain alive within my heart, for there is no other place that can hold the amount of love I have for you. It is you, Di, to whom this thesis is dedicated. Your little sister did it!

TABLE OF CONTENTS

PAGE

CHAPTER

LIST OF TABLES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Background

Cardiorespiratory fitness has become a major topic within the past 15 years and a cornerstone in many peoples' lives. The effects of exercise can lower blood pressure, assist in weight reduction, strengthen the heart, and simply improve one's attitude. Although there are numerous ways to improve the cardiorespiratory system, walking and running are still two of the most common activities that are incorporated into many lifestyles.

Researchers who have investigated cardiorespiratory fitness found that exercises which incorporate the whole body increase the benefits associated with aerobic exercise. Total_body fitness equipment such as cross-country simulation machines, bicycle ergometers, and treadmills that require the upper and lower body to overcome a resistance were designed for the purpose of these halves of the body to act together. This requires the participation of the whole body. Not everyone can afford or accommodate these large pieces of equipment for at home use. It would seem logical that the next step of development for an exercise implement would be to produce similar results without the bulkiness of its predecessors.

Walking and running have been around since the evolution of man. Morris (1994) wrote that walking is the most common form of exercise, as well as the most natural. It is only recently that society has developed enough interest in these activities to prompt companies to manufacture and market products to help achieve total physical fitness. Total physical fitness involves cardiorespiratory endurance, flexibility, appropriate body composition, and may also include a well-toned muscular physique. Many individuals often complain about not having enough time to achieve both cardiorespiratory fitness and a well-toned body. Products were designed to provide a maximum workout for individuals to utilize their time more efficiently. These products, such as hand weights, are advertised under the notion that they will create greater aerobic benefits than exercising without them. Claremont and Hall (1988) suggested that people were led to believe that exercising with the hand weights would increase their caloric expenditure by 30-300%. According to Zarandona, Nelson, Conlee, and Fisher (1986), 30 trained male runners who had walked at 3.5 mph with 5 pound hand weights were thought to have an increase in their metabolic cost during the activity. Walking or running with the hand weights may produce a more difficult workout in half the time, but are the mechanics of the body altered in the process? Very few researchers have investigated the mechanical effects of exercising with hand weights. In addition, of the few studies found, males were the primary subjects. It is unclear what the mechanical effects of walking or running with hand weights have on the body, particular for females. Most of the studies conducted on the arm swing involved male subjects. Very few of these studies have tested for the biomechanical functioning of the arm swing with hand weights on females.

Auble and Schwartz (1991) performed a physiological study using hand weights and found an increase in energy costs, upper and lower body endurance responses, and an increase in strength of the torso while carrying the hand weights. They also pointed out that there was an increase in VO_2 by 41% while the subjects were running with 2 pound hand weights. This increase occurred when the hands were pumped to shoulder height level.

Makalous, Araujo, and Thomas (1988) tested three obese men and eight obese women who carried hand weights while walking. They found an increase in heart rate, energy expenditure, and VO_2. Increasing the arms' range of motion with hand weights can increase the intensity of the aerobic exercise of walking.

Interestingly enough, the majority of studies deal only with the physiological effects associated with hand weights. Auble, Schwartz, and Robertson (1987) conducted a study using nine physically active males and found a potential benefit of aerobic training with the use of hand weights. The benefits were lowered impact forces and reduction in lower limb injuries often associated with jarring activities like aerobic classes or jogging. Walking with the hand weights reduced these impact forces. Aerobic exercise with hand weights allows for the upper and lower muscles to be trained simultaneously. During their study, Auble et al. (1987) did note that a small increase in energy expenditure resulted from the use of the weights, but that this increase could have been achieved by simply walking faster without the hand weights.

There are many researchers who have tested the physiological components of exercising with hand-held weights. There have been a limited number of researchers who have analyzed the biomechanical effects on the body while using hand weights (Auble et al. 1987; Gregersen & Lucas, 1967). As summarized by Leivenberg (1987), the fitness industry is a prime target for manufacturing companies to make exaggerated exercise claims about their products. It is often difficult to distinguish between legitimate and illegitimate exercise equipment.

The fact that the upper extremities have not been investigated as thoroughly as the lower extremities creates a void of information on the mechanical aspects of the arms. Hinrichs, Cavanagh, and Williams (1987) cited the lack of information available on the mechanics of the upper body, which led them to investigate the angular momentum contributions the arms provided to the body while running. Figura, Marchetti, and Leo (1985) conducted an upper body rotational study using 5 female subjects. Figura et al. (1985) were concerned about the limited information on the upper extremities, particularly on female subjects. Therefore, the purpose of their study was to provide information on the locomotion patterns pertaining to women. Most of the data on the upper extremities have been obtained on male subjects. Hinrichs et al. (1987) also noted the lack of information on the arm swing in general.

The upper extremity joint kinematics are crucial to the locomotion techniques and form needed to produce efficient movement, however, there has been a lack of information available to truly establish the importance of these kinematic features. Adding weight at the most distal portion of the upper extremities could potentially alter the mechanical form of the arm swing, thereby affecting the efficiency of the desired movement. If the efficiency is negatively affected by the hand weights, wasted energy will result. This will result in more time being spent on unnecessary movement than on the actual beneficial movements of the activity. Not only might there be a waste of energy, but the change in arm-swing and shoulder rotation could prove to be detrimental to the body as a whole. In this event, a change in one body segment may create a change in another segment, thus leading to a series of alterations in the body's kinetic chain. It was therefore the purpose of this study to investigate the upper body kinematics, specifically shoulder and elbow displacements and velocities during walking and running with and without hand weights.

Hypothesis

The null hypothesis for this study assumed that the added weight load to the arms would not alter the biomechanical form of the arm-swing during walking and running.

1. The use of hand weights while walking would not alter the range of motion at the elbow as compared to walking without hand weights.
2. The velocity at the elbow would not be affected with and without the hand weights while walking.
3. The range of motion at the shoulder with and without hand weights would not be changed while walking.
4. The velocity at the shoulder would not be affected under the two locomotion protocols.

5. Running with and without hand weights the range of motion at the elbow would not be altered.
6. The velocity at the elbow would not be affected while running with and without hand weights.
7. The range of motion and the velocity at the shoulder would not be changed while running with and without hand weights.
8. These alterations would not affect any changes in shoulder and elbow flexion and extension, and the velocity of the arm-swing during walking and running.

Assumptions

This study had the following assumptions:

1. The subjects involved had no predisposing physical condition or infliction which might affect their arm-swing or gait.
2. The subjects would become familiar with the hand held weights during the practice session.
3. The subjects would follow all instructions.

Delimitations

The following delimitations were placed on the study:

1. The subjects were experienced runners, averaging 30-35 miles per week.
2. The subjects wore their own running shoes.

Limitations

The following limitations were placed on this study:

1. All of the subjects had their own individual arm-swing style.
2. The fitness levels of the subjects were similar to one another.

Need for the Study

This research study can be used to identify the normal arm-swing patterns and the influence that hand weights might have on these patterns while walking and running. Specifically, shoulder flexion and extension, elbow flexion and extension, and the angular velocities of the joints were the key kinematic variables investigated. These mechanical variables might assist in the detection of any mechanical changes which may adversely affect the efficiency of the walker and/or runner. As previously stated, very few studies about the hand-held weights' effects on the biomechanics of the arm-swing while walking and running have been conducted. Many uninformed consumers purchase equipment to maximize their workout times to achieve total body fitness, when in fact the use of the equipment may alter the normal mechanical patterns.

Definitions of Terms

The following terms have been defined to provide a common understanding between the author and the reader of this study:

Experienced Runner - one who has ran for no less than one year; has training experience; knows the proper form for desirable movement; runs about 35-40 miles a week.

Hand Weights - a four pound product manufactured by the AMF American Company designed with a grip for the fingers to securely wrap around the weights.

Relative Angle - the angle between two body segments.

Gait Cycle - three consecutive right heel strikes to right heel strike.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

As stated previously, cardiorespiratory exercise has become incorporated into many lifestyles. In that regard, there have been numerous studies focused on the physiological functionings of the body in relation to exercise with hand weights (Auble & Schwartz, 1991; Auble, et al., 1987; Claremont & Hall, 1988; Makalous et al., 1988; Zarandona et al., 1986), but a limited number which analyzed the biomechanical effects that hand weights might have upon the body (Auble et al., 1987, Gregersen & Lucas, 1967). The specific biomechanical effects would be on the arm swing while running or walking with the weights. Claremont and Hall (1988) performed a study on running mechanics with hand weights and found significant reductions of angular velocity of the arm-swing while running with hand weights.

In the following discussion, the related literature has been divided into two categories. The first category identifies the normal mechanics of the arm-swing, while the second category focuses on the physiological and mechanical effects that occur in the body regarding hand weights.

Normal Mechanics of Arm-Swing

There has been some debate over how the arms contribute or assist in the walking and running patterns. Hopper (1964) analyzed the mechanics of arm action in running and found that during the forward downward swing of the arm, there is an upward force generated of roughly 30% of the runner's weight. The same force was found on the backward downward swing of the arm. The downward force transmitted to the ground in the forward upward swing of the arms (i.e., while swinging the arms toward the front of the body), resulted in a 50% increase of force produced by the runner's weight.

Elftman (1939) found the arms to assist in regulating the rotation of the body. This regulation was accomplished through the range of the arm-swing. The degree to which this occurs depends upon the "amplitude of the swing, since this affects the velocity and the positions through which the arms swing, since they affect the distance of the parts from the center of gravity of the body" (p. 532).

Cavanagh and Hinrichs (1980) analyzed the running action of an elite runner and developed what they believed were the essential components of a good arm swing. They suggested that the arms should be kept low and relaxed, similar to placing the hands into pants pockets. If the arms are kept too high, this might increase the speed of lactic acid build-up in the shoulders. Keeping the arms rigid while running will cause the shoulder girdle to rotate, emphasizing the need to keep them relaxed. The elbows should be free to swing backward in a straight line. Any lateral motion can hinder the efficiency of the arms. Cavanagh and Hinrichs (1980) also found that the elbows should not deviate more than 3 to 5 inches on each side of the body to enhance the movements of the swing. All parts of the body should move in the same direction as the running movement. They found the hands to be critical for effective arm usage and believed that the hands would serve the arms better by being cupped or closed.

Murray (1967) investigated the normal gait patterns, including the displacements of the trunk and upper extremities of 60 male and 60 female subjects. Murray found the upper limbs to have a definite flexion and extension phase in assisting to counterbalance the movements of the lower limbs. The displacements of the shoulder region in a forward and backward direction were a function that contributes to stabilizing the rotational pattern created by the thorax with each successive gait cycle. The shoulder and elbow range of motion from Murray's study are shown in Table 1.

Table 1. Range of motion values*

	Shoulder	Elbow
Extension	24 ± 6	17 ± 8
Flexion	8 ± 10	47 ± 11

* = From Murray (1967)

A study identifying walking patterns and gait components of females was conducted by Murray, Kory, and Sepic (1970). Thirty women were filmed using interrupted-light photography. Once the light flashed, the anatomical landmarks were highlighted by the reflective markers. The subjects were required to use two predetermined walking speeds during this study. In the free speed trial, the subjects walked at their own cadence averaging 130 cm/second ± 15. The fast walking speed was 188 cm/second ± 28. Murray and colleagues (1970) found the rotational pattern of the shoulder increased as the walking speeds increased. During the extension phase of the arm-swing, the shoulders averaged 21 ± 2 degrees, while the extension phase for the fast speed was 26 ± 2 degrees, as depicted in Table 2. Flexion and extension of the elbow were greater during the fast speed walking. The values of the total flexion and extension phase under the free speed walking were 25 ± 2 degrees. The fast speed walking generated 36 ± 2 degrees for the combined values of flexion and extension. This increase was associated with the increase in elbow flexion during the forward movement of the arm-swing.

Table 2. Fast speed walking values*

	Shoulder Extension	Elbow Flexion/Ext.
Walking =	26 ± 2	36 ± 2
Walking =	-21 ± 2	25 ± 2

* = From Murray et al. (1970)

In a similar study involving interrupted-light photography, Murray, Drought, and Kory (1964) identified body segment displacements relating to locomotion. There were 60 male subjects grouped in ages of 5 year increments. The age groups were: 20-25, 30-35, 40-45, 50-55, and 60-65 year olds. The grouping system was used to easily identify differences that transformed over a 5 year period. Free and fast speed walking were incorporated to allow for consistent data between each subject. Murray and associates found the thoracic region to shift from a clockwise to counter-clockwise direction with each left heel-strike. As the walking pattern continued, the rotation of the thorax reversed (i.e., when contact was made with the right heel-strike and the pelvis rotated in the opposite direction). The average rotation for all five age increments was 6.9 ± 1.9 degrees. However, Murray et al. (1964) noted the greatest thoracic rotation was found in the 30-35 year old subjects and the least amount of rotation occurred in those 50-55 years old. It was established in this study that the arm-swing was closely associated to the thoracic rotational patterns (i.e., left foot forward, right arm forward). This cooperation between the thorax and the arm-swing created further interest for future studies "of arm-swing and of various speeds of gait" (p. 359).

In finding that the upper extremities work together with the lower extremities to reduce the rotation of the trunk while walking, Hogue (1969) suggested the arms may affect the walking gait by shifting the center of mass in the body. The addition of weights may therefore affect the velocity of the arm swing affecting the running mechanics of the body. Hinrichs et al. (1987) determined that the arms greatly counteract the angular momentum generated from the legs while running. The upper portion of the body must react to and create its own angular impulse in order to maintain the cycle of running. They also discovered that the arms contribute 5 to 10% of the vertical momentum of the whole body, which is known as the "lift". The lift was found to increase with running speed. The lift that occurs while running is in essence the airborne phase of the running cycle. The reduction of horizontal movements of the body center of mass while running is established by the swinging of the arms. This enables a more constant horizontal velocity of the body, as found by Hinrichs (1987). While studying the rotational aspect of the trunk while having their subjects walk, Chapman and Kurokawa (1969) found that there was a decrease of amplitude in shoulder rotations with an increase in walking speed. Increasing the speed of walking may decrease the shoulder rotational patterns. If this were the case, the shoulders would significantly reduce their rotational movements while running. Craik, Herman, and Finley (1976) discovered the shoulder may change its movement pattern with any changes that occur in each muscle of the upper limb. This was found via the use of electromyography in the posterior and anterior deltoids.

Physiological/Mechanical Studies

There have been studies conducted which have found negative impacts on the body from the use of hand weights. Zarandona et al. (1986) found that walking at 3.5 mph with 5 pound hand weights increased the systolic blood pressure of the 30 trained male subjects. While the subjects ran at a 7.0 mph speed carrying the hand weights, their VO_2 increased disproportionately to their blood pressures and heart rates. Zaranadona and colleagues explained that such a response was not beneficial due to the increase of the stress load on the circulatory system. There was no increase in the aerobic conditioning of the subjects. They concluded that exercising with hand weights in conjunction with the extra stress placed upon the circulatory system might be dangerous to people with heart disease.

Gregersen and Lucas (1967) observed that shoulder rotation was greater when walking with 10 pound hand weights then by walking without them. Hand weights create tension in the muscles of the upper limb which might cause changes in the shoulder motion since the muscle fibers are recruited to sustain the extra weight at the distal portion of the upper extremities. The increase in shoulder rotation might be the body's way of compensating for the extra weight burden created by the hand weights.

Auble et al. (1987) found an increase in heart rate and blood pressure in the nine male subjects who had walked while carrying 5 pound hand weights. They attributed this increase to the static grip of the weights in the hands. Those with cardiovascular disease were encouraged to avoid using the weights due to the elevation in blood pressure and heart rate. A person with known cardiovascular disease should not intentionally create increases in heart rate and blood pressure which might be a side effect from adding hand weights to their exercise program.

Graves, Pollack, Montain, and O'Keefe (1987) also found that those who are hypersensitive or who have coronary problems should not exercise with hand weights because of the increase in blood pressure associated with the weights. Abadie (1990) also found that blood pressure elevated in 11 male and 8 female subjects who exercised using 3 pound hand and wrist weights. Auble and Schwartz (1991) also identified the rise in blood pressure and heart rates and recommended to those who do have high heart rates and blood pressure to not exercise with hand weights.

Makalous et al. (1988) tested three obese men and eight obese women who carried hand weights while walking. They concluded that the addition of hand weights on the obese population would almost certainly lead to an increase in blood pressure. Graves et al. (1987) found similar results.

Zarandona et al. (1986) found that walking or running with 5 pound hand weights could be detrimental to those with heart disease. However, they recommended that using the 5 pound weights was all right for individuals who are unwilling or unable to jog, or those who would want to increase their intensity without increasing their speed. The findings of an increase in blood pressure in the 30 trained male runners seems to contradict their recommendation for people unable or unwilling to jog since it might often be these types of people who are more susceptible to injuries due to a medical condition. Those who are unable to jog might already have a medical condition which would render the use of hand weights as being unsafe. Individuals who are unwilling to jog, either due to fitness levels, being overweight, or lacking the time would seem at risk for damaging effects by using the weights.

Auble et al. (1987) stated that "the most likely cause of variability in the effects of hand weights on the energy expenditures of walking is the amount of arm movement used" (p. 138). If the amount of movement of the arms affects energy expenditure, then an increase or decrease in the velocity of the arm swing as well as displacement of the shoulder should occur. This should theoretically have an effect on the mechanics of the arm swing, which can in turn disrupt the whole form of running, especially since this observation was noted during walking.

Auble and Schwartz (1991) found the VO_2 to increase 41% on subjects who ran while carrying 2 pound hand weights. The increase occurred when the hands were pumped to shoulder height. This is not characteristic of good running form. As Cavanagh and Hinrichs (1980) had stated, the hands should be relaxed and at waist level while running. Swinging the arms up to shoulder height is certain to cause a mechanical change in the running form and would increase the energy costs of the movement based upon the work the upper extremities are forced to do. They also found the energy costs may be affected by the vertical distance that the weights travel. Shoulder displacement and arm swing velocity affected by the hands swinging up so high may be related to the energy costs of the movement.

A study conducted by Ballesteros, Buchthal, and Rosenfalck (1965) found that "the function of the muscles in the shoulder and upper arm was to counteract the rotation of the body that occurred while walking" (p. 309). This was also identified in Elftman's 1939 study. This would imply that the arms assist in the locomotion process other than just swinging at one's side.

As Figura and colleagues (1985) pointed out, there have been few studies performed on female subjects for the identification of upper body kinematics. This results in more information on men and their arm swing, which might be different compared to a woman's swing based upon anatomical differences.

Summary

There have been previous studies conducted on the physiological effects of walking and/or running with hand weights. During such studies, it has been determined that blood pressure and heart rate will increase once the hand weights are used in these modes of activity. There is still a void regarding the mechanical effects of hand weights on the body. It has been established that the upper extremities assist in counter-balancing the torque of the lower body during locomotion. What has not been clearly identified is how the addition of an implement (hand weights) at the distal portion of the upper limb would affect the normal movement patterns already discovered. Of the studies that have incorporated mechanical effects from the use of hand weights, few, if any, have involved female subjects. It was the lack of information on females that prompted this study.

CHAPTER III

METHODS AND PROCEDURES

Introduction

There has been very little research conducted on the biomechanics of the arm-swing during running using female subjects only. It was the purpose of this study to investigate the upper body kinematics, specifically shoulder and elbow displacements and velocities during walking and running with and without hand weights.

Subject Selection

Ten members of the University of Wisconsin-La Crosse women's track team volunteered to be participants in the study. All of the subjects had prior running experience and were physically fit based on the fact they exercised at least five days a week and ran 35-40 miles each week. The ages of these women ranged from 20-22 years, as shown in Table 3.

Table 3. Subject characteristics

	Mean	Standard Deviation
Age (yrs.)	21.10	± 1.350
Height (cm.)	167.89	± 6.078
Body weight (kgs.)	47.12	± 10.379

Data Collection

Prior to conducting the test, informed consent (see Appendix A) was obtained from each of the ten subjects. A full and thorough explanation was given to the subjects and included what the subjects would do, how long the activity would last, and a demonstration of the expected activity. At the conclusion of this explanation, the author answered questions from the subjects.

Height and weight were recorded for each subject. The subjects wore their own running shoes to provide for individualized comfort and proper fitting.

Reflective markers were placed on 14 sites on each subject's body. These bony landmarks were at the following locations: the fifth metatarsal, ankle, calcaneus, knee, greater trochanter, head of the humerus, lateral epicondyle of ulna, head of ulna, base of third metacarpal, jugular notch, and the forehead. The landmarks were used to determine the joint locations so that angular displacements and angular velocities of the upper extremities could be calculated. The trunk provided a reference in relation to the movement of the arms.

Prior to the testing, the treadmill was calibrated to establish accurate and consistent results. The test was administered over a 2 day period on a motorized treadmill (Quinton model 1860) for 7 minutes with set speeds of 3 and

6 mph. The elevation was at 0% and remained at this level for the testing days. Each subject had a warm-up period of 3 minutes of walking without using the hand weights. Eighty percent of the subjects had previous experience on a treadmill. Two Panasonic H.S. Shutter CCD VHS HQ video recorders were set up to record the motion of the subjects while they were walking and running on the treadmill (see Figure 1). One camera was perpendicular to the sagittal plane of motion. The other camera was positioned on an oblique plane, bisecting the frontal and sagittal planes, similar to the set-up of Hinrichs et al. (1987).

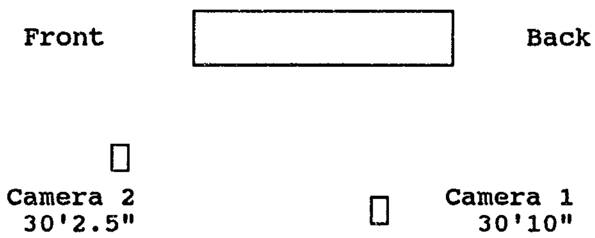

Figure 1. Design of set-up

The first day of testing was conducted without hand weights as the subjects walked for 3 minutes at 3.0 mph and ran for 4 minutes at 6.0 mph on a level treadmill. Once the actual testing began, the filming was activated at minute 3 of the walking phase and was recorded for 15 seconds. The speed of the treadmill was then increased to 6.0 mph and the subjects were filmed 4 minutes into the run. The filming lasted 15 seconds. Videocameras operated at a nominal speed of 30 frames per second. To highlight the reflective markers, spotlights were positioned above the camera lens and aimed along the optical axis of the lens.

Upon completion of walking and running without weights, each subject was instructed to familiarize themselves with the hand weights for the following day. This was accomplished by having them walk with the weights and then run with them to become acquainted with the movement. The familiarization session lasted 3 minutes in addition to the 3 minutes the subjects were given to adjust to the treadmill. The majority of the subjects had prior experience with the hand weights and therefore did not need much time to get reacquainted with them.

The second day of testing required the subjects to walk for 3 minutes at 3.0 mph and then run for 4 minutes at 6.0 mph, 0% grade, with the use of the hand weights. Videotaping began at minute 3 for the walking phase and was recorded for 15 seconds. The speed increased from 3.0 mph to 6.0 mph and the subjects were filmed 4 minutes into this run, with the filming lasting 15 seconds. Each subject was given a trial period to adjust to the treadmill. This period lasted for 3 minutes with the use of the hand weights.

Data Reduction

Upon completion of the testing, the videotape of the subjects was digitized on the ARIEL Performance Analysis System (APAS). The digitization process involved the establishment of a fixed point that was visible in every frame of the video. This point provided a reference to the height of the subjects and distance from the cameras. A control frame (180.34 cm. X 80.01 X 123.19) was used as a reference scale. Once the control frame was digitized, the reflective markers on the subjects were digitized and saved to disk. The transformation process was then utilized to convert the values generated from the digitization into scaled down data to fit a real-life model. The cubic spline process of smoothing was then used to eliminate random errors that might have occurred during the digitization process. Sources of error, as identified by Wood (1982), included "perspective error due to (subjects or scale) out of photographic plane; distortion due to optical system of camera or projector; graininess of film; and operator errors of judgement and parallax in locating joint axes of rotation" (p. 311). Upon the completion of this process, the arm-swing during walking and running with and without hand weights was then analyzed. The analysis included noting any changes in shoulder and elbow flexion and extension and the velocity of the arm-swing which occurred under the four different conditions.

Once smoothing was completed, the joint displacements and velocities were calculated and graphed. The maximum and minimum values of the shoulder and elbow flexion and extension for every gait cycle was recorded and entered into a statistical package for analysis.

Statistical Treatment

To determine whether or not any significant differences were found during this study, an ANOVA with repeated measures was utilized with the alpha level at $p = < .05$. The means and standard deviations were calculated for shoulder and elbow flexion and extension and their velocities. This measure was chosen to identify any significant differences which might have occurred while walking and running with and without hand weights. These variables were calculated for each subject. Also calculated was the average amount that the subjects deviated from their mean and the standard error of the mean (SEM), using the critical ratio formula to help determine if the sample was a representation of the running population.

CHAPTER IV

RESULTS AND DISCUSSION

The following discussion involves the results that were obtained during the study. It has been formatted into walking and running sections which include the mechanical variables that were tested.

Walking Data

Elbow

The arms were free to swing in their natural motion for three consecutive gait cycles during the 3.0 mph walk. This natural swinging motion is conducive to good mechanical technique and assists with the counter-rotation needed to balance out the upper body with the lower body. The relative angle of the elbow was determined by the angle created between the anterior portion of the humerus and the upper arm. The average elbow joint flexion for the ten subjects while walking with no hand weights was 148.0 degrees. Extension at the elbow was 181.6 degrees. When the subjects were videotaped walking with the hand weights, however, there was a slight change in the arm swing. The average elbow flexion with the addition of the hand weights was 156.6 degrees. This was a difference of 8.6 degrees when comparing elbow flexion during walking with and without the weights. The mean for elbow extension was 180.5 degrees, with only a 1.1 degree difference in elbow extension between using hand weights and not using hand weights. The descriptive data for elbow displacement values are identified in Table 4.

Table 4. Elbow displacements walking (in degrees)

	Flexion		Extension	
	WW	WOW	WW	WOW
Mean	156.6	148.0	180.5	181.6
SD.	3.7	5.4	5.9	5.6
Max. Value	161.2	159.8	188.8	190.9
Min. Value	149.6	139.8	166.4	170.6

WW = with hand weights WOW = without hand weights

The values for angular displacements were calculated by subtracting the mean extension angles from the mean flexion angles. For all numerical values represented in these findings, a (+) indicates flexion and a (-) indicates extension, unless otherwise stated.

A 2-way ANOVA with repeated measures was used to determine the statistical difference between elbow displacements with and without hand weights when walking and running. The F value for the main effects of angular displacement at the elbow, with and without the hand weights was 2.06, failing to meet the critical F of 2.46 (see Table 5). The angular displacements (see Table 5) of the elbow joint for the 10 subjects without hand weights was 33.6 degrees. Once the hand weights were added, the angular displacements were 23.9 degrees. Although the observed differences were noted, they were not statistically significant. Using the hand weights did not significantly alter the elbow displacements during walking.

Table 5. Elbow kinematics for walking (in degrees)

	With weights	Without weights	F value
A.D.	23.9	33.6	2.06
A.V.	134.1	242.7	2.07

A.D. = angular displacement   A.V. = angular velocity

Murray et al. (1970) identified the normal range of motion at the elbow to be 36 degrees $\pm$ 2 for 30 normal female subjects walking at a cadence of 130 cm/sec. Walking without hand weights produced an average range of motion of 33.6 $\pm$ 8.4 degrees. The addition of the hand weights slightly reduced this value to 23.9 $\pm$ 5.2 degrees, which is beyond the classification Murray et al. (1970) considered to be normal.

Angular velocity of the elbow was calculated from the angular displacement data. A 2-way ANOVA with repeated measures was utilized to test the statistical significance of the angular velocity at the elbow for the hand weight versus the no hand weight conditions during walking and running. The angular velocities at the elbow without hand weights was 242.7 degrees/sec and 134.1 degrees/sec with the hand weights. The F value for the main effects of elbow velocities for the hand weights versus no hand weights was 2.07 and therefore not statistically significant.

A greater range of motion (i.e., angular displacement) occurred when the subjects did not use the 4 pound hand weights. The angular displacements of the elbow without hand weights was 33.6 degrees and was altered by 9.7 degrees when the hand weights were added. The elbow velocities are different by 107.3 degrees/sec, which was expected based upon the fact that angular velocity is calculated from angular displacement. It was difficult to compare the elbow velocities from this study to normative elbow velocities for walking because arm-swing velocity has not been fully investigated. It seems logical that the velocity of the elbow decreased when an extra load was placed at the distal end of the arm, however, there was no statistical significance although there were observed differences. The arm was weighted and thus unable to move at the same speed it achieved prior to holding the hand weights. In this regard, the body might have been trying to conserve energy by restricting the velocities and range of motion of the arms when the hand weights were carried. For example, in the equation for angular momentum, the moment of inertia increased due to the addition of the 4 pound hand weights the subjects carried. Because angular velocity and moment of inertia are inversely related, the increase in moment of inertia will cause a decrease in the angular velocity. As one part of the equation for angular momentum increases the other will decrease, thus limiting the energy expenditure of the body. This appears to have occurred in this study as hand weights were added.

Shoulder

The angle of the shoulder was calculated by the humerus being relative to the trunk. The mean degree of shoulder flexion was 14.6 degrees while walking without hand weights. Table 6 depicts the shoulder displacements while walking. Once the weights were added the degrees of shoulder flexion changed by 12.1 degrees for a total of 2.5. A 2-way ANOVA with repeated measures was used to determine if the use of hand weights significantly altered the angular displacement of the shoulder while walking. The F value was .56, indicating no statistical significance was found based upon the critical F of 2.46.

Table 6. Shoulder displacements walking (in degrees)

	Flexion		Extension	
	WW	WOW	WW	WOW
Mean	2.5	14.6	-5.1	-16.9
SD	4.2	11.4	9.9	12.0
Max. Value	8.9	39.8	-17.7	-38.3
Min. Value	-.2	1.7	-.4	-5.3

WW = with hand weights WOW = without hand weights
- indicates counter-clockwise direction

Overall, the average angular displacement of the shoulder without hand weights was 31.5 degrees, as illustrated in Table 7.

Table 7. Shoulder kinematics for walking (in degrees)

	With weights	Without weights	F value
A.D.	-7.6	31.5	.56
A.V.	49.0	185.6	1.49

A.D. = Angular displacement A.V. = Angular velocity

Although the angular displacement of the shoulder averaged 31.5 degrees without hand weights, Murray and associates (1970) data indicated normal shoulder range of motion to be 26.0 $\pm$ 2 degrees. Once the hand weights were added, the angular displacement changes by 7.6 degrees. The values found once the hand weights were added still failed to meet Murray and colleagues (1967, 1970) findings for normative shoulder range of motion. Since the angular displacement of the shoulder averaged 31.5 degrees without hand weights, the addition of the 4 pound weight altered the shoulder's range of motion. This alteration, however, was not statistically significant. It is possible for this change to affect other parts of the kinetic chain of the body, however, it was beyond the scope of this study to determine the exact effect. Craik et al. (1976) believed that for every change occurring in the muscles of the upper extremities, the shoulder region would alter its movement pattern to adjust to these changes. If the change is initiated at the shoulder, it could affect other areas of the body.

As portrayed in Table 7, the mean angular velocity of the shoulder while walking without hand weights was 185.6 degrees/sec. The angular velocity decreased to 49.0 degrees/sec when the hand weights were carried by the subjects. The hand weights created an average reduction of 136.6 degrees/sec in the angular velocity of the shoulder for the 10 subjects. As stated previously when using the formula for angular momentum, the moment of inertia increased which contributed to the decrease in angular velocity. The reduction in angular velocity would affect the angular momentum generated by the arms and possibly the angular momentum for the total body.

A 2-way ANOVA with repeated measures was used to test the statistical significance of angular velocity at the shoulder with and without hand weights. The F value was 1.49 indicating no statistical significance. There were observed differences between angular displacement of the shoulder with and without hand weights between subjects while walking and running, however these differences were not significant.

The decrease in total range of motion that occurred over the duration of the distance being covered might be the result of the human body trying to adjust its movement patterns to remain efficient when outside factors such as hand weight are added to the body. This might cause the lower extremities to work harder since the legs may not have the full contributions of the arm swing to assist in the process for productive locomotion. The decreases in range of motion and angular velocity of the arm-swing might actually be the body's attempt to conserve energy to maintain efficient locomotion. For example, the motion lost in the upper extremities must be relinquished in a different area of the body if the body is required to maintain its speed. The total angular momentum that was being generated by the legs and arms in propelling the body forward might be adversely affected because of the reduction in angular velocity of the upper extremity.

Running Data

Elbow

The subjects ran at a 6.0 mile/hour pace without the hand weights. The average amount of elbow flexion was found to be 105.7 degrees. Flexion and extension values are depicted in Table 8.

Table 8. Elbow displacements running (in degrees)

	Flexion		Extension	
	WW	WOW	WW	WOW
Mean	103.8	105.7	114.6	125.5
SD.	10.7	10.8	9.3	14.1
Max. Value	125.9	126.5	132.4	142.2
Min. Value	92.5	87.8	102.4	96.6

WW = with hand weights WOW = without hand weights

The range of motion for running without hand weights was 19.8 degrees (see Table 9). The value changed by 10.8 degrees once the hand weights were included.

Table 9. Elbow kinematics for running (in degrees)

	With weights	Without weights	F value
A.D.	10.7	19.8	2.06
A.V.	105.7	260.8	2.07

A.D. = Angular displacement A.V. = Angular velocity

According to Murray (1967), the normative values for elbow displacement are 30 degrees ± 11, however, Murray's results were based on a walking study with the fastest speed averaging 218 ± 25 cm/sec. Because arm position is different in running than it is in walking, it was difficult to compare the results of this study to Murray's normative data. Hinrichs (1982) found the average range of motion for the elbow was 26.9 ± 6.8 degrees. His results were based on 10 male recreational runners (ranging in age from 20-32 years). The results in this present study are almost within Hinrichs' classification for range of motion values. Although Hinrichs used male subjects in collecting his data, this study used female subjects. A comparison between this study's data and Hinrichs' data was made because of the dearth of literature regarding upper extremity kinematics.

The elbow was flexed 105.7 degrees without hand weights. The 105.7 degrees of elbow flexion assists in maintaining the velocity at which the legs are moving in the horizontal direction. The arms, having less mass than the legs, should have a higher velocity than the legs. The legs have more mass which contributes to their velocity being slower. Increasing or decreasing one part of the equation for angular momentum will affect the overall angular momentum of the object. This balance or canceling out of the both halves of the body, upper and lower, is needed to prevent the center of mass from shifting back and forth. If the center of mass were to shift in such a way, the end product would be wasted energy. When the runners carried the 4 pound hand weights, the mean elbow flexion was 103.8 degrees (see Table 8). This is a change of 1.83 degrees from running without the weights. When the extension of the elbow was calculated for each subject with the hand weights, the mean came to 114.6 degrees. The addition of the weights resulted in a decrease in 10.8 degrees of elbow range of motion (see Table 8). Comparing the range of motion at the elbow while the subjects carried the hand weights to the data found by Hinrichs (1982) suggests that the addition of the hand weights might have contributed to the decrease in the range of motion.

While the average angular displacement of the elbow without the hand weights was 19.8 degrees, the average velocity for this joint was 260.8 degrees/sec. The values for elbow kinematics while running are illustrated in Table 9. The angular velocity of the elbow without hand weights was 260.8 degrees/sec and 105.7 degrees/sec when the hand weights were carried. The addition of hand weights during running resulted in 155.1 degrees/sec reduction in angular velocity for the elbow. Although the observed difference was indicated, there was no statistical significance found for the angular velocity of the elbow.

As shown in Table 9, there were greater angular velocities found in the elbow joint while running without the hand weights when compared to the holding of the hand weights. The body appears to compensate for its restricted range of motion by decreasing the velocity of the arm-swing in an attempt to conserve energy.

A 2-way ANOVA with repeated measures was used to calculate the angular velocity of the elbow between walking and running conditions. The F value for the main effect of speed was 3.96 indicating no statistical significance. There were observed differences found for hand weights versus no hand weights and the interaction between the speed and condition factors, but statistically they were not significant.

Shoulder

Shoulder flexion while running without the hand weights was 10.8 degrees, as illustrated in Table 10. The average amount of motion for the extension phase was -7.5 degrees. The negative number indicates the shoulder extended in the posterior direction, beyond the midline of the subject's body. The average amount of flexion at the shoulder was 36.4 degrees. That is a change of 25.5 degrees compared to the hand weight shoulder flexion values.

Table 10. Shoulder displacements running (in degrees)

	Flexion		Extension	
	WW	WOW	WW	WOW
Mean	36.4	10.8	8.9	-7.5
SD	15.8	14.9	18.3	41.1
Max. Value	53.6	49.4	23.4	55.2
Min. Value	-7.6	-2.2	-43.9	-52.5

WW = with hand weights WOW = without hand weights
- indicates counter-clockwise direction

When analyzing the range of motion for running with no hand weights, the shoulder displacements were 18.3 degrees, which is lower than the 32.0 degrees found by Murray (1967). Murray (1967) investigated walking, therefore the data from this present study cannot accurately be compared to Murray's normative data. Hinrichs (1982) calculated the range of motion at the shoulder to be 45.9 $\pm$ 10.0 degrees. In this present study, the range of motion was 18.3 degrees without the hand weights and 29.5 degrees when the hand weights were used. The average range of motion without hand weights at the shoulder and elbow was 18.3 and 19.8 degrees, respectively. The hand weight values at the shoulder and elbow were 18.3 and 10.8 degrees, respectively. A change in elbow range of motion directly affects the shoulder's range of motion as shown by this comparison.

Gregersen and Lucas (1967) observed that shoulder rotation was greater walking with 10 pound hand weights then by walking without them. This might have occurred from exaggerated movements of the upper trunk via the hand weights in the subject's attempt to stabilize the body. The average extension phase of the shoulder for the 10 subjects was 8.9 degrees without the hand weights versus 15.4 degrees once the hand weights were carried. There was a difference of 15.4 degrees of extension. The shoulders might have assisted with the reduction in movement which occurred in the two segments of the arms in order to keep the body travelling in a forward direction.

A 2-way ANOVA with repeated measures was used to calculate the main effects of walking versus running for angular velocity of the shoulder (see Table 11). The F value was 1.87, which was not statistically significant. There was no statistical difference found for the observed differences between subjects and the condition interaction of hand weights and no hand weights.

Table 11. Shoulder kinematics for running (in degrees)

	With weights	Without weights	F value
A.D.	-27.5	-18.3	.56
A.V.	227.6	398.3	1.49

A.D. = Angular displacement A.V. = Angular velocity

While running without hand weights, the average angular velocity was 398.3 degrees/sec and 227.6 degrees/sec once the hand weights were added. This was a reduction of 170.7 degrees/sec in the angular velocity of the shoulder. The subjects' arm-swing was responsive to mechanical changes that occurred while holding the hand weights. These changes contributed to the change in range of motion and angular velocity of the arms.

A 2-way ANOVA with repeated measures was used to determine the significance between the values for walking versus running on the shoulder range of motion. The F value was 1.87 indicating a lack of statistical significance. To determine the statistical significance for the angular velocity at the elbow joint, a 2-way ANOVA with repeated measures was also used. When comparing the values for angles at the elbow during walking versus running, the F value was 3.96, showing no statistical significance (see Appendix B). There were observed differences found between subjects for walking and running with and without hand weights, but none were significant. The mean angular displacement of the elbow while the subjects walked without hand weights was 33.6 degrees and 23.9 degrees with the hand weights. The F value was 2.06. The mean shoulder angular displacement without hand weights while walking was -31.5 degrees and with hand weights was -7.6 degrees. The F value was .56. Both of the F values found for angular displacement of the shoulder and elbow were not statistically significant.

Discussion

The use of hand weights in either walking or running was found to have no effect on the angular velocity and angular displacement of the elbow and shoulder joints. There was no statistical significance found for the main effects of hand weights versus no hand weights for walking or running. The angular momentum of the arms might be affected by the reduction in the angular velocity of the elbow and shoulder. The decrease in angular velocity in determining angular momentum might have been produced by the increase in the moment of inertia (via the 4 pound hand weights). This consequently may have reduced the values for angular momentum both at the elbow and shoulder when the hand weights were carried, however, angular momentum was not calculated in this study. In addition to the reduction that might be found in the angular momentum, the hand weights might also trigger an increase in muscular tension within the arms and body. The tension created from holding the hand weights could have an effect on blood pressure, causing it to elevate (Abadie 1990; Auble & Schwartz, 1991; Auble et al., 1987; Graves et al., 1987; Makalous et al., 1988; Zarandona et al., 1986).

Table 12. Normative data comparison while walking

	Elbow ROM	Shoulder ROM
Murray (1967)	30.0 ± 8	32 ± 8
Murray et al. (1970)	36.0 ± 2	26 ± 2
Denny (1995) WOW	33.6 ± 8.4	32 ± 23
Denny (1995) WW	23.9 ± 5.2	8 ± 14

WOW = without hand weights WW = with hand weights

Table 12 depicts the normative data for walking identified by Murray (1967) and Murray and colleagues (1970) and the data found in this study. Murray (1967) and Murray et al. (1970) found the elbow travelled through 30-36 degrees range of motion. The values recorded in this study when the subjects walked without hand weights fall within the normative data by Murray (1967) and Murray and associates (1970). Even when the hand weights were added, the range of motion at the elbow remains within the findings by Murray (1967) and Murray and colleagues (1970).

The range of motion at the shoulder while walking is displayed in Table 12. The values of the present study are in agreement with the values found by Murray (1967) and Murray et al.(1970). When the hand weights were carried by the subjects, the range of motion at the shoulder changed by 23.9 degrees. The 7.6 degrees of angular displacement was clearly less than the data recorded by Murray (1967) and Murray et al. (1970).

Running requires the arm to be flexed to approximately a 90 degree angle at the elbow, therefore shortening the arc of the swing that would have been produced if walking. The velocities of the elbow will consequently be greater while running compared to walking. The arms contribute to the locomotion process by counteracting the legs' motion. In an attempt to maintain horizontal movement, the faster the legs move, so too will the arms move at a comparable velocity. Likewise, when the legs are travelling at a walking speed, the arms adjust accordingly to the selected pace of the legs. When hand weights were used by the subjects during the walking and running portions of this study, the velocities at which the elbow travelled through its range of motion were slower than without the hand weights. Overall, the use of the hand weights had affected the upper extremities in contributing to a reduction in angular displacement and angular velocities. The results showed were not statistically significant, therefore the null hypothesis was accepted.

Table 13 shows the range of motion at the elbow and shoulder found in this present study compared to those found by Hinrichs (1982). Hinrichs tested 10 male recreational runners, ages 20-32. Hinrichs' (1982) subjects ran at a slow, medium, and fast speed pace on a motorized treadmill. The degrees shown from that study occurred at the slow speed pace of 5.4 m/sec, which, when calculated, equals a 7 minute per mile pace.

Table 13. Normative data comparison while running

	Elbow ROM	Shoulder ROM
Hinrichs (1982)	26.9 ± 6.8	45.9 ± 10
Denny (1995) WOW	19.8 ± 7.5	18.3 ± 28
Denny (1995) WW	10.8 ± 10.0	45.3 ± 18

WOW = without hand weights WW = with hand weights

The values from this present study were from 10 trained female subjects who ran at a 10 minute per mile pace. When the subjects ran without hand weights, elbow range of motion was just slightly lower than the values found by Hinrichs (1982). When the hand weights were added, the range of motion at the elbow decreased by 9.0 degrees, yielding a value of 10.8 degrees. Hinrichs (1982) found the shoulder averaged 45.9 degrees of displacement while running at a 7 minute per mile pace. The range of motion values identified in this present study were just 18.3 degrees without hand weights. When the hand weights were added, the range of motion increased to almost identical values as those found by Hinrichs (1982). The shoulder range of motion increased to accommodate the decrease in elbow range of motion. This observation is supported by Craik et al. (1976), who found that the shoulder may change its movement pattern with changes occurring in the upper limb.

Although Auble and Schwartz (1991) indicated an increase in VO_2 while their subjects ran with 2 pound hand weights, the increase occurred when the hands were pumped to shoulder height. It might be possible that extra energy is needed to swing the arms at the same velocity with the hand weights, contributing to the increase in VO_2. The limited movements taking place in the arm swing might be difficult to achieve for a population who has not previously been weight training and/or running, which was reflected by the use of trained female subjects. These subjects, in addition to their running regimen, were conditioning their bodies by lifting weights, thus enhancing their strength and muscle endurance.

The means of each subjects' angular displacement and velocity values were entered into a statistical program and in doing so, it might have been possible that their individual difference were negated in the process. The decrease in the velocities of the flexion and extension phases when the hand weights were used might result in a greater reduction in an untrained population. The use of hand weights while walking and running had no statistical significance on upper extremity kinematics.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the biomechanical effects hand weights might have upon shoulder and elbow displacements and velocities while walking and running. Although there have been previous studies conducted which identified the physiological effects with the use of hand weights, (Auble & Schwartz, 1991; Auble et al., 1987; Claremont & Hall, 1988; Makalous et al., 1988; Zarandona et al., 1986) few investigations have focused on the biomechanical consequences involving female subjects.

Ten trained female collegiate track runners volunteered for this study. Each subject was videotaped walking and running with reflective markers placed on 14 anatomical landmarks. The videotape recorded the subjects walking at 3.0 mph and running at 6.0 mph with and without hand weights. The videotape was then used to create a 2-dimensional image via the digitization process through the ARIEL (APAS) system. Shoulder and elbow displacements of flexion and extension and the velocity of these joints were then calculated and entered into a basic statistic program where $p = < .05$.

It was found during this study that the use of hand weights reduced the flexion and extension phases of the elbow and shoulder joint that are involved in walking and running, as well as reducing the velocity of the arm-swing. Ten trained female subjects have been shown to have alterations occur on their normal upper extremity motion to compensate for the reduction in range of motion while walking and running with hand weights.

Conclusions

Although there might be certain physiological benefits to an exercise program that involves the use of hand weights, (Auble & Schwartz, 1991; Auble et al., 1987; Claremont & Hall, 1988; Makalous et al., 1988) the alterations created within the body to accommodate the hand weights might simply negate whatever benefits that were to originally occur. An exercise activity, such as walking or running, whose outcome contributes to cardiorespiratory benefits, should be performed with efficient locomotion techniques. Adding hand weights to the activity might result in altered mechanics which would clash with the efficiency of the intended activity.

Stress and burdens placed upon the body will signal the need for adjustments necessary for changes that may take place within the body under these circumstances. No matter what the stress may be, the body makes every effort possible to rectify the situation by creating alterations within its system. These alterations may include the adjustments for flexion and extension in the upper extremities when the body is asked to carry extra weight. The natural rhythm of the arm-swing might be affected as well. The extra weight may prohibit the full range of motion occurring in these extremities as a way of maintaining the body's horizontal velocity travelling in a linear direction. All of these changes in one body segment will affect other segments. As a result, the kinetic chain of the body will have produced a weak link, thus the mechanical efficiency for locomotion will be diminished.

Recommendations

1. As this study involved female trained athletes, one might focus on the same conditions with untrained female and/or male subjects to identify if similar findings would result. Such a study would be useful to the majority of the population who are currently untrained and in want of an exercise regimen, but unsure of the risks or benefits derived from the use of hand weights.
2. Centering more on the whole population, a future research project could utilize both sexes and various age groups to determine if there would be differences found and if so, of the same magnitude

with men and women of all ages. This could provide insight into the approximate age that certain mechanical changes might be more pronounced while exercising with hand weights. Individuals participating in such a study should be advised that the use of hand weights might increase blood pressure due to the static grip of the implement.

3. Varying the speed at which the activity is administered might identify different situations where the mechanical changes would occur. Elevation could also be manipulated. Changing speeds and elevations would require the body to adjust accordingly, thus producing different results.
4. Creating a 3-dimensional study to identify the angular momentum of the upper and lower body would enable the investigator to view all angles of movement that would occur. The 3-D model can then be rotated to observe all angles as well as putting a trace on the center of gravity for each subjects to determine its movement patterns. Knowing that the angular velocity decreased when the hand weights were used might help in determining what the angular momentum values would be.
5. Using anthropometric measurements and angular momentum of the upper and lower body might identify

if there is a correlation between the two. Certain body dimensions might affect the way in which we travel through space, especially for the different measurements found between the sexes. Men in general have larger body segments and proportions then women. Determining these differences might assist in identifying if there is a correlation between body measurements and mechanical processing of the body for locomotion. Using the anthropometric measurements could help identify this possibility.

6. Using lighter or heavier hand weights could also be another variable manipulated. Varying the weight of the implement might show at what pound the mechanical changes are more likely to occur and to what extent.

REFERENCES

Abadie, B.R. (1990). Physiological responses to grade walking with wrist and hand-held weights. Research Quarterly, 49, 197-205.

Ariel Dynamics, Inc., 7887 Dunbrook Rd. Ste. B San Diego, CA 92126

Auble, T.E., & Schwartz, L. (1991). Physiological effects of exercise with handweights. Sportsmedicine, 11,(4), 244-256.

Auble, T.E., Schwartz, L., & Robertson, R.J. (1987). Aerobic requirements for moving handweights through various ranges of motion while walking. Physician and Sportsmedicine, 15, 133-140.

Ballesteros, M.L., Buchthal, F., & Rosenfalck, P. (1965). The pattern of muscular activity during the arm swing of natural walking. Acta. Physiol. Scand., 63, 296-310.

Cavanagh, P.R., & Hinrichs, R.N. (1980). On the nature of arm action in running. Runner's World, 15,(4), 53-57.

Chapman, M.W., & Kurokawa, K.M. (1969). Some observations on the transverse rotations of the human trunk during locomotion. Bulletin of Prothetics Research, Spring, 38-59.

Claremont, A.D., & Hall, S.J. (1988). Effects of extremity loading upon energy expenditure and running mechanics. Medicine and Science in Sports and Exercise, 20, 167-171.

Craik, R., Herman, R., & Finley, F.R. (1976). Human solutions for locomotion: Interlimb coordinations. Neural control of locomotion (Ed.) Herman, R.M., Grillner, S., Stein, P.G., and Stuart, D.B. pp 51-64. New York: Plenum Press.

Elftman, H. (1939). The function of the arms in walking. Human Biology,11, 529-535.

Figura, F., Marchetti, M., & Leo, T. (1985). Kinematics of female upper body during ambulation at various speeds. In D.A. Winter (Ed.), Biomechanics IX-A, 457-461. Champaign, IL.: Human Kinetics.

Graves, J.E., Pollack, M.L., Montain, S.J., & O'Keefe, J.M. (1987). The effect of hand-held weights on the physiological responses to walking exercise. Medicine and Science in Sports and Exercise, 19, 260-265.

Gregersen, G.G. & Lucas, D.B. (1967). Axial rotation of the human thoracolumbar spine. Journal of Bone and Joint Surgery, 49-A, 247-262.

Hinrichs, R.N. (1982). Upper extremity functioning in running. Dissertation Abstracts International, 43, 3536A. (University Microfilm No. 83-05648).

Hinrichs, R.N. (1987). Upper extremity function in running. II: Angular momentum considerations. International Journal of Sport Biomechanics, 3, 242-263.

Hinrichs, R.N., Cavanagh, P.R., & Williams, K.R. (1987). Upper extremity function in running. I: Center of mass and propulsion considerations. International Journal of Sport Biomechanics, 3, 222-241.

Hogue, R.E. (1969). Upper-extremity muscular activity at different cadences and inclines during normal gait. Physical Therapy, 49, 963-972.

Hopper, B.J. (1964). The mechanics of arm action in running. Track Technique, 17, 520-522.

Leivenberg, R. (1987, February/March). The weight debate. The Walking Magazine, 35-45.

Makalous, S.L., Araujo, J., & Thomas, T.R. (1988). Energy expenditure during walking with hand weights. Physician and Sportsmedicine, 16, (4), 139-148.

Morris, J.N. (1994). Exercise in the prevention of coronary heart disease: Today's best buy in public health. Medicine and Science in Sports and Exercise, 26, 807-814.

Murray, M.P. (1967). Gait as a total pattern of movement. American Journal of Physical Medicine, 46, 290-333.

Murray, M.P., Kory, R.C., & Sepic, S.B. (1970). Walking patterns of normal women. Archives of Physical Medicine and Rehabilitation, 637-650.

Murray, M.P., Sepic, S.B., Barnard, B.S. and E.J. (1967). Patterns of sagittal rotation of the upper limbs in walking. Physical Therapy, 47, 272-283.

Wang, M.Q. Statistical programs. Exercise and Sport Research Institute. Arizona State University.

Wood, G.A. (1982). Data smoothing and differentiation procedures in biomechanics. Exercise and Sport Sciences Reviews, 10, 308-362.

Zarandona, J.E., Nelson, A.G., Conlee, R.K., & Fisher, A.G. (1986). Physiological responses to hand-carried weights. Physician and Sportsmedicine, 14,(10), 113-120.

APPENDIX A

INFORMED CONSENT FORM

INFORMED CONSENT FORM

Title of Proposed Project: A biomechanical analysis of the effects of hand weights on the arm-swing while walking and running.

Principle Investigator: Karen L. Denny

I, ________________, agree to undergo the following procedures and understand that at any time my allowance to withdraw from the program is acceptable. I will be instructed to run and/or walk on a Quinton 1860 motorized treadmill both with and without the use of hand weights. I will run for a total of 14 minutes (seven minutes over a two-day testing period) at 6.0 mph and 0% grade. I will have reflective markers placed on various bony landmarks of my body to highlight the necessary joints. I will be given a practice session to familiarize myself with the treadmill and the hand weights.

I have read the above document and am satisfied with the explanation of the procedures as explained to me by the principle investigator. I understand I may experience dizziness, muscle soreness, and shortness of breath. I realize I may fall on the treadmill and understand there are hand rails to balance and stabilize myself, should the need arise. I understand what is expected of me and voluntarily assume any risks or complications by being involved with this study.

I hereby acknowledge that no representations, warranties, guarantees, or assurances of any kind pertaining to the procedure have been made to me by the University of Wisconsin-La Crosse, the officers, administration, employees, or by anyone acting on behalf of them. For confidentiality purposes, each subject will be given an identification number to record data, rather than using the subject's name.

Signed at _____________ this _________ day of ___________, 19____, in the presence of the witnesses whose signatures appear below opposite my signature.

WITNESSED BY:

____
Subject Signature Date

____
Signature Date

____
Signature Date

APPENDIX B

F VALUES FOR ANGULAR DISPLACEMENTS AND VELOCITIES

F Values for Angular Displacements

	WW/WOW	WK/R	S/C
Elbow	2.06	4.03	.96
Shoulder	.56	1.72	1.06

WW/WOW = With and without hand weights

WK/R = Walking and running

S/C = Speed and condition interaction

F Values for Angular Velocities

	WW/WOW	WK/R	S/C
Elbow	2.07	3.96	.99
Shoulder	1.49	1.87	1.55

WW/WOW = With and without hand weights

WK/R = Walking and running

S/C = Speed and condition interaction

APPENDIX C

SUBJECT DATA SUMMARY

Elbow Data Summary
Walking without hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	144.1	183.5	39.4	242.7
2	159.8	187.7	27.9	333.4
3	144.9	190.0	46.0	336.4
4	144.9	175.9	31.0	216.9
5	145.8	185.1	39.3	266.3
6	154.2	170.6	16.4	102.1
7	147.2	180.2	33.0	199.6
8	150.2	176.9	26.7	204.6
9	139.8	183.8	44.0	286.7
10	149.3	181.6	32.3	238.3
Mean	148.0	181.6	33.6	242.7
S.D.	5.4	5.6	8.4	65.8

Elbow Data Summary
Walking with hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	156.8	180.6	23.8	179.7
2	161.2	184.9	23.7	136.8
3	152.9	181.0	28.1	172.4
4	153.6	181.1	27.5	148.2
5	156.2	188.9	32.7	132.4
6	158.7	177.4	18.7	111.5
7	161.1	185.0	23.9	116.7
8	149.6	166.4	16.8	98.4
9	155.6	183.1	27.5	155.9
10	160.6	176.1	15.5	88.5
Mean	156.6	180.5	23.9	134.1
S.D.	3.7	5.9	5.2	28.9

Elbow Data Summary
Running without hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	105.7	125.4	19.7	194.4
2	97.3	111.4	14.1	260.9
3	97.0	114.0	17.0	250.7
4	101.3	134.0	32.7	386.9
5	113.5	134.4	20.9	302.7
6	114.8	131.4	16.6	223.6
7	87.8	96.6	8.8	120.3
8	104.9	126.9	22.0	294.2
9	107.9	142.2	34.9	386.2
10	126.5	138.1	11.6	188.5
Mean	105.7	125.4	19.8	260.8
S.D.	10.8	14.1	7.9	80.8

Elbow Data Summary
Running with hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	112.3	123.1	10.8	157.3
2	92.9	115.3	22.4	213.0
3	94.4	106.3	11.9	101.2
4	92.5	103.6	11.1	117.7
5	106.9	117.1	10.2	85.3
6	93.9	102.4	8.5	96.0
7	101.6	115.7	14.1	100.5
8	102.2	107.3	4.7	65.5
9	125.9	132.4	6.5	59.1
10	115.6	122.7	7.1	61.5
Mean	103.8	114.6	10.7	105.7
S.D.	10.7	9.3	4.7	45.8

Shoulder Data Summary
Walking without hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang.Vel. $\bar{X}$
1	39.8	-38.3	-1.5	535.4
2	24.0	-17.3	-41.3	244.7
3	1.9	-10.1	-12.0	96.9
4	22.5	-20.3	-42.8	257.4
5	5.2	-5.3	-10.5	39.7
6	5.5	11.4	16.9	79.0
7	15.9	-13.7	-29.6	146.1
8	16.3	-20.8	37.1	200.3
9	1.7	-12.8	-14.5	74.5
10	13.4	-18.9	-32.3	182.2
Mean	14.6	-16.9	-13.1	185.6
S.D.	11.4	12.0	24.3	136.3

Shoulder Data Summary
Walking with hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	-.4	-17.7	-17.3	120.0
2	6.5	-5.8	-12.3	63.3
3	6.8	7.4	.6	10.7
4	.7	-17.5	-18.2	97.2
5	3.5	2.8	-.7	6.8
6	8.9	4.3	-4.6	14.1
7	-.2	-.4	-.6	15.7
8	-6.0	-17.1	-11.1	75.9
9	4.9	6.2	1.3	4.6
10	.2	-12.7	-12.9	81.8
Mean	2.5	-5.1	-7.5	49.0
S.D.	4.2	9.9	7.2	41.1

Shoulder Data Summary
Running without hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	11.4	39.3	27.9	398.3
2	49.4	-3.2	-52.6	443.3
3	8.4	55.2	46.8	401.5
4	20.9	-44.7	-65.6	461.7
5	7.5	-37.1	-44.6	404.0
6	2.7	-34.6	-37.3	318.0
7	5.3	41.4	36.1	301.1
8	4.6	-52.5	-57.1	492.4
9	2.2	46.1	43.9	423.2
10	1.2	-38.8	-40.0	339.4
Mean	10.8	-7.5	-14.3	39[illegible].3
S.D.	14.9	41.1	44.1	59.1

Shoulder Data Summary
Running with hand weights

Subject	Flex $\bar{X}$	Ext $\bar{X}$	ROM	Ang. Vel. $\bar{X}$
1	53.6	11.2	-42.4	338.2
2	41.5	9.4	32.1	266.9
3	44.7	23.6	-21.1	192.1
4	-7.6	-43.9	-36.3	278.9
5	40.1	14.1	-26.0	240.6
6	44.9	13.4	-31.5	261.5
7	34.4	9.6	-24.8	185.4
8	44.2	23.4	-20.8	172.4
9	31.7	15.8	-15.9	155.0
10	36.7	13.1	-23.6	185.2
Mean	36.4	8.9	-21.0	227.6
S.D.	15.8	18.3	19.2	55.6