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TITLE: THE DIFFERENCE IN HEART RATE AND RATING OF PERCEIVED EXERTION AT DIFFERENT INTENSITIES OF LAND-BASED RUNNING AND WATER-BASED RUNNING

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The purpose of this study was to determine if a difference exists in heart rate and rating of perceived exertion (RPE) at different intensities among treadmill running, deep water running with floatation, and deep water running without floatation. Subjects for this study were 14 volunteers, 8 male and 6 female, ranging in age from 18 to 28 years of age. Each subject participated in three testing conditions, including treadmill running, deep water running with floatation, and deep water running without floatation. Subjects were tested 70%, 80%, 90%, and 100% of maximum heart rate for each of these three conditions. All data were analyzed at the $p < .05$ level of significance through the use of a repeated measures analysis of variance. A significant difference in heart rate was found for all workloads tested. A significant difference in RPE was found for 70%, 80%, and 90% of maximum heart rate. Simple linear regression was used to develop two preliminary equations for

the purpose of predicting water-based (with and without floatation) maximum heart rates given the known land-based maximum heart rate.

THE DIFFERENCE IN HEART RATE AND RATING OF PERCEIVED EXERTION AT DIFFERENT INTENSITIES OF LAND-BASED RUNNING AND WATER-BASED RUNNING

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CHAPTER I
INTRODUCTION

Physical fitness continues to grow in popularity across the United States. A popular physical fitness activity, running is no longer limited to members of track and field and cross country teams. More and more Americans are discovering the benefits and enjoyment that come from running. Reasons for running vary from individual to individual. Some runners want to maintain their fitness levels. Others have a desire to compete in such events as road races and track meets. Some simply enjoy the feeling they get from running.

Most running workouts are performed on hard surfaces. This constant pounding on hard surfaces can lead to numerous injuries. Most of these injuries are a result of overuse (Marti, Vader, Minder, & Abelin, 1988). One treatment for these running-related injuries is to decrease or to discontinue running for four to six weeks (Arnheim, 1985; Francis, 1982). However, this could lead to significant loss in cardiovascular fitness. Many runners seek alternative modes of exercise in order to avoid loss of cardiovascular fitness. Water running is one of these alternative forms of training. Other forms include activities such as cycling and swimming.

What is water running? In simplest terms, water running is simulating a running motion in water. Water running may or may not include the use of a floatation device. Water running may be done in shallow water or in deep water. In shallow water running, the feet come in contact with the floor of the pool. The entire body from neck down may or may not be submerged. In deep water running, the feet do not come into contact with the floor of the pool; a person is somewhat suspended in water from the neck down while simulating a running motion. This study is only concerned with deep water running. Therefore, throughout this paper, water running and deep water running will be used interchangeably.

The medium of water has become increasingly popular in physical rehabilitation (Svedenhag & Seger, 1992). Due to the development of such devices as the Wet Vest (Bioenergetics, Inc., Pelham, AL) and the Aqua Jogger (Excel Sport Science, Eugene, Oregon), water running has become a viable training alternative for injured runners and for those individuals wanting to supplement their normal training programs (Perry, 1986; Williams, 1987).

Water running is a relatively new concept and is quickly growing in popularity. Because it is a non-weight-bearing activity, it reduces stress to the joints while maintaining neuromuscular specificity (Butts, Tucker, & Smith, 1991). Water running enables an injured runner to continue an activity specific to running without the possible harmful effects of weightbearing work (Eyestone, Fellingham, George, & Fisher, 1993). Since water running is a low injury-risk sport, it allows injured athletes to recuperate without suffering a significant loss of cardiovascular fitness.

The physiological benefits that occur with water running are similar to those that occur from land-based running. However, a person exercising in water is able to exercise at a lower heart rate than someone doing a similar workout on land. This effect is due to the hydrostatic pressure and the cooling effects of water. Hydrostatic pressure alters cardiorespiratory dynamics allowing the heart to function more efficiently with higher stroke volumes and lower heart rates (Butts, Tucker, & Smith, 1991). Also, the normally cool temperatures of water versus the normally warmer temperatures on land do not require the heart to work as hard to keep the body cool. Since it is not necessary to use as much blood to keep the body cool in water, the blood can be used more efficiently by the body during water exercise.

Regardless of fitness levels, water running can help to maintain an injured athlete's training level (Eyestone et al., 1993). However, the benefit of running in water is not limited to injured persons. Water running can also be used by runners as a psychological break from land training, as a break from the pounding on hard surfaces, as a recovery workout after an intense workout, as a rest phase between seasons, or as an indoor option to inclement weather (Eyestone et al., 1993).

All well-planned exercise programs consist of four basic fitness components: intensity, duration, frequency, and mode of activity. When water running is used as a supplement to land running, it is important that the first three components (intensity, duration, and frequency) are performed at a level equivalent to land running. By maintaining an equivalent workout, runners will be able maintain their running performances (Eyestone et al., 1993). Studies have been completed on the physiological comparison of land-based running to water-based running. But, more research is needed in the area of determining equivalent intensity levels for land-based running and for water-based running.

Statement of the Problem

Over 25 million American adults run or jog regularly (Brody, Knoecke, & Day, 1981). Running and jogging are similar activities. However, the term jogging implies a slower pace than does the term running. Many runners (and joggers) will incur a running-related injury (Eyestone et al., 1993). Many of these injuries are related to overuse (Marti et al., 1988). While injured, these runners have the choice of either inactivity or seeking an alternate mode of training. Seeking an alternate mode of training would perhaps be the most appealing choice, because inactivity can lead to a loss of cardiovascular fitness. One of the newest alternative training methods to running on land is deep water running. Water running provides a safe alternative for injured runners, allowing them to maintain cardiovascular fitness without causing further injury.

Studies have been done regarding the physiological responses to deep water running for submaximal and for maximal levels (Gehring, Keller, & Brehm, 1992; Butts, Tucker, & Greening, 1991; Svedenhag & Seger, 1992). These studies indicated that water running does maintain fitness levels and that water running is a viable option to land running. However, very little research has been done on the comparability of workloads on land and in water. For example, if a person were to run two miles on land at a six minute mile pace (12 minutes total) with a heart rate of 150 beats per minute, what heart rate would this person need to maintain for twelve minutes of deep water running in order to complete a comparable workout?

Due to the lack of information on comparable workloads, prescribing water workouts that simulate land workouts can be difficult. Using land-determined maximal heart rates to prescribe water training intensities could be dangerous to a person's cardiovascular system (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991). The reason for this caution relates to the hydrostatic pressures and cooling effects of water.

Purpose

The purpose of this study was to determine if a difference exists in heart rate and rating of perceived exertion at different intensities among treadmill running, deep water running with floatation, and deep water running without floatation in order to determine comparable workloads for land-based running and water-based running.

Statement of the Hypothesis

1. There is a significant difference in heart rate at comparable workloads (70%, 80%, 90%, and 100% of maximum heart rate) among treadmill running, deep water running with floatation, and deep water running without floatation.
2. There is a significant difference in rating of perceived exertion at comparable workloads (70%, 80%, 90% and 100% of maximum heart rate) among treadmill running, deep water running with floatation, and deep water running without floatation.

Statement of Significance

Many injured runners are often required to decrease or to discontinue exercise. These runners often become concerned that this decrease in exercise will cause a loss in fitness. Many attempt to find an alternate mode of training in order to avoid this loss. Water is an invaluable resource to fitness and provides a safe alternative to land training.

It has been suggested that approximately one half to one third of the speed required to exercise on land is needed to work at the same metabolic intensity in water (Evans, Cureton, & Purvis, 1978). However, no specific recommendations have been made as to exercise intensities in water that simulate a comparable land workout. Water offers passive resistance (De Varona & Tarshis, 1984) which reduces the stress normally placed on joints and muscles during training on hard surfaces. This characteristic of water allows those suffering from a running-related injury to continue running.

Because water training provides a safe alternative to land training, information regarding comparable workloads for land and for water is valuable. Information on comparable workloads will allow injured athletes or those individuals wishing to take a break from their normal running routine to train more effectively in water. At this time, information on comparable workouts is limited, and "prescribing water training intensities based on land-determined heart rates could result in higher stress on the cardiovascular system than intended (Butts, Tucker, & Smith, 1991, p. 238)." Information is needed on comparable workloads to ensure safe and effective workouts in water. Results of this study may be beneficial to those persons prescribing water workouts in lieu of land workouts making water running an even more effective alternative to land running.

Limitations of the Study

1. Subjects for this study were volunteers.

2. Although subjects participated in practice sessions prior to testing, ability to run on a treadmill and in water differed from subject to subject.

3. Fatigue level prior to a testing session could have had some effect on subject motivation and on the physiological results during the testing. Subjects were asked to refrain from any exercise at least two hours prior to testing and from any maximal exercise at least one day prior to testing.

Delimitations of the Study

Originally, 17 subjects started the study. However, due to personal and/or medical reasons, 3 female subjects dropped out of the study. Therefore, data analysis for the study was based upon the performances of 14 subjects, 8 male and 6 female. All subjects, except one, were students enrolled at Emporia State University in the Spring 1994 semester. All subjects were physically active, engaging in at least 16 to 30 minutes of physical activity within the aerobic target zone at least three days per week. The age range of the subjects was 18 to 28 years of age. The average age was 22.8 years.

Assumptions of the Study

1. All subjects were motivated to give their best effort during maximal and submaximal testing sessions.
2. All subjects refrained from eating, drinking, smoking, and exercising at least two hours prior to testing. Subjects were also asked to refrain from any maximal activity at least one day prior to testing.
3. The results of this study will generalize to males and females ranging from 18 to 28 years of age.

Definition of Terms

Aqua Jogger (Excel Sport Science, Eugene, Oregon): The Aqua Jogger is a floatation device designed for the purpose of water running.

Buoyancy: Buoyancy is the quality of floating in water.

Carbon dioxide expired ($\dot{V}CO_2$): $\dot{V}CO_2$ is the volume of carbon dioxide expired in one minute.

Cardiac output: Cardiac output is the amount of blood pumped by the heart in one minute and is equivalent to heart rate times stroke volume.

Deep water running: Deep water running is simulating a running motion in deep water.

Duration: Duration refers to the length of time an exercise is performed.

Frequency: Frequency refers to the number of times an exercise is performed, i. e. per week, per exercise session.

Hydrostatic pressure: Hydrostatic pressure is pressure placed on the body by water during immersion. Hydrostatic pressure increases uniformly with water depth.

Hydrostatic (underwater) weighing: This is a method of assessing body-fat composition by comparing body weight in air to body weight while submerged in water.

Intensity: Intensity refers to how hard a person performs an exercise. Intensity may be determined by heart rate and/or oxygen uptake.

Maximal: Maximal refers to exercise that continues to exhaustion or until maximum physiological values are obtained.

Maximal oxygen uptake (max $\dot{V}O_2$): Max $\dot{V}O_2$ is the maximal rate at which oxygen can be consumed per minute.

Rating perceived exertion (RPE): RPE is a method of rating exercise intensity through an individual's perception of his/her level of exertion.

Residual volume: RV is the volume of air remaining in the lungs following a maximal expiration.

Respiratory exchange ratio (R): R is the ratio of carbon dioxide production to oxygen consumption.

Spirometer: The spirometer is a device used to measure lung volumes, i.e., vital capacity and residual volume.

Stroke volume: SV is the amount of blood pumped by the left ventricle of the heart with each beat.

Submaximal: Submaximal refers to exercise intensity below maximal.

Ventilation ($\dot{V}E$): $\dot{V}E$ is the rate of expiration.

Vital capacity (VC): VC is the maximal volume of air that can be forcefully expired after a maximal inspiration.

Workload: For this study, the term workload will refer to intensity of the exercise.

Summary

The purpose of this study was to determine the difference in heart rate and rating of perceived exertion at different intensities among treadmill running and two conditions of deep water running in order to determine comparable workloads for land-based training and water-based training. Information on this aforementioned topic is needed in order to more effectively use water training as an option to land training. It is hypothesized that there will be a significant difference between heart rate and rating of perceived exertion at the comparable workloads of the two types of training. The results of this study may be particularly valuable to those persons (coaches, athletic trainers, physical therapists, etc.) prescribing water running workouts as a supplement to a land training program.

In the remaining chapters of this paper, several topics regarding this study will be discussed. In Chapter Two, Review of Literature, research related to water and land based running will be examined. Chapter Three, Methodology, contains a discussion of all methods and procedures used in this study. Chapter Four, Analysis of Data, and Chapter Five, Discussion and Recommendations, will be the final two chapters.

CHAPTER II
REVIEW OF LITERATURE

The purpose of this study was to determine if a difference exists in heart rate and rating of perceived exertion at different intensities among treadmill running and two conditions of deep water running in order to determine comparable workloads for the two types of training. The medium of water provides a safe training alternative to land-based workouts. However, no specific recommendations exist regarding the prescription of deep water running workouts that simulate comparable land-based workouts. This chapter will discuss several factors involved in land-based running and water-based running. The factors to be discussed include running and running related injuries, deep water running, properties of water exercise, and physiology of water exercise versus physiology of land-based exercise.

Running and Running Related Injuries

An estimated 30 million Americans run for exercise (Cavanagh, 1990). Along with the increasing number of runners, has come an increase in the number of running related injuries. This section focuses on the characteristics of running and the injuries related to running.

There are two types of running events: anaerobic (without oxygen) events, such as sprints, and aerobic (with oxygen) events, such as distance running. Both types of running events utilize the same basic running biomechanic

(Ecker, 1985).

The action of the legs in running follows a cyclic pattern and consists of three phases: the driving phase, the recovery phase, and the braking phase (Ecker, 1985). Some sources refer to the braking phase as the supporting phase (Hay, 1993). During the driving phase, the body is pushed forward by an extension of the hip, knee, and ankle joints of the driving leg. The driving phase ends when the driving foot leaves the ground. The recovery phase begins at this point. During the recovery phase, both feet are in the air as the driving foot leaves the ground behind the body's center of gravity and begins to move forward. The braking, or supporting, phase begins when the foot opposite the driving foot touches the ground. The body moves forward until the center of gravity has moved ahead of the foot in contact with the ground. The next driving phase begins at this point (Ecker, 1985; Hay, 1993).

Most individuals will have a slight forward lean of the trunk while running. The degree of the lean is determined by the runner's acceleration, i.e., the greater the acceleration, the greater the lean. Therefore, sprinters tend to have a greater forward lean than do distance runners (Ecker, 1985). During running, the arms are flexed at the elbow at about 90 degrees. Hands are lightly clenched in a fist-type fashion. The forward limit of the hands is about shoulder height. The backward limit of the hand is at the hip or slightly behind the hip (Hay, 1993). Arm actions during running are the reverse of leg actions during running. Thus, when the left leg drives forward and upward, the right arm drives forward and upward and when the right leg drives forward and upward, the left arm drives forward and upward (Hay, 1993).

As with all forms of land-based activity, running presents a challenge to the soft tissue and joints. The repetitive stress imposed by the ground strike can lead to injury (Green, Cable, & Elms, 1990). Many of these injuries are overuse injuries or injuries related to training design (Croce & Gregg, 1991; James & Jones, 1990).

Marti, Vader, Minder, & Abelin (1988) examined the running injuries of 4,358 males involved in a ten mile running event. These males were given a survey on which they were to classify their running injuries for the twelve months preceding the race. The results of the study indicated that the most frequently injured sites were the foot, ankle, and knee (85.6% of all injuries). The most common types of injuries were stress and overuse injuries (over 70%). Acute traumatic injuries made up for 27% of all injuries. Lateral ankle sprains were the most commonly experienced acute injury. The results of this study indicated that runners with a previous history of running injuries had an increased risk (74%) of sustaining another injury. This finding suggested that unfavorable structural and biomechanical characteristics may play a possible role in the occurrence of running injuries. Weekly mileage was also shown to have a positive correlation with the occurrence of running injuries. For example, those runners covering over twenty kilometers a week had a 50% increased risk of developing a jogging injury. A significant correlation was also found between running injury occurrence and competitive training motives. Age did not appear to be a significant factor in the development of running injuries. However, with the increasing age of race contestants, the number of running injuries decreased, but the duration of the training interruption per injury increased. Older race contestants experienced fewer running injuries than younger race contestants, but recovery time for the older runners was longer than the recovery time for the younger runners. Other variables such as excessive weight and training surface showed a small but statistically insignificant relationship to running injuries. It should be noted that one out of every five runners surveyed had been forced to interrupt his training at some point during the preceding twelve months.

James and Jones (1990) believed that training errors were the most predominant factor in the development in running injuries. Runners who make training errors are individuals who make rapid changes in their programs and do not allow the body an appropriate amount of time to accommodate for these changes. These rapid changes in training programs include such factors as a sudden increase in mileage or in intensity.

Deep Water Running

Deep water running simulates a running motion in deep water. One of the main problems many people experience when attempting to deep water run is maintaining correct running form in water (Bishop, Frazier, Smith, & Jacobs, 1989; Williams, 1987). Often, water runners have problems maintaining an upright position. Some water runners will have a tendency to bend forward at the waist and allow themselves to float. Others will "dogpaddle" with the arms or "bicycle" with the legs (Williams, 1987). This altered running technique in water could be the result of the lack of a support phase in water running (Svedenhag & Seger, 1992).

To run correctly in water, an individual must imagine his/her normal running gait on land. Water runners should maintain an upright position to help reduce low back tension and to strengthen the abdominal muscles. Arms, bent at approximately 90 degrees, need to drive through the water to the front then extend back. Hands should be relaxed. For the lower body, knees should come up in front of the body at about a 45 degree angle. Legs should extend to allow the heel to plant first. Ankles should plantar flex so that the runner can "push" with the toes as the leg drives back while the opposite leg moves forward to begin the next cycle. Legs should drive forward rather than upward (Williams, 1987).

In deep water running, water resistance tends to slow stride frequency. This slowness may cause sprinters to run more slowly during water workouts. Prescription of water workouts for sprinters should be carefully made. During water workouts, sprinters should, if possible, run at near maximal speed and should not run steadily in water for prolonged periods (Running Research, 1993).

Properties of Water Exercise

Hydrotherapy, a form of rehabilitation, was one of the earliest forms of water exercise. In fact, a form of water healing was used by Hippocrates (Duffield, 1969). Today, water exercise continues to grow in popularity, serving a variety of purposes, including recreation and rehabilitation. Water-based exercises may have some advantages over land-based exercises (Krasevec, 1989). These advantages include a perception of feeling lighter, more relaxed, and less awkward. Unlike many land-based activities, water exercise can be performed by all ages and fitness levels (Krasevec, 1989).

To obtain the benefits of exercising in water, it is important to understand the properties of water. These properties include buoyancy, resistance, water temperature, and hydrostatic pressure. Each property will be discussed separately.

Buoyancy is the quality of floating in water. Water's buoyancy makes the submerged portion of the body 90% lighter than on land (Krasevec, 1989). It is buoyancy that allows water to be a non-weight-bearing medium, which reduces the stress and the impact normally encountered during land-based activities.

Water resists movement as objects move through it. This resistance is often called drag (Costill, Maglishco, & Richardson, 1992). Drag forces the muscles to work harder to move the limbs through the water. The harder a person pushes against the water or the quicker one moves in the water, the greater the resistance (Croce & Gregg, 1991). Water resistance can provide a challenge for cardiovascular fitness, muscular strength, and muscular endurance activities (Krasevec, 1989). The dual effects of buoyancy and resistance make possible high levels of energy expenditure with relatively little movement or strain on lower extremity joints (Eckerson & Anderson, 1992).

The coolness of water often makes water exercise more attractive than land exercise. The coolness of water may be one of the factors that causes individuals to have a lower maximal heart rate when compared to those tested during land-based exercise (Krasevec, 1989). Studies have shown that in a warm pool (approximately 33°C), heart rates for water exercise will be similar to those for land exercise. However, in cooler water (approximately 25°C), heart rates for water exercise will be lower than those for land-based exercise (Running Research, 1993). As water temperature increases or decreases, heart rate correspondingly increases or decreases (Butts, Tucker, & Smith, 1991).

Costill, Cahill, and Eddy (1967) examined the metabolic responses to submaximal swimming in water temperatures of 17.4°C, 26.8°C, and 33.1°C. Eight male proficient swimmers were used as subjects. Results of the study indicated that the subjects ventilated more air in 17.4°C and 33.1°C water and heart rate during recovery was greatest in 33.1°C water and lowest in 17.4°C water.

Craig and Dvorak (1969) studied the effects of different water temperatures during exercise. A bicycle ergometer was used to test the responses of two subjects in air and in a variety of different water temperatures. Craig and Dvorak used two testing series. During the first series, subjects were tested in air and in water temperatures of 25°C, 30°C, and 35°C. The second series consisted of testing in air and in water temperatures of 22°C, 25°C, 30°C, 32°C, and 34°C. The results of the study indicated that in 22°C and 25°C water, oxygen uptake ($\dot{V}O_2$) averaged .14 liters per minute (L/min) greater than for the warmer water and air temperatures. In water of 30°C and 35°C, $\dot{V}O_2$, for any given workload, was the same as for air. Heart rate, for any given $\dot{V}O_2$, averaged 10 beats per minute (bpm) lower in 25°C water. Respiratory frequency was slightly greater in water than in air during exercise. In 25°C water, subjects were cold at rest but comfortable during work. In 35°C water, subjects complained about being warm after a period of work. Craig and Dvorak stated (p. 124), "except for differences related to thermal regulation and the mechanics of respiration, responses to exercise are the same in water as those in air."

In a study by Nadel, Holmer, Bergh, Astrand, and Stolwijk (1974), three male swimmers were exposed to water temperatures of 18°C, 26°C, and 33°C during resting and submaximal swimming conditions. In the 18°C and 26°C water, subjects tended to have lowered internal temperatures after twenty minutes. However, in the 33°C water, subjects had increased internal temperatures after twenty minutes. Body-fat composition played an important role in the fluctuation of internal temperature. The leaner subjects had the greatest decrease in internal temperature and the least lean subjects had the lowest decrease in temperature. During rest and submaximal swimming, $\dot{V}O_2$ was greater in 18°C water than in 26°C water. Similarly, $\dot{V}O_2$ was greater in 26°C water than in 33°C water. Heart rate was 15 to 35 bpm higher in 33°C water, at any level of $\dot{V}O_2$, than for either of the cooler water conditions.

The metabolic and cardiovascular adjustments to work in air and water at 18°C, 25°C, and 33°C of six male subjects was studied by McArdle, Magel, Lesmes, and Pechar (1976). Results of this study showed that in 18°C and 25°C water, $\dot{V}O_2$ averaged 25.3% and 9%, respectively, than $\dot{V}O_2$ values for 33°C water. Heart rate was lower in 18°C and 25°C water than in air or 33°C water. This decrease in heart rate in the cooler water temperatures was compensated for by an increase in stroke volume, keeping cardiac output consistent in air and in 18°C, 25°C, and 33°C water for similar levels of $\dot{V}O_2$. Heart rate and $\dot{V}O_2$ were linearly related in 33°C water and in air. In 18°C and 25°C water, heart rate was slightly reduced for a particular $\dot{V}O_2$.

Avellini, Shapiro, and Pandolf (1983) studied physical training of fifteen unconditioned males on land and in water. The males were divided into three groups. These groups included a group to train on land, a group to train in 20°C water and a group to train in 32°C water. All three groups trained on a cycle ergometer. Throughout the study, the subjects in 20°C water averaged heart rates 20 bpm and 10 bpm lower than subjects on land and in 32°C water, respectively. At the end of the study, all three groups showed an improvement in maximal oxygen uptake (max $\dot{V}O_2$).

Hydrostatic pressure is pressure exerted on the body by water during immersion and increases uniformly with water depth (Guyton, 1981). Hydrostatic pressure has been shown to alter cardiorespiratory dynamics (Butts, Tucker, & Smith, 1991). Some of these changes include a decrease in ventilation and an increase in central and cardiac blood volumes (Butts, Tucker, & Smith, 1991; Green, et al., 1990). These changes are thought to facilitate venous return, or the return of blood to the heart via the veins. Thus, cardiac output is maintained more efficiently through higher stroke volumes and lower heart rates (Butts, Tucker, & Smith, 1991). Although water temperature is believed to play a part in a reduced heart rate during water running, "hydrostatic pressure appears to be the key factor which suppresses heart rate during aquarunning (Running Research, 1993)." Besides improving venous return and cardiac output and lowering heart rate, hydrostatic pressure places resistance against the chest. This resistance may be responsible for some of the above physiological changes as well as improved breathing capacity (Croce & Gregg, 1991).

Arborelius, Balldin, Lilja, and Lundgren (1972) investigated the changes that occurred as a result of head above water immersion. Ten subjects (20 to 31 years of age)were tested seated in neutral temperatures in air or immersed with the head above water. They found immersion with the head above water to result in an increase in cardiac output by 32% over cardiac output on land. The increased cardiac output is believed to be the result of a 35% increase in stroke volume and an almost unchanged heart rate.

Physiology of Water-Based Exercise vs. Physiology of Land-Based Exercise

Several studies have indicated that heart rate and $\dot{V}O_2$ are linearly related in both land-based and water-based activities (Evans, Cureton, & Purvis, 1978; Holmer, Stein, Saltin, Ekblom, & Astrand, 1974; McArdle, Glaser, and Magel, 1971). However, in these studies heart rate and $\dot{V}O_2$ responses were shown to differ in the two environments. McArdle, et al., (1971) compared the metabolic and cardiorespiratory responses of five college-age male trained swimmers during free swimming and treadmill walking. The walking test was performed on a motor-driven treadmill at a speed of 3.8 miles per hour (mph). The percent grade of the treadmill was increased every four minutes until subjects reached maximum, or exhaustion. For the maximal swim test, subjects performed the crawl stroke. Every four minutes, the frequency of the stroke was increased. During this study, lower heart rates were elicited during swimming than for walking at any level of $\dot{V}O_2$ measured. The mean difference in heart rate between swimming and walking ranged from 9 to 13 bpm. $\dot{V}O_2$ averaged 250 to 350 milliliters (ml) higher during swimming for any given mean heart rate. In this study, the range of cardiovascular response for swimming was also less than for treadmill walking. Mean heart rates in walking ranged from 112 to 190 bpm. $\dot{V}O_2$ ranged from 1.41 to 3.75 (L/min). During swimming, heart rates averaged from 115 to 169 bpm and $\dot{V}O_2$ ranged from 1.80 to 3.36 L/min.

Costill (1971) studied heart rate and work efficiency of ten physically active men (21 to 36 years of age) during exercises performed in water and on land. Subjects participated in water-based and land-based cycling at maximal and submaximal workloads. The cycling exercises consisted of four separate work conditions: vertical-land, prone(face down)-land, prone-water, and supine(face up)-water.

Inconsistent with many studies, Costill found $\dot{V}O_2$ and heart rates to be higher in water than on land during submaximal workloads. However, at maximal workloads, max $\dot{V}O_2$ and maximal heart rate were significantly lower in water than those recorded on land. This finding is consistent with the findings of other similar studies.

Studies of maximal responses to treadmill running and deep water running have shown that maximal physiological responses of water running are significantly lower than those of treadmill running. These responses include lower peak $\dot{V}O_2$ values and peak heart rate values (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991). Butts, Tucker, and Smith (1991) studied the maximal responses to treadmill and deep water running in twelve high school female cross country runners. These runners performed a maximal treadmill running test and a maximal deep water running test with a floatation device. At least 24 hours, and no more than one week, were allowed between testing sessions. Peak $\dot{V}O_2$ values obtained during water running were found to be approximately 17% below the values obtained during the treadmill run. For these same subjects, maximal heart rate values were 17.6 bpm lower during water running than during treadmill running. During water running, maximal heart rate may be 8% to 10% lower than normal maximal heart rate (Running Research, 1993).

In a second study by Butts, Tucker, and Greening (1991), water running with a floatation device was found to elicit a 16% lower max $\dot{V}O_2$ in women and a 10% lower max $\dot{V}O_2$ in men than treadmill running. It was suggested that water exercise intensities not be prescribed based on land-determined heart rates, since this could result in increased stress on the cardiovascular system (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Cassady & Nielson, 1992; Green, Cable, & Elms, 1990).

Svedenhag and Seger (1992) studied physiological responses to running on land and in deep water at submaximal and maximal workloads. Ten trained runners performed submaximal and maximal deep water running and treadmill running tests. A floatation device was used for the deep water tests. For the water test, four pre-determined submaximal intensities based on heart rate were performed followed by a test to maximum. Within two weeks after the water test, a treadmill running test similar to the water test was performed. Maximal oxygen uptake was significantly lower during water running than during treadmill running. Heart rates at a given submaximal and maximal $\dot{V}O_2$ tended to be lower for water running than for land running. Respiratory exchange ratios were higher for running in water than for running on the treadmill.

Holmer, Stein, Saltin, Ekblom, & Astrand (1974) compared physiological responses of swimming and running. Five male subjects (18 to 29 years of age) participated in both swimming and running experiments at maximal and submaximal workloads. At similar submaximal $\dot{V}O_2$, subjects had similar cardiac output, stroke volume, and heart rate during swimming and running. At maximal work rates, they found running to have a higher max $\dot{V}O_2$ (17% higher) than the max $\dot{V}O_2$ for swimming. Also, cardiac output and heart rate were found to be higher during maximal running.

Hamer and Morton (1990) completed an eight week study of water running and its training effects on aerobic, anaerobic, and muscular parameters. Twenty subjects were pre-tested before and post-tested after an eight week treatment period on aerobic, anaerobic, and muscular performance parameters. For eight weeks, subjects participated in a water running program three times per week. All tests of water running were performed in shallow water without a floatation device at the submaximal workloads of 50%, 60%, 70%, 80%, and 90% of each subject's pre-treatment max $\dot{V}O_2$. Post-testing for the study demonstrated similar values for max $\dot{V}O_2$ and O_2 pulse rate for water running and treadmill running. However, significantly reduced heart rates were found for water running. For any given $\dot{V}O_2$, heart rate in water was lower when compared to heart rate for the same $\dot{V}O_2$ during treadmill running. Also, cardiorespiratory parameters and max $\dot{V}O_2$ were shown to improve during water running. In fact, max $\dot{V}O_2$ increased by 9%. Water running for the eight week period invoked anaerobic changes in the skeletal muscles. These changes included increased capacities of the ATP-PC and anaerobic glycolysis systems. Few significant changes occurred in the measures of muscular performance. Results of this study indicated that water running and land-based running elicit similar cardiorespiratory responses and adaptations.

Johnson, Stromme, Adamczyk, and Tennoe (1977) compared oxygen uptake and heart rate during calisthenic exercises on land and in water. Two types of calisthenic exercises were performed: arm exercises and leg exercises. For arm exercises, mean $\dot{V}O_2$ increased by 6.94 ml/kg/min for men and 6.25 ml/kg/min for women during water exercise. Leg exercises showed an increase of 8.50 ml/kg/min for men and 5.43 ml/kg/min for women during water exercises. Heart rate for arm exercises in water were 21 bpm higher for men and 16 bpm higher for women than heart rates for arm exercise on land. Heart rate responses for leg exercises were similar to arm exercises. Heart rates for water exercise were 31 bpm higher for men and 13 bpm higher for women.

Evans, Cureton, and Purvis (1978) found that approximately one-half to one-third the speed was required in water to work at the same metabolic intensity as on land. Similarly, Costill (1971) found that at submaximal workloads, exercise in water increased energy requirements by 33% to 42%

for any given work level. Contrary to the findings by Evans, et al., (1978) and Costill (1971), Bishop, Frazier, Smith, and Jacobs (1989) found the mean metabolic costs of water running to be less than the mean metabolic costs of treadmill running at a preferred intensity. In their study, they found motivation to be a key factor in achieving high metabolic rates in water exercise.

A recent study on water exercise was done by Eyestone, Fellingham, George, and Fisher (1993). These researchers studied the effect of water running with a floatation device and cycling on maximal oxygen consumption and two-mile run performance. Thirty two male subjects between 18 and 26 years of age participated in this study. Subjects participated in a two-mile run pre-test and were then randomly divided into three training groups: a water running group, a cycling group, and a land-based running group. Results of this study showed that over a six week period of time, a near normal max $\dot{V}O_2$ and two-mile run performance could be maintained by running in water, provided one exercises with the same intensity (percent of maximum heart rate), duration, and frequency. This maintenance occurred regardless of the subject's fitness level.

Controversy exists over the use of floatation devices for running. Some researchers believe that floatation devices aid in maintaining an upright position, which would permit an individual to more closely simulate a running motion (Bishop, et al., 1989). Other researchers suggest that floatation devices may alter running technique (Ritchie & Hopkins, 1991; Running Research, 1993).

Research suggests that the use of a floatation device may lower the intensity of deep water running (Gehring, Keller, Brehm, & Smith, 1992; Ritchie & Hopkins, 1991; Running Research, 1993). The drive to keep afloat is eliminated. Therefore, less energy is used to maintain posture. This reduction in energy may cause a reduction in the rate of oxygen consumption and in heart rates, resulting in a decrement in the training effects of water running (Gehring, et al., 1992; Ritchie & Hopkins, 1991; Running Research, 1993).

Gehring, et al., (1992) compared the physiological responses of deep water running to treadmill running. Three conditions were studied: deep water running with a buoyancy vest, deep water running without a buoyancy vest, and treadmill running. Fourteen female subjects were used. Seven subjects were competitive runners and seven subjects were non-competitive runners. The competitive group consistently elicited lower heart rates for the buoyancy vest condition than for the non-vest or treadmill conditions. The non-competitive group elicited a 23% to 27% lower $\dot{V}O_2$, heart rate, and $\dot{V}E$ for the buoyancy vest condition compared to the treadmill condition. During the non-vest condition, the non-competitive group had a 13% lower $\dot{V}O_2$ than during the treadmill condition and a 14% to 24% higher $\dot{V}O_2$, heart rate, and $\dot{V}E$ compared to the buoyancy vest condition. The non-competitive runners were able to train at 85% of their land-based intensities without a floatation device. With floatation devices, these runners were only able to train at approximately 70% of normal (Gehring, et al., 1992; Running Research, 1993). It may be best for beginning water runners to use a floatation device for security. However, most water runners may be better off without floatation devices, since the use of floatation decreases the demand for oxygen (Running Research, 1993).

Summary

Water-based running is a viable option to land-based running. The medium of water is known to reduce the stress and the impact placed on the joints and soft tissue during most land-based activities. The buoyancy, resistance, temperature, and hydrostatic pressure properties of water are all important factors that must be considered when prescribing water exercise. These variables are known to have certain physiological effects different from those of land-based activity. Water exercise has been shown to have lower maximal heart rate and oxygen uptake values than land exercise. Therefore, prescribing submaximal water exercise intensities based on land-determined intensities could place strain on the cardiovascular system. Studies have shown that running in water does provide training effects similar to those of land-based running. Based on this, water running could be used by injured runners or anyone looking to escape the impact and stress of land-based exercise to maintain fitness levels.

CHAPTER III
METHODOLOGY

This study investigated the difference in heart rate and rating of perceived exertion (RPE) at different intensities among treadmill running and two conditions of deep water running in order to determine comparable workloads for land-based and water-based running. This chapter describes the methods and procedures used in this study. Information on population and sampling, reliability and validity of instrumentation, and statistical design will also be discussed.

Population and Sampling

Originally, 17 subjects began the study. However, due to personal and/or medical reasons, 3 female subjects dropped out of the study. Fourteen subjects, 8 male and 6 female, completed all testing for the study. All subjects, except 1, were students enrolled at Emporia State University in the Spring 1994 semester. All of the subjects were physically active, engaging in at least 16 to 30 minutes of physical activity at least three days per week. All subjects were volunteers ranging from 18 to 28 years of age. Permission to use human subjects was obtained from Emporia State University's Human Subjects Committee (Appendix A).

Procedures

During a seven week time period, subjects participated in eight separate sessions. The first two sessions were labeled as practice sessions and were held with at least 1 day separating the sessions. The final six sessions were actual testing sessions and were held 1 week apart from one another. Subjects were asked to refrain from eating, drinking, smoking, and exercising at least 2 hours prior to each of these sessions. All of the sessions were held in the Physical Education Building at Emporia State University.

During the first of the two practice sessions, subjects completed an informed consent (Appendix B), a PAR-Q (Appendix C), and a Survey of Activity Level (Appendix D). The PAR-Q screened for any possible medical problems. The Survey of Activity Level was used to determine each subject's regular activity level. Height, weight, and percent body fat were measured during this first meeting. Height was measured in inches, and weight was measured in pounds. Both measurements were taken using a standard Health-O-Meter scale.

Percent body fat was determined through hydrostatic weighing. First, the subject's vital capacity was measured through the use of a spirometer. Next, the subject was asked to go to the restroom and to change into swim gear. The subject then reported back to the weighing area. The subject entered the tank, which was filled with warm water (30°C or warmer), and sat on a swing seat attached to an overhead scale (Appendix E). The subject was asked to forcefully expel air from the lungs while staying completely submerged in the water. While the subject was submerged, the scale was read and the weight recorded. The weighing procedure was completed 4 to 6 times in order to get an accurate reading. A mean of the consistent weights was used as the underwater weight. The subject exited the tank, and the tare weight (the weight of all the equipment suspended in the water) was measured. Subject age, weight, water weight, tare weight, vital capacity, expired air temperature, and water temperature were all entered into a computer program designed to compute percent body fat using the Brozek formula (Appendix F and G).

The final step of the first practice session, following a change of clothing, was to practice treadmill running. Subjects began running on the treadmill at a pace chosen by the subject. As the subject became more familiar with the treadmill, speed and percent grade were increased. During this practice session, subjects received instructions on correct treadmill running form.

The second practice session was a practice session on deep water running with and without floatation. A metronome was used to help subjects keep a consistent pace. Subjects received instructions on correct deep water running form with and without floatation.

Both the treadmill and the deep water running practice sessions were important in helping subjects to feel comfortable on the treadmill and in deep water. These practice sessions were designed to decrease the nervousness or stress caused by novelty or unfamiliarity of the testing sessions. The two practice sessions were held at least 1 day apart.

Following completion of the practice sessions, each subject was tested in three different testing conditions. Each of these three conditions required two sessions for a total of six testing sessions for each subject. These three testing conditions included treadmill running, deep water running with floatation, and deep water running without floatation. Subjects were tested to maximum, or exhaustion, and to submaximum levels for each condition.

A rotation schedule was established for the six testing sessions. This schedule was chosen to help control for any extraneous variables which could occur during testing. These possible extraneous variables included changes in the environment, pressures of school and social life, and any training effects that may have occurred. The 14 subjects were divided into 3 groups for the 6 weeks of testing. Every 2 weeks, the groups rotated to a new testing condition following maximal and submaximal testing sessions at the previous testing situation. For example, group 1 tested to maximum on the treadmill during week one. During week two, group 1 completed the submaximal treadmill testing session. For weeks three and four, group 1 tested to maximum and to submaximum in deep water with floatation, respectively. Group 1 tested to maximum and to submaximum in deep water without floatation during weeks five and six, respectively. Groups 2 and 3 followed a similar rotation for the six weeks of testing. Group 2 began in deep water with floatation, and group 3 began in deep water without floatation.

Each of the testing sessions lasted approximately 30 to 40 minutes. Each subject was tested independently of the other subjects. Subjects were tested during the same time of day for each test. Prior to each testing session, each subject's 60 second heart rate was measured by palpation at the radial artery by the researcher. Subjects were asked to determine their pre-exercise fatigue level based on a scale of 1 to 10 with 10 being very fatigued. Air and/or water temperature were also measured prior to each testing session. (During testing, air temperature in the laboratory and in the pool area averaged 24.5°C (76°F) and 25°C (77°F), respectively. Water temperature averaged 29°C (84°F).)

The variables measured for each subject included heart rate and RPE. Heart was measured every 60 seconds using a POLAR Vantage XL Heart Rate Monitor. This monitor was placed on the subject's chest using an elastic strap. The chest monitor relayed information on the subject's heart rate to a watch worn on the subject's wrist. The watch stored the heart rate measurements throughout the test. At the end of each test, the heart rate measurements in the watch's memory were recorded.

RPE was measured and recorded during the last 15 seconds of each workload, or change in pace or percent grade of the metronome or treadmill. The scale was printed on a large piece of posterboard placed directly in front of the subject. The subject indicated the number on the scale that best corresponded to his/her perceived exercise intensity level.

Subjects tested to maximum and submaximum for each of the three conditions. The maximum workload was the first to be performed for each testing condition. Testing of the maximum workload determined the maximum heart rate of each subject. This maximum heart rate was then used to determine the appropriate heart rates of each subject for the remaining submaximal workload testing sessions. It should be understood that the maximum heart rate for the treadmill test is expected to be higher than the maximum heart rate for either of the water-based tests. This expectation is based on prior studies regarding maximal responses to treadmill running and deep water running (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991). These studies have shown that a person can exercise in water at a lower heart rate than a person participating in a similar exercise on land and still receive the same physiological benefits. Intensities for water training should not be based on land-determined heart rates.

Because of this, it is necessary to test each subject to maximum in each medium in order to determine appropriate workload heart rates.

Prior to each maximal and submaximal testing session, subjects performed a five minute warm-up. Heart rate and RPE were measured during this warm-up. For the treadmill running test, the warm-up consisted of a pace of 5 miles per hour (mph) at a 0% grade. For both deep water running tests, subjects ran at a metronome cadence of 100 beats per minute (bpm). Previous studies by Butts, Tucker, and Greening (1991) and Butts, Tucker, and Smith (1991) indicated that a 100 bpm cadence to be equivalent to a treadmill pace of 5 mph. Following the 5 minute warm-up, subjects were given 1 to 2 minutes to stretch. Subjects were asked to stretch either off of the treadmill or near the wall in the deep end of the pool, depending on the condition in which they were being tested.

The treadmill maximal run test took place in the Human Performance Laboratory at Emporia State University. For the maximal treadmill run test, subjects began at pre-determined workload of 6 mph at a 2.5% grade following the warm-up period. This workload was increased by 2.5% every 3 minutes. Treadmill speed was maintained at 6 mph. Workload continued to be increased until subjects reached maximum, or exhaustion. Exhaustion was determined by the subject. Subjects were allowed to terminate testing at any time when they felt they could go no longer.

Both water-based tests, with and without floatation, took place in the indoor swimming pool at Emporia State University. For the all water-based tests, including the practice sessions, subjects were tethered to the edge of the pool using a tethering rope (Appendix H). Tethering the subject kept the subject from drifting too far from the edge. For deep water running with floatation, a device known as an Aqua Jogger (Excel Sport Science, Eugene, Oregon) (Appendix H) was used. For deep water running without floatation, a belt (Appendix H) was wrapped around the subject's waist to aid in tethering the subject.

A deep water running frame (Appendix I) was used to ensure that a subject maintained the correct upright running form and did not convert to a horizontal position. This frame was constructed of 2 inch PVC pipe. The frame was 6 feet tall and 4 feet wide. The frame was positioned near the edge of the pool with half of the frame under water and half of the frame above water. If a subject did begin to convert to a horizontal position, they were asked to bring themselves back to a more vertical position.

For the maximal water-based tests, subjects began at a pre-determined workload of 120 bpm following the warm-up period. Every 3 minutes, this workload was increased by 20 bpm. This increase of 20 bpm was an attempt to equate the 2.5% grade increase during the treadmill run (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991). Workloads for deep water maximal run tests were continuously increased every 3 minutes until the subject reached maximum. As with the treadmill test, exhaustion was determined by the subject. The deep water running tests were identically administered except for the use of floatation. One situation called for the use of floatation, and the other did not.

Following the testing of maximum for a particular testing condition, subjects tested three submaximal workloads for each of the testing mediums. These submaximal workloads (70%, 80%, and 90% of the maximum heart rate) were determined during the maximal testing session. Each of the submaximal workloads was tested for 3 minutes. A three minute time frame was chosen to make sure that each subject achieved steady state. Steady state is a time period in which the physiological responses to exercise remain constant. Following all testing sessions, subjects were given time to cool down and stretch.

Validity and Reliability of Instrumentation

In this study, the POLAR Vantage XL Heart Rate Monitor was used to measure heart rate. When used correctly, this monitor is 98% accurate, measuring only 1 to 2 beats off of an electrocardiogram (Ebbeling, Ebbeling, Ward, & Rippe, 1991; POLAR CIC, Inc.). This monitor is a measuring technology used by many national and international world-class athletes and Olympic teams (POLAR, 1991).

Borg's RPE scale (Appendix J) was used to measure perceived exertion. This scale has a correlation of .72 with heart rate and workload during a maximal test with increasing workloads. Borg's RPE scale has the highest correlation with heart rate and workload among all other perceived exertion scales (Borg, 1973). Borg's RPE scale has a reliability of .80 and a validity of .79 for tests using progressive workloads (Skinner, Hutsler, Bergsteinova, & Bukirk, 1973).

Statistical Design

Subject data, including age, height, weight, and percent body fat were analyzed using basic descriptive statistics (means, ranges, and standard deviations). The purpose of this study was to determine the differences of heart rate and rating of perceived exertion within each subject. Therefore, the differences in heart rate and rating of perceived exertion at different intensities of treadmill running and deep water running with floatation and deep water running without floatation were analyzed using a repeated measures analysis of variance (ANOVA). A Newman-Keuls Multiple Comparisons Test was used to determine where any significant differences existed. All data were analyzed at the $p < .05$ level of significance. Simple linear regression was used to determine preliminary equations to be used for the prediction of water-based maximum heart rates given the land-based maximum.

Summary

The purpose of this study was to determine if a difference exists in heart rate and rating of perceived exertion at different intensities among treadmill running and two conditions of deep water running. Fourteen volunteer subjects participated in six testing sessions, including maximal and submaximal tests for treadmill running, deep water running with floatation, and deep water running without floatation. All testing was completed within a period of seven weeks.

CHAPTER IV
ANALYSIS OF DATA

The purpose of this study was to determine the difference in heart rate and rating of perceived exertion (RPE) at different intensities (70%, 80%, 90%, and 100% of maximum heart rate) among land-based running and two conditions of water-based running. Subjects were tested in three conditions: treadmill running, deep water running with floatation, and deep water running without floatation. Subjects tested at submaximal and maximal levels for each of these three conditions.

This chapter presents an analysis of the data obtained from the testing of the three conditions. A repeated measures analysis of variance (ANOVA) was used to test the difference of heart rate and rating of perceived exertion for each of the intensities tested for treadmill running and deep water running. A Newman-Keuls Multiple Comparisons Test was used to determine where any significant differences existed (Appendix O). All data were analyzed at the $p < .05$ level of significance. Simple linear regression was used to determine preliminary equations to be used for the prediction of a water-based maximum heart rate given a land-based maximum heart rate.

Sample Analysis

Seventeen subjects began the study. However, due to medical and/or personal reasons, 3 female subjects dropped out of the study. Therefore, analysis of data is based upon the data obtained from the 14 subjects, 8 male and 6 female, who completed the study. Table 1 summarizes the demographic characteristics of the 14 subjects.

Table 1:

Demographic Characteristics of Subjects

	MEAN AGE (years)	AGE RANGE	MEAN HEIGHT (inches)	HEIGHT RANGE
GROUP	22.79	18-28	68.39	64-73.5
MALES	24.50	22-28	70.44	68-73.5
FEMALES	20.50	18-25	65.67	64-68.0

	MEAN WEIGHT (pounds)	WEIGHT RANGE	MEAN % BODY FAT	% BODY FAT RANGE
GROUP	157.12	127-198	19.3	9.2-26.1
MALES	169.44	142-198	16.0	9.2-24.0
FEMALES	140.67	127-155	23.68	21.0-26.1

Statistical Analysis

Descriptive statistics, including means and standard deviations, were computed for each workload of treadmill running, deep water running with floatation, and deep water running without floatation (Tables 2, 3, 4, 5, 6, and 7).

Table 6:

Descriptive Statistics for

Deep Water Running without Floatation

(RPE)

	70%	80%	90%	100%
MEAN	12.43	15.00	16.77	19.36
STD DEV	2.65	2.04	2.35	0.84

Table 7:

Descriptive Statistics for

Deep Water Running with Floatation

(RPE)

	70%	80%	90%	100%
MEAN	9.93	12.29	14.77	19.07
STD DEV	1.98	2.09	2.49	0.92

Hypothesis 1 stated that there was a significant difference in heart rate at comparable workloads (70%, 80%, 90%, and 100% of maximum heart rate) among treadmill running, deep water running with floatation, and deep water running without floatation. This hypothesis was not rejected at the $p < .05$ level of significance for 70% ($p = 0.0001$), 80% ($p = 0.0001$), 90% ($p = 0.0001$), and 100% ($p = 0.0001$) (Tables 8, 9, 10, and 11).

Based on the Newman-Keuls test (Appendix O), a significant difference existed between treadmill running and each of the deep water running conditions at the maximum workload. At 90% of maximum heart rate, a significant difference was found among each of the three conditions tested. For 70% and 80% of maximum heart rate, a significant difference existed between treadmill running and deep water running with floatation and between deep water running with floatation and deep water running without floatation.

Table 8:

Repeated Measures ANOVA for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at Maximum Heart Rate

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	4358.57	335.27	1.38	0.2302
WITHIN SUBJECTS	28	6809.33	243.19	45.11	0.0001*
TOTAL	41	11167.90	272.39		

*$p < .05$

Table 9:

Repeated Measures ANOVA for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 90% of Maximum Heart Rate

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	12	4700.77	391.73	1.37	0.2413
WITHIN SUBJECTS	26	7431.00	285.81	23.28	0.0001*
TOTAL	38	12131.77	319.26		

*$p < .05$

NOTE: It should be noted that one subject was unable to complete the 90% submaximal workload.

Table 10:

<u>Repeated Measures ANOVA for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 80% of Maximum Heart Rate</u>

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	5096.63	392.05	1.13	0.3760
WITHIN SUBJECTS	28	9706.33	346.66	38.14	0.0001*
TOTAL	41	14802.96	361.05		

*p < .05

Table 11:

Repeated Measures ANOVA for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 70% of Maximum Heart Rate

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	3896.10	297.62	0.789	0.6651
WITHIN SUBJECTS	28	10558.50	377.09	27.142	0.0001*
TOTAL	41	14427.60	351.89		

*$p < .05$

Hypothesis 2 stated that there was a significant difference in rating of perceived exertion at comparable workloads (70%, 80%, 90%, and 100% of maximum heart rate) of treadmill running, deep water running with floatation, and deep water running without floatation. This hypothesis was rejected at the $p < .05$ level of significance for 100% of maximum heart rate ($p = 0.4161$) (Table 12). This hypothesis was not rejected at the $p < .05$ level of significance for the workloads of 70% ($p = 0.0012$), 80% ($p = 0.0001$), and 90% ($p = 0.0167$) of maximum heart rate (Tables 13, 14, and 15).

Based on the results of the Newman-Keuls test (Appendix O), a significant difference existed between treadmill running and deep water running without floatation and between deep water running with floatation and deep water running without floatation at 70%, 80%, and 90% of maximum heart rate.

Table 12:

Repeated Measures ANOVA for Rating of Perceived Exertion at Maximum Workload for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	11.24	0.86	1.58	0.1513
WITHIN SUBJECTS	28	15.33	0.55	0.91	0.4161
TOTAL	41	26.57	0.65		

Table 13:

Repeated Measures ANOVA for Rating of Perceived Exertion at 90% Submaximal Workload for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running Without Floatation

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	12	83.59	6.97	1.51	0.1835
WITHIN SUBJECTS	26	120.00	4.62	4.88	0.0167*
TOTAL	38	203.59	5.36		

*$p < .05$

NOTE: It should be noted that one subject did not complete the 90% submaximal workload.

Table 14:

Repeated Measures ANOVA for Rating of Perceived Exertion at 80% Submaximal Workload for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	77.07	5.93	1.28	0.2831
WITHIN SUBJECTS	28	130.00	4.64	13.83	0.0001*
TOTAL	41	207.07	5.05		

*$p < .05$

Table 15:

Repeated Measures ANOVA for Rating of Perceived Exertion at 70% Submaximal Workload for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

SOURCE OF VARIATION	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO	PROB. F
BETWEEN SUBJECTS	13	100.31	7.72	1.29	0.2751
WITHIN SUBJECTS	28	167.33	5.98	8.87	0.0012*
TOTAL	41	267.64	6.53		

*$p < .05$

A sub-purpose of this study was to develop a method of determining comparable workloads for land-based running and water-based running. To do this, simple linear regression was used to develop preliminary two equations, one for predicting the maximum heart rate for deep water running with floatation and one for predicting the maximum heart rate for deep water running without floatation (Tables 16 and 17). Those individuals who know their land-based maximum can determine their estimated water-based (with and without floatation) maximum heart rate using one of the two equations. It should be noted that the results of the simple linear regression indicate that a linear trend does exist between treadmill running and each of the two deep water running conditions tested (Figures 1 and 2). However, these two equations should be used with caution. For some individuals, large errors in the predicted water-based maximum heart rate may occur.

Table 16:

<u>Simple Linear Regression for Treadmill Running and Deep Water Running with Floatation</u>

COEFFICIENT	CONSTANT	CORRELATION	R-SQUARE	PROB.
0.9807	-21.8440	0.5100	0.2601	0.0624

EQUATION: Max HR in Water w/Floatation = 0.9807 * Land-Based Max HR - 21.8440

Table 17:

Simple Linear Regression for Treadmill Running and Deep Water Running Without Floatation

COEFFICIENT	CONSTANT	CORRELATION	R-SQUARE	PROB.
0.8514	7.1350	0.5940	0.3528	0.0251

EQUATION: Max HR in Water w/out Floatation = 0.8514 * Land-Based Max HR + 7.1350

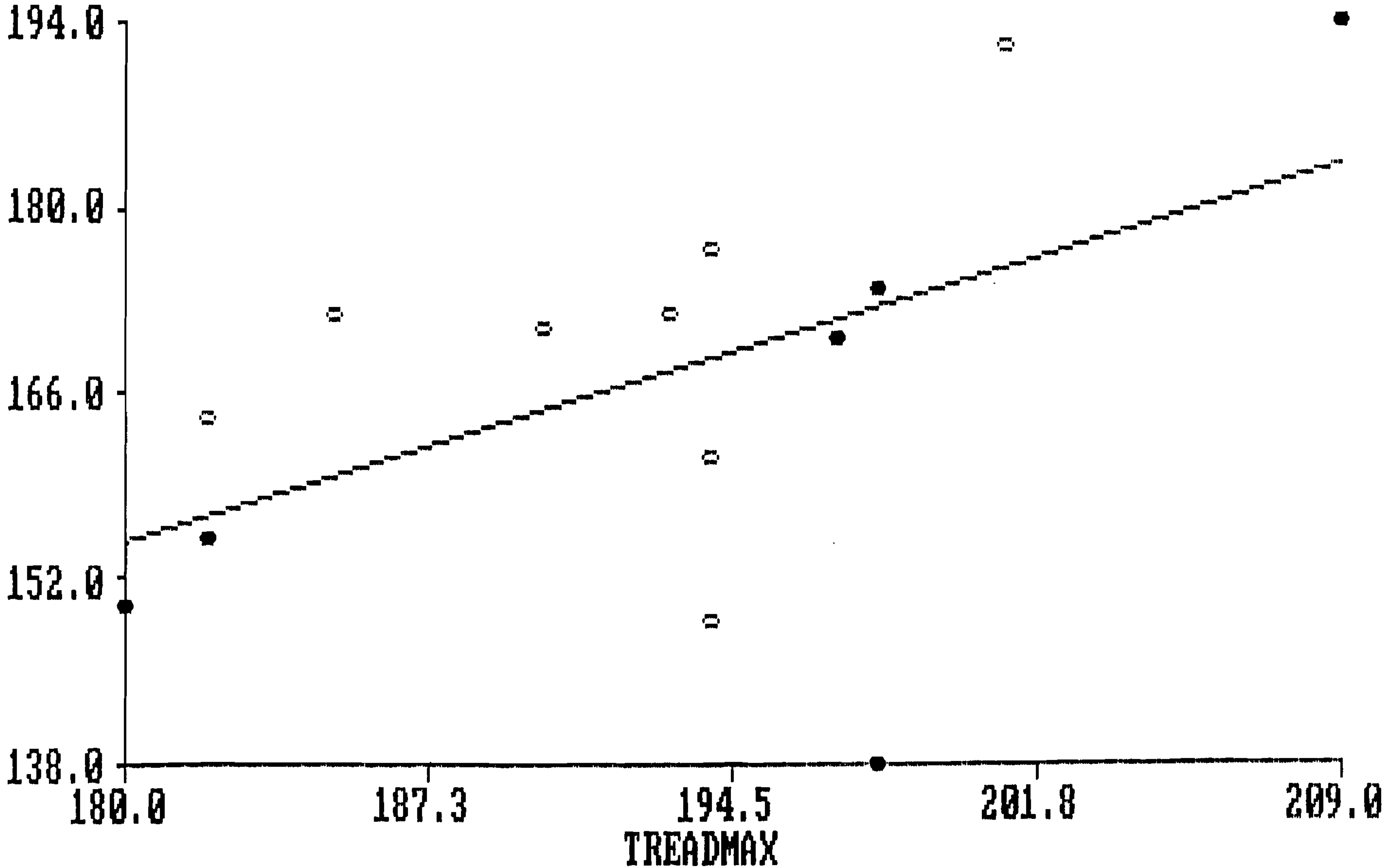

Figure 1. Simple Linear Regression for Treadmill Running (x-axis) and Deep Water Running with Floatation (y-axis).

O = males
● = females

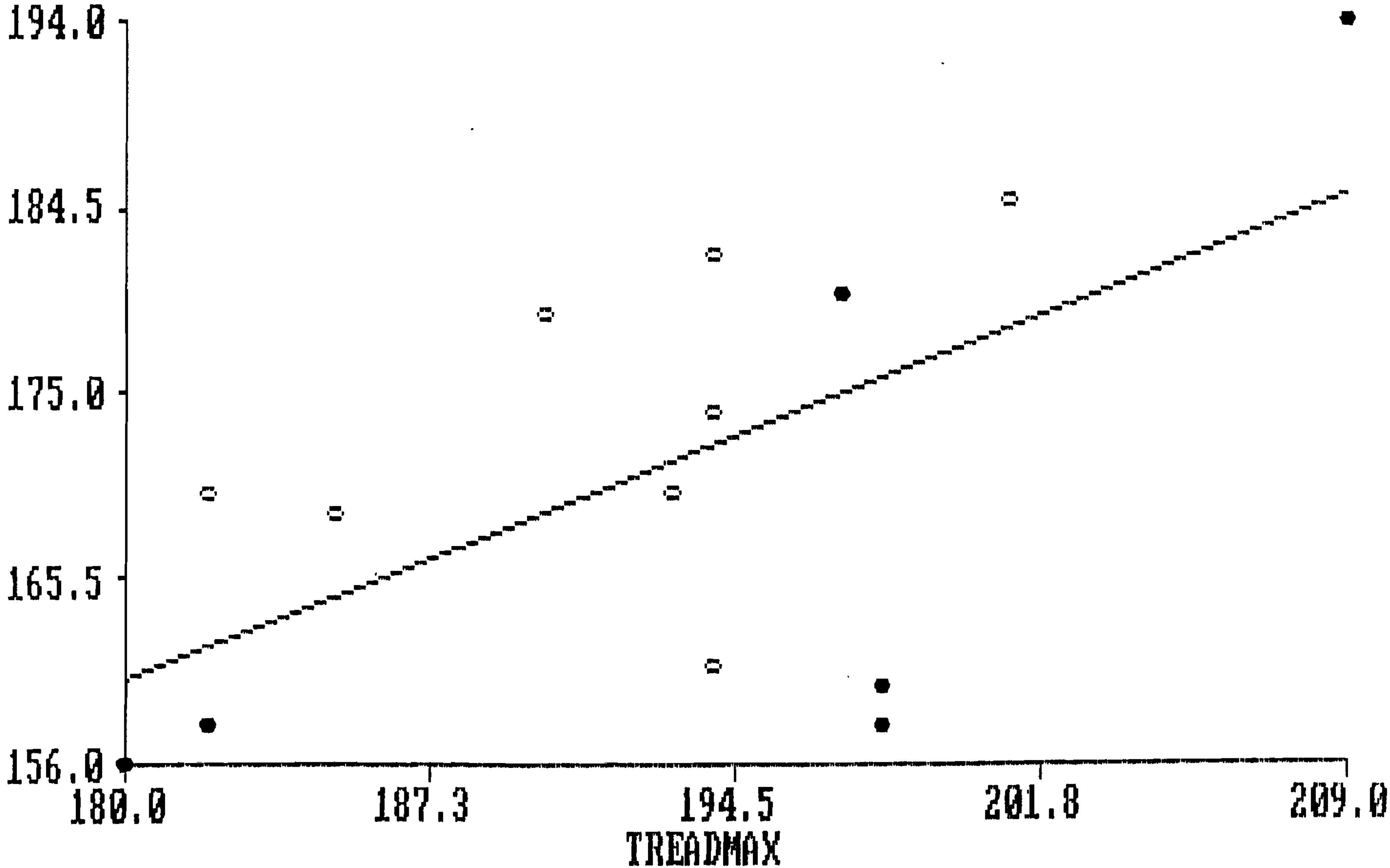

Figure 2. Simple Linear Regression for Treadmill Running (x-axis) and Deep Water Running without Floatation (y-axis).

○= males
●= females

Summary

Hypothesis 1 and 2 for this study were tested at the $p < .05$ level of significance using repeated measures ANOVA's. Hypothesis 1 focused on the difference in heart rate at comparable workloads of treadmill running, deep water running with floatation, and deep water running without floatation. The results of this study indicate that a significant difference in heart rate does exist among these three conditions for each of the workloads tested. Hypothesis 2 focused on the difference in RPE at comparable workloads of treadmill running, deep water running with floatation and deep water running without floatation. The results indicate that a significant difference in RPE does exist at the workloads of 70%, 80%, and 90% of maximum heart rate. However, a significant difference in RPE was not found at the maximal workload. Simple linear regression was used to develop two preliminary equations to be used in the prediction of water-based (with and without floatation) maximum heart rates given the known land-based maximum heart rates.

CHAPTER V
DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to determine if a difference exists in heart rate and rating of perceived exertion (RPE) at different intensities among treadmill running, deep water running with floatation, and deep water running without floatation. Based on the results of the study, it appears that a significant difference does exist in heart rate at comparable workloads among the three conditions tested. A significant difference was also found to exist in RPE among the three conditions at the workloads of 70%, 80%, and 90% of maximum heart rate. In addition, a sub-purpose of the study was to develop two preliminary equations for use in predicting water-based maximum heart rates given the land-based maximum heart rate. The following chapter will discuss these results and offer recommendations for future research.

Discussion

Across all conditions tested, those findings that were consistent with previous findings on land-based running versus water-based running included a significant difference in heart rate between treadmill running and deep water running without floatation at 90% and 100% of maximum heart rate and a significant difference in heart rate between treadmill running and deep water running with floatation at 70%, 80%, 90%, and 100% of maximum heart rate (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Hamer & Morton, 1990; Svedenhag

& Seger, 1992). For these findings, the submaximal and maximal heart rates obtained for deep water running were lower than those obtained for treadmill running.

The study did result in some unexpected or inconsistent findings. The determination of submaximal workloads for deep water running without floatation based on the results of the maximal test were difficult. Many subjects tended to elicit higher heart rates than expected during deep water running without floatation at the submaximal levels. This resulted in some unexpected findings. These findings included a significant difference in heart rate between deep water running with floatation and deep water running with/out floatation at 70%, 80%, and 90% of maximum heart rate and a failure to find a significant difference in heart rate between treadmill running and deep water running without floatation at 70% and 80% of maximum heart rate. Several factors may have influenced these findings, including the nature of deep water running without floatation, running efficiency, stride frequency, and range of motion (ROM).

The nature of deep water running without floatation requires an individual to keep himself/herself afloat. During this study, this drive to stay afloat led to increased heart rates and running inefficiency early in the submaximal testing sessions. This drive was particularly evident in the very lean subjects who found it difficult to stay afloat and keep their heads above water.

For the water-based tests, stride frequency was controlled by a metronome. Some subjects found the slower paces of the metronome difficult to maintain when floatation was not used. These subjects felt as though they were not moving fast enough to keep themselves afloat. These subjects appeared to struggle early in the testing and tended to become fatigued quickly.

Range of motion was found to vary from subject to subject and from condition to condition. The extent of arm and leg movement while running differed from subject to subject. This fact was much more evident during the water-based testing than during the treadmill testing. The absence of a running surface for the water-based tests allowed for more fluctuation in stride length to occur during deep water running than during treadmill running. A greater range of motion tended to elicit higher heart rates than a limited range of motion due to the increased demand for oxygen when greater muscle mass is used (Fox, Bowers, & Foss, 1989).

Deep water running with floatation tended to elicit lower maximum heart rates ($\overline{X}$ = 167.07) than did deep water running without floatation ($\overline{X}$ = 171.14). This finding is consistent with previous findings suggesting that floatation may lower the intensity of deep water running due to the elimination of the drive to keep afloat (Gehring, Keller, Brehm, & Smith, 1992; Ritchie & Hopkins, 1991; Running Research, 1993). During the study, several subjects commented that their arms and legs were extremely fatigued following testing in water without floatation. However, only their legs felt fatigued following testing in water with floatation. The fact that floatation reduced the need for use of the arms to keep afloat may have also reduced the body's demand for oxygen. The muscles in the arm did not require large amounts of oxygen due to limited work. Since oxygen uptake and heart rate are linearly related, this reduced volume of oxygen could have led to the lower heart rates in water when floatation was used (Fox, Bowers, & Foss, 1989).

No significant difference was found in RPE at the maximal workload. This finding could relate to the fact that RPE and workload are highly correlated (Borg, 1973). Thus, subjects testing to maximum in all three conditions would have rated the maximum workload near the high end of the scale.

Significant differences in RPE were found at 70%, 80%, and 90% of maximum heart rate between treadmill running and deep water running without floatation and between deep water running with floatation and deep water running without floatation. Many of the factors mentioned previously may have influenced these findings. Many subjects tended to perceive deep water running with floatation as much easier than either treadmill running or deep water running without floatation. In addition, subjects tended to perceive deep water running without floatation as much more difficult that either of the other two conditions tested. Thus, deep water without floatation tended to have higher ratings of perceived exertion at all submaximal workloads than for treadmill running or deep water running with floatation.

In this study, heart rates were found to be lower for water running during both submaximal and maximal conditions. This is an important point to note, since it has been suggested that water-based exercise intensities should not be prescribed based on land-determined exercise intensities (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991). The two preliminary equations developed as a result of this study may be beneficial in prescribing water-based exercise intensities. Those individuals who know their land-based maximum can determine their estimated water-based maximum (with or without floatation) using one of the two equations. Although treadmill running appears to have a linear relationship with both deep water running with floatation and deep water running without floatation, these two equations should be used with caution. For some individuals, large errors may result in the prediction of the water-based maximum heart rate. In addition, the submaximal workloads of 70%, 80%, and 90% of maximum heart rate appear to have a linear trend between treadmill running and each of the two water-based conditions tested. However, this linear trend is not strong enough to support equations for these three submaximal workloads.

Recommendations for Future Research

The following are recommendations for future study.

1. Many factors influence the intensity of water-based running. Some of these factors include range of motion, water temperature, stride length, stride frequency, length of time exercised, and running efficiency. More study needs to be done on these factors and their influences on water-based running.

2. Results of this study indicate that a linear relationship occurs for 70%, 80%, 90%, and 100% of maximum heart rate. However, due to limited data, these results are not strongly supported. A similar study needs to be done with a larger number of subjects to determine the exact nature of these linear relationships. Factors such as age, gender, and percent body fat should be considered in future studies. Future studies should also include the measuring of such variables as $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}E$, and R.

3. A similar study should be conducted in shallow water.

References

Arborelius, M., Balldin, U. I., Lilja, B., & Lundgren, C. E. G. (1972). Hemodynamic changes in man during immersion with the head above water. Aerospace Medicine, 43, 592-598.

Arnheim, D. D. (1985). Modern principles of athletic training. St. Louis: Times Mirror/Mosby College Publishing.

Avellini, B. A., Shapiro, Y., & Pandolf, K. B. (1983). Cardio-respiratory physical training in water and on land. European Journal of Applied Physiology, 50, 255-263.

Bishop, P. A., Frazier, S., Smith, J., & Jacobs, D. (1989). Physiologic responses to treadmill and water running. The Physician and Sportsmedicine, 17(2), 87-89; 92; 94.

Borg, G. A. V. (1973). Perceived exertion: a note on "history" and methods. Medicine and Science in Sports. 5(2), 90-93.

Butts, N. K., Tucker, M., & Greening, C. (1991). Physiologic responses to maximal treadmill and deep water running in men and women. American Journal of Sports Medicine, 19(6), 612-614.

Butts, N. K., Tucker, M., & Smith, R. (1991). Maximal responses to treadmill and deep water running in high school female cross country runners. Research Quarterly for Exercise and Sport, 62(2), 236-239.

Cassady, S. L. & Nielsen, D. H. (1992). Cardiorespiratory responses of healthy subjects to calisthenics performed on land versus in water. Physical Therapy, 72(7), 532-538.

Cavanagh, P. R. ("Ed."). (1990). Chapter 1: The mechanic of distance running: A historical perspective. In Cavanagh, P. R. (1990). Biomechanics of distance running. Champaign, IL: Human Kinetics Books.

Costill, D. L. (1971). Energy requirements during exercise in the water. Journal of Sports Medicine and Physical Fitness, 11, 87-92.

Costill, D. L., Cahill, P. J., & Eddy, E. (1967). Metabolic responses to submaximal exercise in three water temperatures. Journal of Applied Physiology, 22, 628-632.

Costill, D. L., Maglischo, E. W., & Richardson, A. B. (1992). Swimming. Oxford: Blackwell Scientific Publications.

Craig & Dvorak. (1969). Comparison of exercise in air and in water of different temperatures. Medicine and Science in Sports, 1, 124-130.

Croce, P. & Gregg, J. R. (1991). Keeping fit when injured. Clinics in Sports Medicine, 10(1), 181-195.

De Varona, D. & Tarshis, B. (1984). Donna De Varona's hydro-aerobics. New York: Ballentine Books.

Duffield, M. H. (1969). Exercise in water. Bailliere, Tindall, & Cassell, LTD.

Ebbeling, C. B., Ebbeling, C. J., Ward, A., & Rippe, J. M. (1991). Comparison between palpated heart rates and heart rates observed using the POLAR Favor Heart Rate Monitor during an aerobics exercise class. (Report No. EPNL-1991-010). Worcester, MA: University of Massachusetts Medical School, Exercise Physiology and Nutrition Laboratory.

Ecker, T. (1985). Basic track and field biomechanics. Tafnews Press.

Eckerson, J. & Anderson, T. (1992). Physiological response to water aerobics. Journal of Sports Medicine and Physical Fitness, 32(3), 255-261.

Evans, B. W., Cureton, K. J., & Purvis, J. W. (1978). Metabolic and circulatory responses to walking and jogging in water. Research Quarterly, 49, 442-449.

Eyestone, E. D., Fellingham G., George, J., & Fisher, A. G. (1993). Effect of water running and cycling on maximum oxygen consumption and 2-mile run performance. American Journal of Sports Medicine, 21(1), 41-44.

Fox, E. L., Bowers, R. W., & Foss, M. L. (1989). The physiological basis of physical education and athletics (4th ed). Iowa: Wm. C. Brown.

Francis, R. S. (1982). Diagnosis and management of athletic injuries - study manual. Provo, Utah: Brigham Young University.

Gehring, M., Keller, B., & Brehm, B. (1992). Physiological responses to deep water running in competitive and non-competitive runners. Medicine and Science in Sports and Exercise, 24(5), p. S23.

Green, J. H., Cable, N. T., & Elms, N. (1990). Heart rate and oxygen consumption during walking on land and in deep water. Journal of Sports Medicine and Physical Fitness, 30(1), 49-52.

Guyton, A. C. (1981). Textbook of medical physiology (6th ed.). W. B. Saunders Company.

Hamer, P. W. & Morton, A. R. (1990). Water-running: training effects and specificity of aerobic, anaerobic, and muscular parameters following an eight-week interval training programme. Australian Journal of Science and Medicine in Sport, 21(1), 13-22.

Hay, J. G. (1993). The biomechanics of sports techniques (4th ed.). New Jersey: Prentice Hall.

Holmer, I., Stein, E. M., Saltin, B., Ekblom, B., & Astrand, P. (1974). Hemodynamic and respiratory responses compared in swimming and running. Journal of Applied Physiology, 37(1), 49-54.

James, S. L. & Donald, D. C. (1990). Chapter 10: Biomechanical aspects of distance running injuries. In Cavanagh, P. R. (1990). Biomechanics of distance running. Champaign, IL: Human Kinetics Books.

Johnson, B. L., Stromme, S. B., Adamcyzk, J. W., & Tennoe, K. O. (1977). Comparison of oxygen uptake and heart rate during exercises on land and in water. Physical Therapy, 57(3), 273-278.

Krasevec, J. A. (1989). Y's way to water exercise instructor's guide. National Council of Young Men's Christian Associations of the United States of America.

Marti, B., Vaer, J. P., Minder, C. E., & Abelin, T. (1988). On the epidemiology of running injuries. The 1984 Bern Gran-Prix study. American Journal of Sports Medicine, 16, 285-294.

Mathews, D. K. (1978). Measurement in physical education (5th ed.). Philadelphia, London, Toronto: W. B. Saunders Company.

McArdle, W. D., Glaser, R. M., & Magel, J. R. (1971). Metabolic and cardiorespiratory response during free swimming and treadmill walking. Journal of Applied Physiology, 30(5), 733-738.

McArdle, W. D., Magel, J. R., Lesmes, G. R., & Pechar, G. S. (1976). Metabolic and cardiovascular adjustment to work in air and water at 18°, 25°, and 33°C. Journal of Applied Physiology, 40(1), 85-90.

Nadel, E. R., Holmer, I., Bergh, U, Astrand, P. O., & Stolwijk, J. A. J. (1974). Energy exchanges of swimming man. Journal of Applied Physiology, 36(4), 465-471.

Perry, P. (1986). Weightless workouts. Americn Health, 6, 78-81.

POLAR CIC, Inc. (1994). Phone conversation with POLAR representative.

Pollock, M. L. (1977). Submaximal and maximal working capacities of elite distance runners. part I: cardiorespiratory aspects. Annals of the New York Academy of Sciences, 301, 310-322.

Powers, S. K. & Howley, E. T. (1990). Exercise physiology; theory and application to fitness and performance. Dubuque, IA: Wm. C. Publishers.

Ritchie, S. E. & Hopkins, W. G. (1991). The intensity of exercise in deep-water running. International Journal of Sports Medicine, 12(1), 27-29.

Running Research News. (1993). 9(4), 1, 4-6.

Safrit, M. J. (1986). Introduction to measurement in physical education & exercise science. (p. 393). Times Mirror/Mosby College.

Shiling, C. W., Werts, M. F. & Schandelmeier, N. R. ("Eds."). (1976). The underwater handbook. New York and London: Plenum Press.

Skinner, J. S., Hutsler, R., Bergsteinova, V. & Buskirk, E. R. (1973). The validity and reliability of a rating scale of perceived exertion. Medicine and Science in Sports. 5(2), 94-96.

Svedenhag, J. & Seger, J. (1992). Running on land and in water: comparative exercise physiology. Medicine and Science in Sports and Exercise, 24(10), 1155-1160.

User's instruction manual: POLAR Vantage XL Heart Rate Monitor. (1991). Stamford, CT.: POLAR USA, Inc.

Williams, L. (1987). Pooling your talents: Float through tough workouts by running in water. Runners World, 22(3), 81-83.

APPENDIX A

Emporia State University Institutional
Review Board for Treatment of
Human Subjects Approval

EMPORIA STATE UNIVERSITY

1200 COMMERCIAL EMPORIA, KANSAS 66801-5087 316/341-5351 RESEARCH AND GRANTS CENTER - BOX 48

September 27, 1993

oan Brewer
21 Lincoln
mporia, KS 66801

ear Ms. Brewer:

The Institutional Review Board for Treatment of Human Subjects as evaluated your application for approval of human subject esearch entitled, "A Physiological Comparison of Land-Based unning to Water-Based Running at Comparable Workloads." The eview board approved your application which will allow you to egin your research with subjects as outlined in your application aterials.

Best of luck in your proposed research project. If the review board can help you in any other way, don't hesitate to contact us.

Sincerely,

Faye N. Vowell

Faye N. Vowell, Dean
Office of Graduate Studies
and Research

FV:pf

cc: Mark Stanbrough

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APPENDIX B

Informed Consent Form

APPENDIX B

INFORMED CONSENT DOCUMENT

I, Joan Brewer, am requesting your voluntary participation in a study designed to determine the relationship of heart rate and oxygen uptake at comparable workloads of treadmill running and deep water running. Such research is needed in order to make water running a more effective alternative to land-based running.

The Division of HPER supports the practice of protection for human subjects participating in research and related activities. The following information is provided so that you understand the procedures of the study, and therefore, can make an informed decision on whether you wish to participate in this study.

As a subject in this study, you will be asked to participate in two practice sessions and in seven testing sessions over a period of approximately eight weeks. The two practice sessions will last approximately 20 minutes. All testing sessions will last approximately 30 to 40 minutes. Below, the procedures for each testing session are outlined.

Practice Sessions: There will be two practice sessions. During the first practice session, subjects will practice running on a motor-driven treadmill. The second practice session will include practice time on deep water running with and without a flotation device.

Session One: In the first session, height, weight, and percent body fat will be measured for each subject. Percent body fat will be determined through the hydrostatic, or underwater, weighing method.

Treadmill Running Sessions: All subjects will participate in two treadmill running sessions. During the first treadmill running session, subjects will test to maximum (exhaustion). In the second session, subjects will test the submaximal workloads of 70%, 80%, and 90% of maximum heart rate as determined by the first treadmill test. During testing, a Polar Heart Rate Monitor will be used to monitor the subject's heart rate.

Deep Water Running Sessions: There will be four deep water running sessions. During the first two deep water running sessions, subjects will test to maximum (exhaustion). A flotation device will be used for one of the sessions. The other session will be completed with no flotation device. The remaining two deep water running sessions will test the submaximal workloads of 70%, 80%, and 90% of maximum heart rate as determined by the first deep water running tests to maximum. Again, a flotation device will be used in one the sessions and will not be used in the other session. During all of the deep water running tests, a Polar Heart Rate Monitor will be used to monitor the subject's heart rate.

The purpose of this paragraph is to make all subjects aware that dangers do exist and that participation is done with the understanding that risks are involved. The testing sessions will require some physical exertion which might induce temporary discomfort and/or muscle soreness. Subjects may terminate testing at any time.

Each subject will be given a code number. Only the researcher, Joan Brewer, will have a list matching subject names and subject numbers. All personal information and data collected on the subject will be kept confidential.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and possible risks involved. I understand the potential risks involved and I assume them voluntarily. I likewise understand that I can withdraw from the study at any time without being subjected to reproach."

Subject and/or authorized representative ______________ Date

APPENDIX C

PAR-Q
(Medical Readiness Questionnaire)

BORATORY INVENTORY

2.1

hysical Activity Readiness Questionnaire (PAR-Q)*

Q & You

Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people, physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small ber of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (✓) the ☐ YES ☐ NO opposite the question if it applies to you.

S NO

☐ 1. Has your doctor ever said you have heart trouble?

☐ 2. Do you frequently have pains in your heart and chest?

☐ 3. Do you often feel faint or have spells of severe dizziness?

☐ 4. Has a doctor ever said your blood pressure was too high?

☐ 5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

☐ 6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

☐ 7. Are you over age sixty-five and not accustomed to vigorous exercise?

you answered yes to any of the above questions, complete 8, 9,& 10 below.

es No

☐ ☐ 8. If you answered yes to any of the above questions, have you consulted with your physician regarding these conditions?

☐ ☐ 9. After consulting with your physician, has your physician cleared you for unrestricted physicial activity?

☐ ☐ 10. What restrictions, if any, has your physician placed on you?

____

____

have read the above questionaire, and to the best of my knowledge, elieve that my answers are true and correct.

__________________________ (signature) ________________ (date)

*Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE). Translation, reproduction and use in its entirety is encouraged. Modifications by written permission only. Not to be used for commercial advertising in order to solicit business from the public.

Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

*Produced by the British Columbia Ministry of Health and Department of National Health and Welfare.

You Answered YES to One or More Questions

ou have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical ivity and/or taking a fitness appraisal. Tell your physician what questions you answered YES to on PAR-Q or present your R-Q copy.

ograms

er medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity starting off easily and progressing gradually;
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

You Answered NO to All Questions

you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- a graduated exercise program—a gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort;
- a fitness appraisal—the Canadian Standardized Test of Fitness (CSTF).

Postpone

If you have a temporary minor illness, such as a common cold.

APPENDIX D

Survey of Activity Level

APPENDIX D

SURVEY OF ACTIVITY LEVEL

Please circle the answer that best describes you.

1. In one week, what is the average number of days that you participate in an exercise activity?

a.	0 days	e.	4 days
b.	1 day	f.	5 days
c.	2 days	g.	6 days
d.	3 days	h.	7 days

2. During one exercise session, how long do you exercise?

a.	0 minutes	d.	31 - 45 minutes
b.	1 - 15 minutes	e.	46 - 60 minutes
c.	16 - 30 minutes	f.	other (please specify)

3. How would you classify the majority of your exercise sessions?

   a. Very light

   b. Light

   c. Somewhat hard

   d. Hard

   e. Very hard

4. In what type(s) of activity do you regularly participate?

   Please list:____

APPENDIX E

Picture of Hydrostatic Tank

APPENDIX E

APPENDIX F

Formulas for Residual Volume, Body Density and Percent Body Fat

APPENDIX F

FORMULAS

Formulas for residual volume:

Males: RV = 0.24 x VC(BTPS)

Females: RV = 0.28 x VC(BTPS)

Formula for body density in grams/cc:

$$D_b = \frac{W_a}{K - (RV + 100)}$$

where

D_b = body density (gm/cc)
W_a = weight in air in grams
K = weight in air minus weight in water divided by the density of water at the weighing temperature
RV = residual volume in cc
100 = estimate of G.I. gas in cc

Brozek formula for percent body fat:

$$\text{percent of fat} = \frac{4.570}{D_b} - 4.142 \times 100$$

APPENDIX G

Body Composition (Percent Body Fat)
Computer Printout

BODY COMPOSITION
HYDROSTATIC WEIGHING
HUMAN PERFORMANCE LABORATORY

NAME: JOHN DOE SEX: MALE AGE: 22

MEASUREMENTS	RESULTS
1. DRY WEIGHT	150 LBS 68.1 KG
2. WATER WEIGHT	5.6 KG
3. SCALE (TARE) WEIGHT	1.25 KG
4. VITAL CAPACITY	4.7 LITERS
5. EXPIRED AIR TEMPERATURE	22.2 C 72 F
6. WATER TEMPERATURE	32 C 89.6 F

SUMMARY OF COMPUTATIONS

MEASUREMENTS	RESULTS
1. BODY DENSITY	1.085
2. SPECIFIC GRAVITY	1.091
3. PERCENT FAT (BROZEK FORMULA)	7
4. PERCENT FAT (SIRI FORMULA)	6.2
5. FAT WEIGHT	10 LBS
6. IDEAL BODY WEIGHT	160.9 LBS

-- BODY COMPOSITION CLASSIFICATION ACCORDING TO PERCENT BODY FAT --

MEN

AGE	IDEAL	GOOD	MODERATE	FAT	OBESE
< 19	12	12.5-17.0	17.5-22.0	22.5-27.0	27.5+
20-29	13	13.5-18.0	18.5-23.0	23.5-28.0	28.5+
30-39	14	14.5-19.0	19.5-24.0	24.5-29.0	29.5+
40-49	15	15.5-20.0	20.5-25.0	25.5-30.0	30.5+
> 50+	16	16.5-21.0	21.5-26.0	26.5-31.0	31.5+

WOMEN

< 19	17	17.5-22.0	22.5-27.0	27.5-32.0	32.5+
20-29	18	18.5-23.0	23.5-28.0	28.5-33.0	33.5+
30-39	19	19.5-24.0	24.5-29.0	29.5-34.0	34.5+
40-49	20	20.5-25.0	25.5-30.0	30.5-35.0	35.5+
> 50+	21	21.5-26.0	26.5-31.0	31.5-36.0	36.5+

APPENDIX H

Picture of Aqua Jogger (Excel Sport Science, Eugene, OR), and Tethering Rope and Belt

APPENDIX H

<u>APPENDIX I</u>

Picture of Deep Water Running Frame

APPENDIX I

APPENDIX J

Borg's Perceived Exertion Scale

APPENDIX J

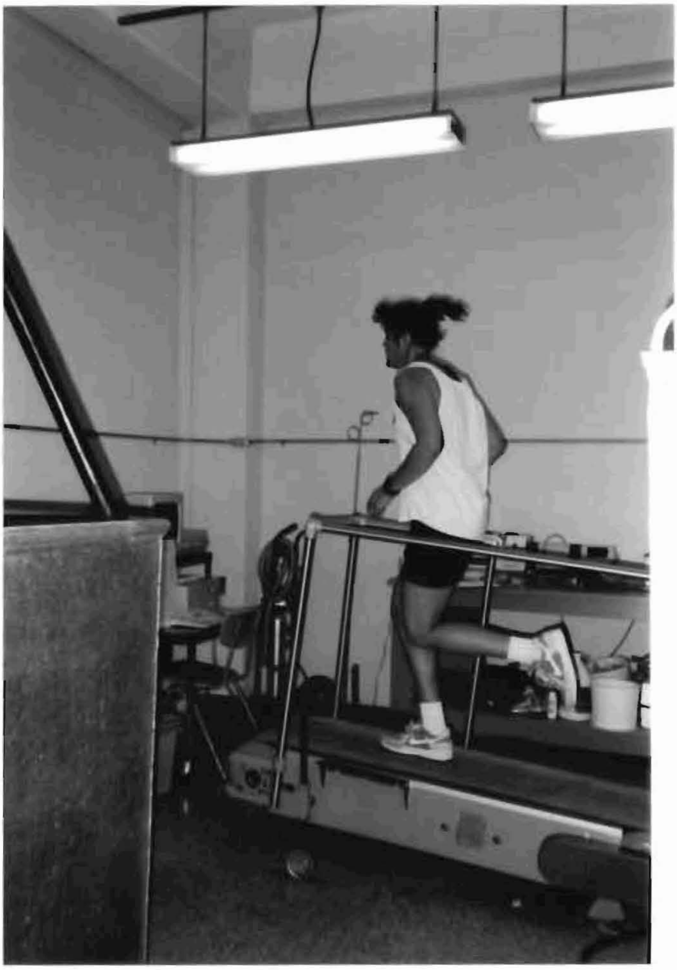
BORG'S PERCEIVED EXERTION SCALE

6
7 Very, very light
8
9 Very light
10
11 Fairly light
12
13 Somewhat hard
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20

APPENDIX K

Picture of Treadmill Running

APPENDIX K



<u>APPENDIX L</u>

Picture of Deep Water Running
with Floatation

APPENDIX L

APPENDIX M

Picture of Deep Water Running
Without Floatation

APPENDIX M

APPENDIX N

Table of Raw Data

APPENDIX N

Raw Data for Treadmill Running

(Heart Rate)

SUBJECT	70%	80%	90%	100%
1	148	164.5	179	194
2	125	155.5	176.5	201
3	141	155	168.5	185
4	134	149	159.5	190
5	141	160	176	194
6	143	165.5	182	194
7	138	165	173.5	193
8	123	142.5	156.5	182
9	133	145.5	160.5	182
10	153	163.5	175	197
11	119.5	146.5	158	180
12	161.5	175	194	209
13	163	181	190	198
14	144.5	160	179.5	198

Raw Data for Treadmill Running

(RPE)

SUBJECT	70%	80%	90%	100%
1	11	13	15	18
2	10	12	14	19
3	10	12	15	20
4	7	11	14	20
5	13	14	16	20
6	11	15	17	19
7	6	10	13	20
8	8	12	15	20
9	9	11	13	19
10	11	13	15	19
11	10	13	17	20
12	6	10	12	19
13	11	13	15	20
14	11	14	16	19

Raw Data for Deep Water Running without Floatation

(Heart Rate)

SUBJECT	70%	80%	90%	100%
1	142	152	172	174
2	150.5	177.5	192	185
3	143	154	162.5	169
4	145.5	154	147.5	179
5	116	130	146	161
6	135.5	149.5	161.5	182
7	156.5	166.5	172	170
8	138	141	146	170
9	112	136	140.5	158
10	109.5	121	149	180
11	143	149.5	149	156
12	168	175	185	194
13	155.5	175.5	NA	160
14	131	142.5	154.5	158

Raw Data for Deep Water Running without Floatation

(RPE)

SUBJECT	70%	80%	90%	100%
1	14	17	19	20
2	15	17	20	18
3	15	17	19	20
4	14	15	18	19
5	12	14	15	18
6	13	16	17	20
7	15	17	20	19
8	12	14	16	20
9	6	13	14	20
10	8	11	13	20
11	13	16	17	20
12	11	12	14	19
13	14	17	NA	20
14	12	14	16	18

Raw Data for Deep Water Running with Floatation

(Heart Rate)

SUBJECT	70%	80%	90%	100%
1	120	132	161	161
2	117	141	149.5	192
3	117.5	128	140.5	172
4	121	128	155	171
5	107	122	134.5	149
6	113	129	144	177
7	119.5	136	145	172
8	109	121	151.5	164
9	110.5	125	140.5	155
10	102	125	148	170
11	98.5	112	123.5	150
12	129.5	160	172.5	194
13	110.5	118.5	131	174
14	95	107	116.5	138

Raw Data for Deep Water Running with Floatation

(RPE)

SUBJECT	70%	80%	90%	100%
1	13	15	19	18
2	12	14	16	20
3	12	14	16	20
4	9	10	12	19
5	11	12	13	17
6	10	15	18	19
7	6	8	11	19
8	10	12	16	19
9	8	13	15	20
10	11	13	15	19
11	9	12	16	20
12	7	9	11	20
13	10	13	15	19
14	11	12	14	18

APPENDIX O

Data from Newman-Keuls Multiple Comparisons Test

APPENDIX O

Results of the Newman-Keuls Test for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at Maximum Heart Rate

	P	Q	CRITICAL VALUE
MEAN(1) - MEAN(3) = 25.57	3	12.50	3.517
MEAN(1) - MEAN(2) = 21.50	2	10.51	2.909
MEAN(2) - MEAN(3) = 4.07	2	1.99	2.909

Results of the Newman-Keuls Test for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 90% of Maximum Heart Rate

	P	Q	CRITICAL VALUE
MEAN(1) - MEAN(3) = 27.42	3	9.64	3.532
MEAN(1) - MEAN(2) = 12.38	2	4.35	2.919
MEAN(2) - MEAN(3) = 15.04	2	5.28	2.919

NOTE: MEAN(1) = TREADMILL, MEAN(2) = W/OUT FLOATATION, AND MEAN(3) = W/FLOATATION

Results of the Newman-Keuls Test for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 80% of Maximum Heart Rate

	P	Q	CRITICAL VALUE
MEAN(1) - MEAN(3) = 30.82	3	11.83	3.517
MEAN(1) - MEAN(2) = 7.46	2	2.87	2.909
MEAN(2) - MEAN(3) = 23.35	2	8.97	2.909

Results of the Newman-Keuls Test for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation at 70% of Maximum Heart Rate

	P	Q	CRITICAL VALUE
MEAN(1) - MEAN(3) = 28.39	3	9.26	3.517
MEAN(1) - MEAN(2) = 1.54	2	0.50	2.909
MEAN(2) - MEAN(3) = 26.86	2	8.76	2.909

Results of the Newman-Keuls Test for RPE at Maximum Workload for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

	P	Q	CRITICAL VALUE
MEAN(1) - MEAN(3) = 0.35	3	1.80	3.517
MEAN(1) - MEAN(2) = 0.17	2	0.36	2.909
MEAN(2) - MEAN(3) = 0.29	2	1.44	2.909

Results of the Newman-Keuls Test for RPE at 90% of Maximum Heart Rate for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

	P	Q	CRITICAL VALUE
MEAN(2) - MEAN(1) = 2.0	3	3.82	3.532
MEAN(2) - MEAN(3) = 2.0	2	3.82	2.919
MEAN(3) - MEAN(1) = 0.0	2	0.00	2.919

Results of the Newman-Keuls Test for RPE at 80% Maximum Heart Rate for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

	P	Q	CRITICAL VALUE
MEAN(2) - MEAN(3) = 2.71	3	6.52	3.517
MEAN(2) - MEAN(1) = 2.64	2	6.35	2.909
MEAN(1) - MEAN(3) = 0.07	2	0.07	2.909

Results of the Newman-Keuls Test for RPE at 70% of Maximum Heart Rate for Treadmill Running, Deep Water Running with Floatation, and Deep Water Running without Floatation

	P	Q	CRITICAL VALUE
MEAN(2) - MEAN(1) = 2.86	3	5.47	3.517
MEAN(2) - MEAN(3) = 2.50	2	4.78	2.909
MEAN(3) - MEAN(1) = 0.35	2	0.68	2.909

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Joan Carley Brewer
Signature of Author

5/5/94
Date

THE DIFFERENCE IN HEART RATE AND RATING OF PERCEIVED EXERTION AT DIFFERENT INTENSITIES OF LAND-BASED RUNNING AND WATER-BASED RUNNING

Title of Thesis/Research Project

Signature of Graduate Office Staff Member

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