ABSTRACT

GREENING, C. J. Effects of training on land and in water on VO_2max in college-aged men and women. M. S. in Adult Fitness/Cardiac Rehabilitation, December, 1989. 81 p. (N. K. Butts)

21 volunteers, aged 18-24 yrs, were randomly assigned to train on land (males, n=6; females, n=5) or in water (males, n=5; females, n=5) for 6 wks. Max exercise tests utilizing running protocols were completed on the TM and in the pool before and after training. A MANOVA with repeated measures was used to analyze diff in pre-post training, gender, mode of testing and type of training. For all groups, post-training VEmax, RERmax, and VO_2max were sig ($p<0.01$) higher than pre-training, while HRmax was sig ($p<0.01$) higher during pre-training trials. Males were sig ($p<0.01$) higher than females in VEmax, HRmax, and VO_2max. No sig ($p>0.01$) diff between gender was noted for RERmax. No interaction of factors was shown for gender, indicating that males and females responded similarly to training. TM values for VO_2max, and RERmax were sig ($p<0.01$) higher than pool values, with no sig ($p>0.01$) diff in VEmax or HRmax.There were no sig ($p>0.01$) diff in VEmax, HRmax or VO_2max between the group which trained on land versus in water. The only statistical sig ($p<0.01$) noted was the water group exhibited higher RERmax values than the land group, indicating the group which trained in water may have been more motivated during testing. Running on land and in water produced similar physiological adaptations to training, evident by no interaction between factors.

EFFECTS OF TRAINING ON LAND AND IN WATER ON VO_2MAX

IN COLLEGE AGED MEN AND WOMEN

A Thesis Presented

to

The Graduate Faculty

University of Wisconsin - La Crosse

In Partial Fulfillment

of the Requirements for the

Master of Science Degree

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by

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We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

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The candidate has completed his/her oral report.

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DEDICATIONS

This thesis is dedicated to those who provide the foundation for my accomplishments:

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To my sisters, Carol and Karen, who are my best friends through thick and thin.

To my brothers, Scott and Eric, who I know will always be there for me whenever I need them.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Benefits of regular aerobic exercise are generally common knowledge. Popular modalities of aerobic exercise include running, bicycling, swimming, and aerobic dance. Certainly there are pros and cons to each of these forms of exercise. The main concern for any method of exercise is that it be effective in producing positive physiological changes and/or improve exercise performance.

Recently, running in water has been advocated as an alternative exercise which allows specificity of training in a non-weight bearing medium thus reducing stress and minimizing injuries (Evans, Cureton, & Purvis, 1978; Perry, 1986; Williams, 1987). Use of this exercise medium for runners, as well as individuals restricted in their ability to exercise, may be a viable choice if, in fact, it does provide a sufficient conditioning stimulus.

Response to training while immersed in water versus on land has raised questions regarding corresponding physiological adaptations. Exercising in water may produce different responses due to the hydrostatic effect of water, altered heat dissipation (Avellini, Shapiro, & Pandolf, 1983), buoyancy and resistance (Costill, 1971; Johnson, Stromme, Adamczyk, & Tennoe, 1977). These factors are believed by some to affect venous return thus altering stroke volume and heart rate response. Since cardiac output has been noted to be the same at a given oxygen consumption level on land and in water, exercising in a water medium at the same heart rate as on land may provide a greater physiological stress due to the increased relative intensity (McArdle, Macel, Lesmes, & Pechar, 1976).

The training program and modality are major factors influencing exercise performance (Butts, 1982; Wells, Hecht, & Krahenbuhl, 1981). The degree of improvement with conditioning over time is also dependent upon age, initial health status (Astrand, 1960; Bruce, Larson, & Stratton, 1989; Costill, 1986; Pollock, 1978) and genetics (Bouchard et al., 1989; Prud'homme, Bouchard, Leblanc, Landry, & Fontaine, 1984).

Males and females do not differ in their ability to adapt to training (American College of Sports Medicine, 1979; Burke, 1977; Butts, Pein, & Stevenson, 1984; Costill, 1986), but differences in body size or lean muscle mass, heart size, body fat, hemoglobin concentration, and initial fitness levels usually make it inappropriate to make direct comparisons (Brooks & Fahey, 1985; Costill, 1986). The values for VO_2max are closer in studies which account for body size and composition when comparing the sexes, with the main difference in VO_2max then attributed primarily to differences in previous training (Maksud, Cannistra, & Dublinski, 1976; Sparling, 1980; Wells et al., 1981). Better exercise performances are usually attributed to higher VO_2max values rather than gender factors (Iwaoka, Hatta, Atomi, & Miyashita, 1988; Ramsbottom, Nute, & Williams, 1987).

Purpose of the Study

The purpose of this investigation was to compare the effects of training on land versus in water on maximal exercise performance in normal college aged males and females.

Need for the Study

The acclaimed benefit of improving cardiorespiratory fitness while maintaining the training specificity of running in a non-weight bearing medium is certainly desirable for runners. Unfortunately, the paucity of studies investigating the responses to training while running in water compared to similar training on land leaves this claim unsubstantiated.

The few research studies which have examined the physiological response to exercise in water have varied in their results. The discrepencies may be due to variations in body position, water temperature, depth of immersion, exercise modality, or the training methodology employed. Not only do these factors influence immediate physiological responses such as lowered heart rate, but may also affect the long term adaptations to training.

Null Hypothesis

When comparing maximal exercise performance, there will be no significant difference between physiological responses to training via running on land versus deep water running. The null hypothesis was tested at the 0.01 level of significance.

Assumptions

1. Subjects remained in proper form and kept with the cadence of the metronome while performing the VO_2max pool test.

2. Subjects maintained proper form during training.

3. Subjects reached their maximal oxygen uptake capacity in all pool and treadmill tests based on meeting at least two VO_2max criteria: attaining predicted maximal heart rate, exceeding a respiratory quotient of unity (>1.0), or leveling off of oxygen consumption signified by an increase of less than 150 ml/min or 2.1 ml/kg/min with an increased work load (ACSM, 1986; McConnell, 1988).

4. Subjects adhered to their training regime and honestly reported activity level.

5. Training activities for the group in the pool and on land were similar in intensity, duration and frequency.

Delimitations

1. All males (n=11) and females (n=10) were healthy and between the ages of 18-24 years.

2. Each subject completed both treadmill and pool VO_2max tests no more than 72 hours apart.

Limitations

1. All subjects were volunteers.

2. Training schedules and adherence to the program was under the direction of the PE 100 instructor and not under control of the author.

3. The training period was six weeks in duration.

4. Heart rates were self-monitored during training.

Definition of Terms

Cardiac Output (Q) - the product of stroke volume and heart rate expressed in liters of blood per minute (L/min) (Guyton, 1986).

Maximal Oxygen Uptake (VO_2max) - the maximum capacity for aerobic metabolism or the ability to consume, transport and use oxygen. This study determined VO_2max in males and females while using a continuous, multi-stage protocol running on a treadmill and in water before and after six weeks of training.

Training - subjects in this study ran on land or in water for six weeks, three times per week, at 75-90% of their predicted maximal heart rate (220-age) for a minimum of 20 minutes per session.

Wet Vest - a flotation device which allows the exerciser to remain in an upright position keeping the head above water thus facilitating an accurate running simulation (Bioenergetics).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The following review of related literature discusses training overload, training specificity, physiological adaptations to training, alterations made when immersed in water, exercise performance in water, and the response to training by women compared to men.

Training Overload Principle

The purpose of training is to stress the body to induce physiological adaptations which will help meet increased demands with less strain (Hickson, Hagberg, Ehsani, & Holloszy, 1981). The appropriate stress or overload applied regularly is necessary for optimal conditioning. When the stress is not sufficient no adaptation will occur. An insufficient overload is the most common cause for lack of training response (Brooks & Fahey, 1985). In contrast, if the stressors are too great, injury may ensue.

The workload can be manipulated by varying the volume or frequency and duration, or the intensity of the exercise session.

Frequency

Gettman et al. (1976) compared running one, three and five days per week for 30 minutes per session in 55 males ranging in age from 20-35 years old. Significant improvements occurred in resting and recovery heart rates, VO_2max, ventilation, treadmill time, and oxygen pulse in proportion to the number of days running. After 20 weeks of training those who ran one day a week improved VO_2max by 8%, for three days a week it increased 13%, and a 17% increase was reflected by running five days a week. Due to the fact that the incidence of leg injuries increased with frequency, running five days per week was not recommended for beginners. Pollock et al. (1972) found two days per week adequate for improved cardiovascular response as long as the training was of sufficient intensity and duration.

Brynteson and Sinning (1973) noted that VO_2max, oxygen pulse and recovery heart rates improved in response to training on a cycle ergometer for five weeks at 80% of maximum heart rate. The 21 male subjects, 20-38 years old, exercised either one, two, three or four days per week. The conclusion of the researchers was that for moderately trained males, exercising three or four days to maintain fitness was better than one or two days per week.

Duration

In a study conducted by Milesis et al. (1976), 59 healthy drug free male prison inmates, ages 20-35, underwent a walking/running program for 20 weeks, three times per week. The subjects were divided into separate groups which exercised for either 15, 30, 45 minutes or not at all. Each exercise group improved significantly in treadmill time, VO_2max, maximum oxygen pulse, resting blood pressure and percent body fat. The magnitude of improvement in these parameters varied in accordance with the duration of exercise. The authors concluded that sedentary individuals should train for 30 minutes or less initially since the 45 minute group incurred a disproportionate number of leg injuries.

It is generally accepted that exercising 15-60 minutes (American College of Sports Medicine, 1979) is appropriate, keeping in mind that 20-30 minutes is required to increase functional capacity (American College of Sports Medicine, 1986), and exercising more than 30-45 minutes per session increases the risk of injury (Pollock, 1978).

Intensity

An acceptable intensity of an exercise session to yield cardiovascular improvement ranges from 60% - 90% of maximum heart rate reserve or 50-85% of maximal oxygen uptake (American College of Sports Medicine, 1979).

Edwards (1974) looked at the effects of training 15 minutes daily for four weeks at predetermined heart rate levels in 12 sedentary women, aged 17-21 years. The objective of the study was to find an intensity threshold for improvement. The intensity levels chosen were based on past research which found that maximal stroke volume levels were associated with a heart rate of 120 beats per minute. The first group exercised at 125 beats per minute (59.0 - 66.5% max heart rate), and the second group at 145 beats per minute (71.1 - 80.6% max heart rate). Edwards concluded that exercising at 125 beats per minute provided a sufficient training stimulus to increase maximal oxygen intake in sedentary women.

Significant improvements in VO_2max, maximum oxygen pulse and ventilation were noted in 22 middle aged men who ran for 20 weeks, 2 days per week for 45 minutes at 80% or 90% of maximum heart rate (Pollock et al., 1972). The researchers commented that the two days per week were adequate for improvement and the different intensities had little effect. Since the 80% group actually exercised at a range of 78-83% maximum heart rate and the 90% group ranged from 87-94%, there may not have been a sufficient difference in the intensities between the groups to determine a threshold.

Progression

The overload factors, frequency, duration and intensity, are all important components of the exercise prescription and are difficult to separate. The conditioning response to each session is a product of the intensity and duration or total energy expended. According to Pollock et al. (1972) and Pollock (1978), 300 calories expended per workout is the minimum level in order to achieve a training effect. The threshold level for improvement will vary according to the initial physical status and the energy cost of the exercise session. Individuals at a low fitness level will improve with a lower exercise intensity (Pollock, 1978). Exercising 5-10 minutes at 90%, or 20-30 minutes at 40-70% will improve capacity but the former alternative would not be appropriate for sedentary individuals (American College of Sports Medicine, 1986; Pollock, 1978).

Some researchers feel that adaptation of tissues to an exercise program is a slow process which happens over a period of time, therefore, it is important to gradually increase stress applied over weeks or even months (Costill, 1986; Gettman et al., 1976; Guyton, 1986). Hickson et al. (1981) found the adaptation process which can limit VO_2max to be actually rather rapid with a half life of less than 11 days. They stated that unless the training stimulus is increased after three weeks, the exercise program becomes a maintenance program with no further gains in VO_2max. Costill (1986) noted that because of the fine line between adaptation and overstress, it is sometimes difficult to prescribe an optimal training level for sedentary individuals.

Training Specificity

It is generally accepted that the adaptations which occur in response to habitual overload are specific to the muscle groups that are exercised or on the recruitment of specific motor units within a muscle. Training adaptations are also specific to the energy system supporting the activity, which is largely determined by the intensity of work performed in a period of time (Brooks & Fahey, 1985; Wilt, 1972).

Mode

Choice modes of exercise to improve cardiorespiratory fitness include endurance activities which involve movement of large muscle mass in a continuous, rhythmical fashion such as in running, walking, cycling, cross-country skiing and swimming. On the other hand, static exercise such as weight training has not been found to be beneficial in altering cardiovascular response. Longhurst, Kelly, Gonyea, and Mitchell (1980) found endurance runners had lower heart rates, diastolic blood pressure, and higher stroke volume at rest, whereas weight lifters were similar to control subjects for these measures.

It is important to recognize that the mode used to measure maximal oxygen uptake may influence values obtained. Buchfuhrer et al. (1983) tested 12 male volunteers on a treadmill and an electronically braked cycle ergometer. The treadmill tests yielded higher values for VO_2max, CO_2max, oxygen pulse, anaerobic threshold, and heart rates. The maxVE, respiratory exchange and ventilatory equivalent ratios were not significantly different.

The protocol may influence the test results as well. Work load increments which elicit test durations of less than eight minutes, or greater than 17 minutes, yield lower values of 10% and 5%, respectively, on a cycle as well as a treadmill (Buchfuhrer et al., 1983). Discontinuous versus continuous protocols have not been found to yield signficantly different values for maximal heart rate, oxygen consumption or respiratory exchange ratio in swimming (Meerloo, Collis, & Wenger, 1987), or cycling tests (Lawler, Powers, & Dodd, 1987).

The highest VO_2max values have been shown when using a modality that utilizes the same muscle groups trained. In 1978, McArdle et al. evaluated 19 college-aged male recreational swimmers via treadmill and tethered swimming. Testing was completed before and after the experimental group (n=11) exercised by running 20 minutes, three times weekly for 10 weeks at 85% of their maximal heart rate, as determined by the initial treadmill test. Values obtained on the treadmill versus tethered swimming for oxygen consumption, ventilation, respiratory exchange, and heart rate were significantly less during the tethered swim trial. After run training, relative VO_2max values significantly increased by 6.3% as measured by the treadmill trial (54.6 to 58.2), and only by 2.6% during tethered swimming (from 45.1 to 46.5). The lower increase shown during the tethered swimming exemplifies the specificity of metabolic adaptation to training. McArdle et al. concluded that run training was not an effective way to increase maximal aerobic power during swimming.

Training Methodology

An individual's state of training, exercise tolerance, and the pace and distance of each training session determine the number of weekly sessions which should be included in a training program. The development of a training program must also include a balance between work and rest. Most importantly, rest periods need to be considered since at that time anabolic reactions occur. In addition, hard and easy days should be alternated to provide the needed variation in stress and rest (Brooks & Fahey, 1985; Costill, 1986).

Several training options are available to runners. A combination of techniques is ideal in order to maximize motor unit recruitment. To start, total mileage, often quantified as miles per week, is an important consideration. A survey questionnaire completed by 428 Swiss female contestants who participated in a 16 kilometer race was analyzed to look at previous running activity, injuries, as well as other lifestyle factors. The researcher (Marti, 1988) found that the average kilometers run weekly was an important determinant of endurance capacity. In this epidemiological study it was also determined that women who ran 25 kilometers per week or more had a higher endurance capacity than men in the general population. Unfortunately an increase in injuries was also noted with running more than 20 kilometers per week.

An overview of various training techniques described by Costill (1986) are summarized below:

Long slow distance involves running at least 45-75 minutes continuously at a fairly steady speed. The intensity usually is lower with heart rates of approximately 130-170 beats per minute.

Aerobic interval training generally describes repeated runs at a faster pace, five to six seconds less than a 10K pace or at 70% VO_2max over shorter distance with brief rest intervals of 10-15 seconds. This form of training elicits gains similar to running five to six miles hard but provides more variety to the routine. Ekblom, Astrand, Saltin, Stenberg, & Wallstrom (1968) described interval running more specifically as three to seven repetitions of running bouts that are three to six minutes in duration at 70-75% of maximal heart rate, each bout is followed by three to four minutes of rest.

Aerobic-anaerobic interval training generally involves running at or near race pace or 80-95% of VO_2max with a heart rate greater than 160 bpm. Rest intervals of 30-45 seconds are manipulated so that the race pace can be repeated. Since recovery is slower due to muscle glycogen breakdown and lactate accumulation, this form of training should only be incorporated two to three times in a week.

Anaerobic interval training is the most stressful form of training, thus should be limited to once or twice weekly. Maximal bursts of running should be followed by two minute rest intervals. Anaerobic training elicits increases in strength, speed, and develops the ability to remove lactate, therefore increasing the tolerance of greater race pace speed. An increased risk of injury demands that a warm-up and mild stretching be done prior. Total distance is not as important when utilizing this form of training since the purpose and response is generally improvement in strength. Ekblom et al. (1968)

described this as "Dash Training" and specify's that it include five to 10 repetitions of 30 to 60 seconds of exercise at full speed with two to three minutes of rest between. Heart rates should reach 150-170 beats per minute and blood lactate exceed 10 mmoles/liter.

Steady state pace training as described by Priest and Hagan (1987), involves running at a pace which elicits blood lactate levels of approximately 2.2 mmol/L. In their study, after seven weeks of training by running at a mean steady state pace, the 12 male runners improved their mean steady state training pace (11.3%), improved VO_2max (8.1% ml/kg/min; 8.9% L/min), running performance times, and reduced heart rate responses at rest and during submaximal exercise.

Adaptations to Training

The magnitude of physiological adaptations due to endurance training is largely dependent on the initial fitness status (Burke, 1977; Butts et al, 1984; Drinkwater, 1973; Ekblom et al., 1968) and experience. Priest and Hagan (1987) separated male volunteers into novice and experienced running groups. When comparing the improvement in VO_2max between the groups, novice runners improved by 11.1%, with a significant improvement in anaerobic power as well. Experienced runners only showed a 5.8% improvement in relative oxygen consumption capacity.

Endurance training produces physiological adaptations which result in increased VO_2max ranging from 8-23% (Brynteson & Sinning, 1973; Ekblom et al., 1968; Evans et al., 1978; Gettman et al., 1976; Milesis et al., 1976; Pollock et al., 1972; Priest & Hagan, 1987). Adaptations which result from training that affect maximal exercise capacity include an increased arterial-venous oxygen difference (Bevegard, Holmgren, & Jonsson, 1963; Ekblom et al., 1968), number (Kiesling, Piehl, & Lundquist, 1971) and size of mitochondria (Morgan, Cobb, Short, Ross, & Gunn, 1971), increased coronary and active muscle blood flow (Costill, 1986), stroke volume, and cardiac output (Ekblom et al., 1968; Costill, 1986; Rerych, Scholz, Sabiston & Jones, 1980), improved ability to use fat as a fuel (Astrand, 1960; Meyer, Mayer, Weib & Weicker, 1988; Morgan et al., 1971), and an improved ability to sustain increased breathing rate and volume by the respiratory muscles (Costill, 1986).

The most significant improvement in VO_2max is believed to be a result of improvement in the ability to deliver blood via increased cardiac output. Since maximal heart rate is not thought to change with training, the increase in cardiac output is due to a greater stroke volume in athletes (Bevegard et al., 1963; Rerych et al., 1980). Past research has clearly documented larger stroke volumes in endurance trained athletes. A greater stroke volume is primarily attributed to structural changes enlarging the heart (Bevegard et al., 1963; Hickson et al., 1981; Longhurst et al., 1980), increased end-diastolic volume due to the change in heart size (Longhurst et al., 1980; Rerych et al., 1980), and enhanced myocardial contractility through the Frank-Starling mechanism (Hickson et al., 1981; Rerych et al., 1980). Improved venous return, slower heart rate and an increase in stroke volume means less work will be required of the heart to maintain cardiac output.

A greater difference between arterial and venous oxygen content is also evident in trained individuals. Ekblom et al. (1968) stated that since they found no increase in the arterial oxygen, the difference had to be due to a greater decrease in oxygen in the mixed venous blood. The researchers felt this improvement in the extraction of oxygen was probably due to less blood distributed to inactive parts of the body. It may also be due to greater extraction by the working muscles, increases in the number of capillaries and mitochondria, and an increase in muscle mass (Brooks & Fahey, 1985). Although athletes have a greater arterial-venous oxygen difference than non-trained individuals, the difference is not considered to contribute to the increased oxygen transport capacity as significantly as the increase in stroke volume (Bevegard et al., 1963).

Endurance training has been recognized as a factor in attenuated resting and submaximal heart rate response. Chronic changes in heart rate may be due to changes in the autonomic balance with training (Meyer et al., 1988; Priest & Hagan, 1987; Smith, Hudson, Graitzer, & Raven, 1989).

Water Immersion

Unique properties of water, such as hydrostatic pressure, heat dissipation, and resistance, influence several hemodynamic alterations. Immediate circulatory changes and heart rate response may vary depending on factors such as body position and immersion in water.

Influence of Body Position

In general, body position will not significantly affect heart rate (Begin et al., 1976; Bevegard et al., 1963). In contrast, stroke volume at rest will be greatest in a supine position (Bevegard et al., 1963; Lange, Lange, Echt, Gauer, & Dannenberg, 1974) and arterial-venous oxygen difference is greatest when sitting (Bevegard et al., 1963). During exercise, stroke volume will increase the greatest when in an upright position due to enhanced venous return and left ventricular end-diastolic volume (Bevegard et al., 1963; Longhurst et al., 1980). VO_2max values have been found to be lowest when supine (Costill, 1971).

It is interesting to note that Begin et al. (1976) found no significant changes in VO_2, cardiac index, diffusing capacity, or heart rate when immersed in the supine position compared to the supine position in air. These researchers noted that redistribution of blood which results from an upright position to supine is similar, although not as great, as the redistribution that occurs while immersed in an upright position. Lange et al. (1974) studied ten male volunteers between the ages of 24 and 32 years and found a mean heart volume of 658.8 ml when standing, an increase in stroke volume to 739 ml when supine, and 839.1 ml while standing in water. The conclusion of these researchers was that the change in blood volume when immersed is twice as great as the shift due to the supine position.

Hydrostatic Pressure

When immersed in water, the hydrostatic pressure forces blood from the periphery to the thoracic area. This redistribution of blood may result in hemodynamic alterations in peripherial resistance, venous return and cardiac output (Arborelius, Balldin, Lilja, & Lundgren, 1972; Begin et al., 1976).

Ten healthy volunteers were studied by Arborelius et al. (1972) while sitting in air at $28^{\circ}C$, in $35^{\circ}C$ water and while breathing oxygen in air. Catheters were inserted to measure pressure in the right atrium, pulmonary artery and left brachial artery. Cardiac output, as measured using a dye dilution method, was 32% greater when immersed due to a 35% increase in stroke volume even though there was a slight decrease in heart rate. These changes were thought to result from a hydrostatic pressure gradient exerted on the body which displaced blood from the lower extremities to the thoracic area. The blood volume displacement was evident with an increased pressure in the centrally located pulmonary arteries and right atrium while pressure changes in the left brachial artery only rose 10 mmHg, with a 15 mmHg increase in the hydrostatic pressure. The researchers thought the decrease in peripherial resistance was a result of low pressure receptors activation in an effort to maintain blood pressure, although arterial baroreceptors are more likely to play a role.

Begin et al. (1976) also looked at circulatory changes during water immersion to the neck. Their findings were in agreement with Arborelius et al. (1972) in that immersion in the seated position resulted in a redistribution of blood volume from the periphery into the thoracic area. The five young men in this study underwent examination during six hours of sitting in air, four hours of sitting in thermo-neutral water, and four hours while supine in water up to the sternoclavicular notch. Immersion while seated resulted in no change in oxygen consumption or heart rate, as estimated by counting the radial pulse. Nor was the vascular engorgement of blood in the central area accompanied by fluid into the pulmonary interstitial space. There was a 36% decline in functional residual capacity which was probably due to more blood occupying space in the thoracic area along with the increased hydrostatic pressure. The significant increase found in pulmonary capillary flow (25-36%) and diffusing capacity per unit of alveolar volume were not surprising since these factors relate to the pulmonary intravascular pressure changes, and, as Arborelius et al. (1972) found, immersion increased the pulmonary arterial pressure. Lastly, cardiac index (L blood/min/M^2) increased significantly as well. Once again, changes were found in cardiac output and stroke volume which reflect altered blood circulation and pressure due to immersion.

Heat Dissipation

Water is also noted for its heat dissipating quality. This assistance in heat loss also means less blood flow to the skin, potentially improving venous return as well as allowing more blood to go directly to the working muscles.

Colder temperatures are associated with changes in catecholamines which influence the circulatory adjustments. Weib, Hack, Stehle, Pollert and Weicker (1988) demonstrated that when subjected to cold on land and in water, there was an increase in norepinephrine and slight decrease in epinephrine levels in the resting state. The increased secretion of norepinephrine, probably triggered by thermoreceptors in the skin, resulted in reduced blood flow to the skin and an increased stroke volume. In opposition to rest, cycling in water of lower temperatures elicited a decrease in norepinephrine as well as heart rate and oxygen pulse, while stroke volume increased. Since blood flow to the skin was less, peripherial resistance increased and less norepinephrine was needed for vasoconstriction. Increased peripherial vascular resistance due to less need to dissipate heat was also noted in

1971 by Costill.

Six males took part in a study conducted by McArdle et al. (1976) where the subjects exercised on an air-water cycle ergometer utilizing both arm and leg pedals while in air, and water of 18, 25, and 33°C. The subjects displayed a linear relationship to oxygen consumption with the exercise workload under all conditions. In fact the oxygen consumption and response to exercise for air and 33°C water were almost identical. Cardiac output, ventilation and the arterial-venous oxygen difference were maintained during succeeding work loads. Heart rate response to a given workload decreased with colder water temperatures; heart rates at 25°C and 18°C were 10 and 15 beats per minute lower, respectively. The researchers concluded that the decreased temperature to 18°C and 25°C were the primary cause for the hemodynamic adjustments and increase in stroke volume.

McMurray, Horvath, and Miles (1983) also found a decreased heart rate response to exercise corresponding with change in temperature while cardiac output remained constant. During exercise, runners' heart rates only increased 5.0, 5.4 and 5.8 beats per minute in water of 20°C, 25°C and 30°C, respectively, while in thermoneutral water of 35°C, the heart rate increased 15.2 beats per minute. Heart rates of the water polo swimmers increased by 10.8, 10.5, and 19.0 beats per minute at the respective cooler water temperatures, and by 24.7 beats per minute in water of 35°C. Although heart rate response was altered in both groups, training in the water medium actually induced adaptations to compensate for heat loss in the water polo swimmers. The trained runners were adapted more for heat dissipation since they did not train in a heat loss environment. The water polo players were unable to maintain stroke volume and increased heart rate while exercising in water, and the runners increased cardiac output with a lower heart rate.

Body fat percent is also an important factor in determining heat loss in cold water. A higher percent of adipose tissue will aid thermoregulation in cooler water (Brooks & Fahey, 1985; McArdle et al., 1976; McMurray et al., 1983).

Water Resistance

Evans et al. (1978) studied six males, aged 21-42 years, while walking or jogging at various speeds on a treadmill versus in waist deep water. The researchers concluded that 1/2 to 1/3 the speed was required to work at the same level of energy during exercise in waist deep water as compared to on land since the water medium elicited an increase in energy expenditure due to the added resistance. Others have noted elevated heart rates and energy expenditure attributed to water resistance as well (Costill, 1971; Johnson et al., 1977; Whitley & Schoene, 1987).

A water running study using the "Wet Vest" was conducted by Bishop, Frazier and Smith in 1987. In seven male runners they found that during 45 minutes of self paced running, values for treadmill versus water running were significantly higher for ventilation (79.1 vs 58.1 L/min), oxygen consumption (2.68 vs 1.97 L/min), and respiratory exchange ratio (.95 vs .91), respectively. Heart rates (157 vs 122 beats per minute), and perceived exertions (10.7 vs 11.7) were not significantly different. Accordingly, the researchers concluded that since ventilation, oxygen consumption and respiratory exchange were lower during water running, metabolic costs of self paced running was less in the water medium.

Coad, Storie, Perez, and Wygand (1987) also measured physiological parameters while running and walking in water with weight supported by a "Wet Vest" and compared the results to the same activity on a treadmill. Ventilation, oxygen consumption and caloric expenditure while walking in water were significantly higher than walking on land due to the movement being done against the resistance of the water. In contrast, values for running in water were not different than those on land. This finding was noted to be due to an inability of the subjects to maintain proper form with a higher cadence while in the water.

Exercise Performance in Water

The hemodynamic alterations produced during water immersion affect exercise and training. Disagreement in the literature regarding the adjustments made to exercise in a water medium may be due to different training methodology used, the water temperature, or mode of exercise employed.

In a study by Beaudet (1984), swimming and run training were compared. An assessment was done on a cycle ergometer to use muscle mass not affiliated with training specificity and eliminate bias of training. After six weeks of training at 150 beats per minute for 12 minutes four times weekly by swimming in a pool or running on a treadmill at 3% grade, the improvements in VO_2max (5.8 ml/kg/min for runners; 6.3 ml/kg/min for swimmers) were not significantly different. Swimming resulted in cardiorespiratory fitness gains similar to running on a treadmill when measured on a cycle ergometer.

Sheldahl et al. (1986) looked at the influence of water on training as well. In their study, the male volunteers trained on a cycle ergometer on land (n=9) or in water (n=9) for 12 weeks, three times weekly at 60-80% of maximal heart rate. They found that while VO_2max, as measured on a cycle ergometer, increased significantly for both the land (16%) and water (14%) group, the difference between training methods was not significant. During submaximal exercise both groups decreased heart rates, and increased stroke volume and cardiac output. It was concluded that exercise training in a non-weight bearing medium (i.e., water) was beneficial and that redistribution of blood volume does not change adaptations to training.

Avellini et al. (1983) had 15 males train while seated upright on a cycle ergometer on land, in thermoneutral water (32^{o}C), and in cold water (20^{o}C) for four weeks. Exercise intensity was increased from 75% to 90% VO_2max in succeeding weeks. Heart rate values corresponding to the same VO_2 levels were significantly lower for the water groups throughout the training duration. As a result of training, all groups significantly increased their VO_2max by 15.9, 12.6 and 15%, respectively. Although the water medium did not provide a greater training stimulus, the individuals in water trained with lower heart rate values and greater stroke volume, thus the heart was more efficient at transporting oxygen.

Differences between Gender

In order to compare exercise performance and training response in males and females, variances in body size, the quality of training encountered, and initial fitness levels should be accounted for

(Drinkwater, 1973) since these factors may profoundly affect the interpretation of the results.

Response to Training

Males and females respond similarly to training. Butts et al. (1984) conducted a study in which males and females underwent an eight week swimming program. The subjects swam 90 minutes per day, five days a week at an initial exercise intensity of 60% of maximum heart rate, and 80-85% during the final six weeks. Every effort was made to ensure that the training program was equivalent for both sexes. Data were analyzed for 14 males and 14 females, in which maximal ventilation and VO_2max (L/min and ml/kg/min) was significantly higher. No significant differences were noted for maximal heart rates or respiratory exchange ratios. In response to the exercise training, males and females both improved their absolute (7.9% & 8.7% L/min, respectively) and relative (10.2% & 9.7% ml/kg/min, respectively) maximal oxygen capacity. No significant improvements were made by males or females in maximal ventilation, heart rate or respiratory exchange ratios. This study confirmed the belief that both sexes respond similarly to the same training stimulus. Peak power values were also measured in this study which revealed women increasing in power by 13.5% and men improving by 4.6%. This variation in improvement is accounted for by the fact that the women had much lower power initially (46% of the males' value). Since there was no significant interaction between the sexes with the power increases, the point was reiterated that the males and females in this study responded similarly to equal training.

In 1977, Burke conducted a study comparing nine untrained college-aged males and eight females to see if there was a difference between gender in response to similar training. The subjects completed eight weeks of training three times weekly at an intensity of 75-85% of maximum heart rate. The training session included 1/2-mile interval runs separated by 1/4-mile walks. Training progressed from 1 mile to 2 1/2 miles of running on a track. The total distance that was run was equal for both sexes, therefore the time training each session varied since men completed the mileage in a shorter period of time. Primary sex differences were weight and ventilation at VO_2max. Both males and females improved in VO_2max (17% versus 24% mk/kg/min, respectively; 17% versus 22% L/min, respectively), VE at VO_2max (26% versus 18%, respectively), and oxygen pulse at VO_2max (18% versus 25%, respectively). Initially, there was a 22% difference in aerobic capacity between the sexes, after training there was only an 8% difference in VO_2max. In conclusion, Burke stated "that the average female can expect relative improvement in aerobic power similar to that of a male following a period of systematic training," (p. 515) and, the greater gains derived from training were probably due to the lower initial health status of the women.

Fitness level categories are generally developed and based upon aerobic capacity. Table 1 summarizes fitness categories for males and females aged 20-29. The appropriate category is based upon relative oxygen consumption (American Heart Association, 1972).

Table 1. Aerobic work capacity (ml/kg/min) for males and females aged 20-29.

	Low	Fair	Average	Good	High
Females	<24	24 - 30	31 - 37	38 - 48	>49
Males	<25	25 - 33	34 - 42	43 - 52	>53

Energy Cost

Researchers have found little difference between the sexes when comparing energy cost at a given submaximal workload (Maksud et al., 1976; Ramsbottom et al., 1987; Wells et al., 1981).

Maksud et al. (1976) tested 26 females who participated in intercollegiate sports at the end of their competitive season and found that their energy costs at various submaximal levels of a modified Balke treadmill protocol to be similar to values reported for males.

A study by Wells et al. (1981) found four endurance trained women with similar relative maximal oxygen capacity as seven endurance trained men, ran at a higher percentage of their VO_2max during a marathon. This difference in the ability of the women to utilize a greater percentage of their oxygen capacity was probably due to the variations in which the groups trained. The males trained for the marathon by running an average of 66.7 miles per week at slow to moderate paces. The females trained by combining fast steady-state running with high intensity interval work, averaging 80.8 miles per week. It was also noted that the women of this study performed as well or better than men who had similar maximal aerobic capacities relative to body weight. Energy cost required to complete the 42.2 km was calculated to be slightly lower for the women of this study group (2,191 Kcal vs 2,903 for women and men, respectively) due to smaller body size.

Aerobic Capacity

In the past, speed and endurance for women has been noted to be less than values attained by men due to physiological and structural factors (James & Brubaker, 1973). Lower oxygen transportation capacities for women are believed to be a result of a decreased stroke volume at maximal exercise primarily due to differences in heart size as well as lower hemoglobin values. Less muscle mass and greater body fat percentages are also physiological differences that may lower maximal exercise capacity.

Senior physical education male (n=55) and female (n=43) students were assessed on a treadmill to determine maximal oxygen consumption and oxygen cost of submaximal running by Ramsbottom et al. (1987). The males had significantly greater VO_2max values (57.6 ml/kg/min versus 46.6 ml/kg/min for males and females, respectively) while maximal heart rates and energy cost at a given submaximal level were the same. The researchers concluded that the males could have greater VO_2max values due to greater cardiac output, oxygen carrying capacity of the blood, and differences in body fat.

In 1988, Iwaoka et al. compared ten male and eight female competitive runners. VO_2max (ml/kg/min) was significantly greater in the males, but when compared on the basis of lean body mass the difference was reduced substantially to 74.4 versus 71.6 ml/kgLBM/min for males and females, respectively. The researchers also looked at lactate thresholds, as a representative of peripheral circulation and local metabolism, and at respiratory compensation thresholds, an indicator of metabolic acidosis. No significant differences were found between the males and females when looking at these values on a %VO_2max basis (lactate threshold = 66.4% vs 63.6%; respiratory compensation threshold = 69.9% vs 73.1%). The authors did find that the lactate threshold occurred at a higher treadmill speed and VO_2 for the men. This discrepancy was attributed to the fact that the men trained 100 to 140 km/wk and the women only ran 60-70 km/wk. The respiratory compensation threshold was highly correlated to running performance in both groups.

Sparling (1980) reviewed differences in maximal exercise capacity between males and females through a meta-analysis study. He found that males had a 56% greater VO_2max than women. The difference was lessened when compared relative to body size (28% greater ml/kg/min), or lean body mass (15% greater ml/kgLMB/min). Although the magnitude of the difference was less when equating for body size, there was still a 12-15% difference probably due to differences in hemoglobin and physical activity levels.

Summary

Many factors come into play which affect the response to training. The magnitude of physiological adaptations depend upon the individual's health status (Priest & Hagan, 1987), the training stimulus (American College of Sports Medicine, 1979, 1986; Brynteson & Sinning, 1973; Buchfuhrer et al., 1983; Gettman et al., 1976; Guyton, 1986; Hickson et al., 1981; Longhurst et al., 1980; Milesis et al., 1976; Pollock et al., 1972), and methodology employed (Costill, 1986; Ekblom et al., 1968; Priest & Hagan, 1987).

The ability to consume, transport and use oxygen improves with training. Physiological adaptations which improve this capacity involve several peripheral and central factors. Various peripheral factors improve the consumption and utilization of oxygen. For instance, muscle mass is increased (Brooks & Fahey, 1985), along with mitochondria (Kiesling et al., 1971; Morgan et al., 1971), and increased ventilation capacity (Costill, 1986). Central components contribute significantly to the transportation of oxygen. Changes with training include an increase in cardiac output due to enhanced stroke volume (Bevegard et al., 1963; Rerych et al., 1980) and a decreased heart rate.

Immersion in a water medium is believed to result in several hemodynamic changes, particularly the redistribution of blood volume or enhanced venous return. These changes are often reflected by a lower heart rate response to exercise. If cardiac output is maintained at a given work load, a lower heart rate and enhanced stroke volume would indicate less demand on the heart and more efficient pumping of blood to the periphery. Earlier research indicated that exercising in water may result in a greater relative training intensity due to the hemodynamic alterations (McArdle et al., 1976). Many of the studies examining the effects of exercise and training on land versus water reflect no significant difference in the physiological measures between the exercise mediums (Avellini et al., 1983; Bishop et al., 1987; Coad et al., 1987; Sheldahl et al., 1986).

Differences between males and females in oxygen transportation capacities are attributed to differences in heart size, hemoglobin, body fat, and total muscle mass available. Little difference is found when comparing oxygen cost, and the magnitude of the difference in VO_2max is lessened when compared relative to lean body composition and initial fitness level (Drinkwater, 1973; Iwaoka et al., 1988; Maksud et al., 1976; Ramsbottom et al., 1987; Sparling, 1980; Wells et al., 1981). Response to training is also noted to be similar when similar training programs are employed (Butts et al., 1984; Burke, 1977).

CHAPTER III

METHOD AND PROCEDURE

Introduction

The purpose of this study was to compare the effects of training on land versus in deep water on maximal exercise performance. This chapter discusses the subjects, data collection, training, and the statistical treatment employed.

Subjects

The subjects included 21 volunteers who were 18 - 24 years old enrolled in the University of Wisconsin-LaCrosse Jogging and Fitness course. Each subject signed an informed consent (see Appendix A) prior to participation in any phase of the study. Subjects reported they were fairly inactive with the majority running less than five miles per week. Subject names were drawn out of a box to randomly divide the volunteers into two training groups, land (L) and water (W). Group L_m, consisted of five males, and L_f, consisted of five females, who trained by running on land. Group W_m, was composed of six males, and W_f, five females, who trained by running in deep water while wearing a Wet Vest.

Data Collection

All testing and data collection were conducted at the University of Wisconsin-La Crosse. Four VO_2max tests were completed by each volunteer. These included a treadmill and pool test performed prior to training and after six weeks of training. All pre-tests were completed within a four day period. Each subject completed the treadmill and pool VO_2max tests within 24 to 72 hours. The same procedures held true for post-testing.

Land Trials

Subjects completed a treadmill practice session prior to participating in the pre-test. The practice session consisted of getting on and off the treadmill, as well as walking and running at various speeds until the subject was comfortable.

Height and weight were measured and recorded prior to each test. Heart rates were monitored continuously through ECG using a Burdick M200 Monitor recorder. The skin was prepped with alcohol gauze pads and an abrasive pad prior to placing disposable electrodes on the individual. A Lead II was used for all subjects with the right arm electrode placed on the midclavicular line immediately inferior to the right clavicle. The left leg and right leg ground electrodes were placed on the midclavicular line below the inferior border of the left and right rib cage, avoiding large muscle mass. A Burdick EK-8 single channel recorder was used to record a rhythm strip on ECG heat sensitive paper during the last 15 seconds of each minute interval. Heart rate was calculated by counting the number of cardiac cycles within 15 seconds and multiplying by four to give the estimated beats per minute.

Gas analyses were done using open-circuit spirometry with a Beckman Metabolic Measurement Cart (MMC) as described by Wilmore, Davis, and Norton (1976). The oxygen (OM-11) and carbon dioxide (LB-2) analyzers were calibrated before and after each test with known gases standardized by the Scholander Technique. Values given from the gas analysis which were recorded minute by minute and at maximal exercise for each subject included VE (L/min), VO_2 (ml/min and ml/kg/min), VCO_2 (ml/min), and RER.

At the end of the warm-up period and each stage thereafter, the rating of perceived exertion (RPE) was determined using Borg's scale (Borg, 1982; Borg & Linderholm, 1967; Borg & Noble, 1974) (see Appendix B) to assess the subjects' perception of how hard they were working and assist with the testing process (Ekblom & Goldbarg, 1971; Noble, 1982; Pandolf, 1982). Prior to each test the following instructions were given to the subject:

> Throughout the test we will ask you how hard you feel you are working. This RPE chart ranges from six to 20, with six indicating the lightest possible effort and 20 being a maximal effort or the hardest. There are no right or wrong answers, we simply want you to point to a number and that number will indicate to us how you are feeling. Remember we will encourage you to continue on as far as you can but you are in control and can stop the test at anytime. Do you understand?

The treadmill VO_2max test was conducted on a motor driven pit treadmill using a continuous multistage protocol. The male subjects warmed up by running for five minutes at 6 miles per hour at 0% grade. The workload then was initially increased to 7.5 miles per hour at 2.5% grade, followed by continued grade increases of 2.5% every two minutes until a 10% grade was attained. Thereafter speed was increased by 0.5 miles per hour each two minutes (see Appendix C). Female subjects warmed up by running for five minutes at 5 miles per hour at 0% grade. The workload then increased initially to 6 miles per hour at 2.5% grade, followed by continued grade increases of 2.5% every two minutes until a 10% grade was attained. Speed was then increased by 0.5 miles per hour per successive stage (see Appendix D).

The test was terminated upon volitional exhaustion or upon reaching VO_2max as determined by attaining a predicted maximal heart rate (220-age), exceeding an R value of 1.0, and/or demonstrating a leveling off of VO_2 values by increases less than 150 ml/min or 2.1 ml/kg/min with an increased work load (American College of Sports Medicine, 1986; McConnell, 1988). A minimum of 30 seconds of work was required to accept the corresponding values as maximal oxygen capacity, values computed from less than 30 seconds were disregarded.

Water Trials

All subjects attended a familiarization session for deep water running. Prior to entering the pool, subjects were fitted with a Wet Vest (Bioenergetics). The Vest was fitted tightly but allowed freedom of movement. Proper body alignment and running technique were emphasized throughout testing and training. Arm and leg movements were coordinated to emulate the individual's usual running style. It was emphasized that leg movement proceed upward and down utilizing knee flexion and extension as well as hip flexion/extension, not forward and back or similar to a scissors kick.

Height and weight were measured and recorded prior to each test. Heart rates were monitored continuously on a Lifepak Monitor and portable telemetry unit. A modified Lead II was used with electrode placement as previously described, disregarding the right leg ground. Adhesive spray and surgical tape were applied over the electrodes to waterproof the electrode and enhance conduction. A rhythm strip was recorded on ECG heat sensitive paper during the last 15 seconds of minute four and five during warm-up and at the end of each stage or every two minutes thereafter until test termination.

Gas analyses were completed as previously described. Perceived exertion was also assessed throughout the water trial. The scale was identical to that used during the land trials but instructions for application differed:

> Throughout the test we will be asking you how hard you feel you are working. This RPE chart ranges from six to 20, with six indicating the lightest possible effort and 20 being a maximal effort or the hardest. There are no right or wrong answers. We will count off the numbers to you and when we reach the appropriate number, simply indicate to us by nodding your head. That number will indicate to us how you are feeling.
>
> Near the end of the test, if you are no longer keeping with the cadence of the metronome or you feel you are unable to continue much longer we want you to do an all out sprint. Remember we will encourage you to continue on as far as you can but you are in control and can stop the test at anytime. Do you understand?

Pool testing was conducted in the deep end of a 20 meter swimming pool. The pool temperature was checked prior to each test and remained constant at approximately 29^{o}C. Subjects were tethered to prevent movement away from the testing apparatus. Instructions for proper running form were reiterated prior to the test and deviations from proper running technique were corrected as necessary throughout. Subjects were allowed to slightly cup their hands if they felt it was necessary to comfortably keep the non-rebreathing valve above water. At no time were the subjects permitted to get their faces wet.

Subjects ran in accordance to a pre-recorded metronome. Each beat signified when one leg and knee should be in an extended or down position. Male subjects had a five minute warm up period of 120 beats per minute. The following two minute stages increased by 20 beats per minute until 200 beats per minute were attained (see Appendix E). The warm up period for women was 100 beats per minute followed by two minute stages increased by 20 beats per minute until 200 beats per minute were attained (see Appendix F). If at any point it was noticed that speed was not maintained or when VO_2 consumption decreased, the subject was instructed to increase speed. Once the cadence could no longer be maintained or the subject felt they could not continue much farther, they were encouraged to perform an all out sprint to exhaustion.

The test was terminated upon reaching maximal effort. Physiological parameters to assess when true maximal effort was attained were identical to criteria described for the treadmill test.

The land and water protocol fulfilled the requirements accepted as necessary to assess true VO_2max. These criteria included 1) large muscle mass involved on the mode specific to their training, 2) adequate warm-up at a level considerably below the maximal capacity, 3) test duration of eight to 17 minutes, optimally at 10 minutes (Buchfuhrer et al., 1983), 4) gradually increasing intensity in stages of two minutes per stage, and 5) strenuous activity involving some anaerobic metabolism (American College of Sports Medicine, 1986; McConnell, 1988).

Training

The objectives of the Jogging and Fitness class were to learn a variety of endurance training methods as well as actively participate in a training regime. The class met eight consecutive weeks, four days per week. Excluding lecture sessions, the subjects officially trained three days per week for six weeks.

Heart rate intensity was determined using the appropriate percentage of age predicted maximal heart rate (220 - age). Subjects were instructed how to manually count their pulse by palpating the carotid or brachial artery and were reminded to take their pulse while exercising. Attendance records were documented at each exercise session as well.

In addition to the endurance activity listed below, sit ups and push ups were completed at the end of each training session.

<u>Land</u>

<u>Week 1 - Aerobic Runs</u>: The subjects ran continuous for 20 minutes per session (except during the first class where the run was maintained for 18 minutes) at 75-80% of predicted max heart rate.

<u>Week 2 - Par Course Runs</u>: Subjects completed a series of ten exercise stations, running before, after and between each station for two minutes totaling 22 minutes of running at an intensity of 75-80% of predicted max heart rate. Subjects were allowed to choose which level or the quantity of exercises to be completed as listed in parentheses. The exercise stations included Good Mornings or burpees (10, 20, 30), push-ups (10, 15, 20), arm-circles (20, 30, 40), sit-ups (15, 20, 25), clippers (25, 40, 50), squat thrusts (10, 15, 20), squats (20, 30, 50), curl-ups (15, 20, 25), toe-raises (20, 30, 50) and bent knee leg-lifts (10, 15, 20).

<u>Week 3 - Fartlek Runs</u>: A continuous running bout for 20 minutes. Running intensity was at 75-80% predicted max heart rate for 14 minutes with three two-minute sprints at 80-90% predicted max heart rate randomly dispersed during the run.

<u>Week 4 - Dynamic Runs</u>: A continuous running bout for 20 minutes

with varying intensity. Initial eight minutes at 75%, three one-minute sprints at 80-90% returning to 75% for one-minute between each sprint, then completing the final seven minutes at the standard 75% predicted max heart rate.

Week 5 - Interval Runs: The subject's best two mile time was established. Six 400, yard runs were completed at race pace interspersed with six 400's at 75% predicted maximal heart rate.

Week 6 - Running Games: Cones were set up around a circle with a color swatch under the cone. A card with matching swatch colors was controlled by the instructor. The individual had to run to each cone in the same successive order that the colors were noted on the card. If the subjects completed the order correctly a new card was initiated. Running continued for 20 minutes at 75-80% predicted target heart rate.

Water

All activities which took place by L_m and L_f were equally matched by W_m and W_f. Training intensity was self-monitored by palpating the pulse for ten seconds during exercise. Activity at the appropriate training intensity was maintained for 20 minutes per session, except for the first session which was 18 minutes in duration and the par course sessions which were 22 minutes of running each.

Statistical Treatment

After completion of testing the data were analyzed using a four-way analysis of variance with repeated measures to determine if there were significant ($p<.01$) differences in physiological responses between pre and post tests, land versus water training, treadmill versus pool testing, or gender.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to compare the effects of training on land versus in water on maximal exercise in college-aged men and women. Data obtained from the study were analyzed using a 2 x 2 x 2 x 2 factorial design analysis of variance with repeated measures. The first factor compared males and females. The second consisted of training by running in water or on land. The third factor involved mode of testing in the pool and on the treadmill. The last factor accounted for pre and post tests.

Subjects

Initially fourteen men and eleven women who were enrolled in a Jogging and Fitness course at the University of Wisconsin-LaCrosse volunteered to be subjects in this study. One male and one female were excluded from the study since they were unable to complete the initial pool test due to an inability to maintain a position with their head above water. One male dropped the university course and opted not to participate, and another did not return to complete any tests after his initial treadmill test.

Eighteen training sessions were conducted over the six week period. One water training session was missed by three subjects, one male and two females. Two training sessions were missed by one male in the land training group. Final statistical analysis included a total of 21 subjects, eleven males and ten females, who completed testing and training requirements.

Physical Characteristics

Means and standard deviations for age, height and weight of each group are shown in Table 2.

Table 2. Means and standard deviations for physical characteristics of the training groups

Variable	Training Group: Men, Water (n=6)	Men, Land (n=5)	Women, Water (n=5)	Women, Land (n=5)
Physical Characteristics				
Age (yrs)	19.2[a] 1.6[b]	19.6 1.1	19.6 1.7	19.2 2.7
Height (cm)[c]	178.2 6.6	172.6 6.4	160.0 0.9	160.0 7.0
Pre-Training Weight (kg)[c]:				
Water trial	72.1 9.1	74.4 8.4	53.5 4.3	53.9 5.8
Treadmill trial	71.2 9.6	74.4 8.6	54.2 3.7	54.4 5.8
Post-Training Weight (kg)[c]:				
Water trial	72.1 7.9	73.6 7.7	54.6 4.7	54.2 5.0
Treadmill trial	72.3 7.7	74.2 8.1	55.3 4.2	54.4 4.5

[a]Mean
[b]Standard Deviation
[c]Female values significantly ($p<0.001$) less than males.

All groups were similar in age. As expected, the males were larger than the women in stature, evident by significant ($p<0.001$) differences in height and weight. The heights and weights of the male and female subjects were similar to moderately trained subjects of similar age. Reported values for males ranged from 72 to 75 kg in weight, and 178.3 to 179.3 cm in height and for females from 51.4 to 62.2 kg in weight, and 165.6 to 166.9 cm in height (Burke, 1977; Butts et al., 1984; Maksud et al., 1976; Ramsbottom et al., 1987).

In contrast, trained distance runners tend to be smaller than our subjects. For example, Iwaoka et al. (1988) documented enduranced trained women at 158 cm tall, 51.4 kg in weight and males at 170 cm, 57.9 kg, while Priest and Hagan (1987) recorded male distance runners of 178.4 cm at 67.2 kg of body weight.

The weight of the subjects did not significantly ($p>0.01$) change during the six weeks of training or between pool and treadmill testing. Burke (1977) noted that because the women decreased their weight significantly more than the men during their eight weeks of training, a greater increase in aerobic capacity was seen in the women.

Mileage

The magnitude of improvement in maximal exercise capacity due to training is largely dependent on the physical activity level rather than simply on gender (Burke, 1977; Butts et al., 1984; Drinkwater, 1973; Ekblom et al., 1968). Initially most of the subjects were inactive, running less than five miles per week. Running mileage prior to the study as well as outside of the scheduled training were not significantly ($p>0.01$) different between the land and water training groups, or between gender. A few subjects were very active which included one male in the water group who swam on the varsity swim team with two others in the land group who ran 18 to 30 mpw. Two females in the land group were on the track team and averaged 30 mpw and 12-15 mpw each, and another female in the water group cycled approximately 40 mpw.

Maximal Exercise Data

Separate MANOVA's were performed for each physiological response measured at maximal exercise. The responses measured included ventilation (VEmax), heart rate (HRmax), respiratory exchange ratio (RERmax), and absolute (L/min) and relative (ml/kg/min) oxygen uptake (VO_2max).

VEmax

Ventilation, controlled by the respiratory center in the medulla, is the means to incorporate oxygen into the circulatory system. Factors which would influence changes in ventilation include a decrease in the partial pressure of oxygen, a decrease in hydrogen, increases in body temperature, changes in lactic acid concentrations, or an increase in the partial pressure of carbon dioxide, with the latter factor exerting the greatest influence (Brooks & Fahey, 1985).

Ventilation is not generally a limiting factor in VO_2max since the ability to increase ventilation is much greater than the ability to extract oxygen. The actual movement of air occurs with changes in thoracic volume. At rest, breathing is a passive process. During exercise, ancillary musculature is called upon to assist by increasing the size of the rib cage to aid inspiration and decreasing size to aid in forceful exhalation (Brooks & Fahey, 1985; Guyton, 1986).

In this study, the volume of air expired per minute represented the ventilation at maximal exercise. The VEmax values, expressed in liters of oxygen per minute (L/min), are presented in Table 3.

Table 3. Means and standard deviations of ventilation (L/min) by sex[a], training, mode and prepost[b]

Training Group	N	Pre-training Pool	Pre-training Tread	Post-training Pool	Post-training Tread
Males:					
Water	6	130.1[c]	139.5	134.9	145.8
		12.3[d]	11.6	18.8	13.2
Land	5	121.6	134.9	124.3	137.6
		37.4	32.4	31.6	33.4
Females:					
Water	5	71.7	90.6	77.1	88.6
		18.0	8.6	13.4	16.5
Land	5	79.0	96.8	84.6	97.2
		6.1	7.3	7.2	2.7

[a]Female values significantly ($p<0.001$) less than male.
[b]Pre-training values significantly ($p<0.001$) less than post-training.
[c]Mean
[d]Standard Deviation

The main effect of sex was significant ($p<0.001$), with males ventilating 56% more air (134 L/min versus 85.7 L/min, males and females, respectively). Significant differences in ventilation between the sexes were a result in differences in height and weight. Other studies comparing moderately trained males to females all identified a significant difference between sexes in VEmax, and reported similar values, ranging from 70.7 L/min to 101.3 L/min in females, and from 97.7 L/min to 141.4 L/min in males (Burke, 1977; Butts et al., 1984; Ramsbottom et al., 1987).

Overall, VEmax significantly ($p<0.001$) increased with training from 108.2 L/min to 111.5 L/min, or a 3% increase. Butts et al. (1984) reported similar findings, with VEmax increasing by 3% from 117.8 L/min to 121.4 L/min with eight weeks of training. Burke (1977) reported more dramatic differences with males increasing VEmax by 26% (from 97.7 L/min to 123 L/min) and females by 18% (from 70.7 L/min to 83.5 L/min) after eight weeks of training.

There were no significant ($p>0.01$) differences between treadmill and pool VEmax values, although treadmill values were higher. It was expected that pool values would be lower since immersion in water has been noted to decrease ventilation due to more blood occupying space in the thoracic area along with increase in pressure. Former researchers have found treadmill VEmax to be significantly higher than swimming (McArdle et al., 1978). Impaired ventilation may have been due to the mechanical requirements of breathing while swimming (Brooks & Fahey, 1985) which were not evident in the present study since the head and face was not immersed in the water at any time.

Heart Rate

The heart acts as a pump to deliver oxygenated blood to the body with cardiac output determined by the stroke volume and heart rate. Heart rate increases in proportion to the amount of muscle mass utilized and amount of oxygen needed.

At maximal exercise, heart rate is the major determinant of cardiac output. Heart rate and oxygen consumption increase linearly with increasing workloads, but once maximal exercise capacity is reached these levels plateau.

Maximal heart rate is often considered age related. Heart rate values, expressed in beats per minute (bpm), are displayed in Table 4.

Table 4. Means and standard deviations of heart rate (beats per minute) by sex[a], training, mode and prepost[b]

Training Group	N	Pre-training Pool	Pre-training Tread	Post-training Pool	Post-training Tread
Males:					
Water	6	191.7[c]	200.7	195.2	197.0
		7.1[d]	3.5	13.9	4.9
Land	5	197.2	200.2	192.8	194.8
		7.0	11.4	11.4	7.8
Females:					
Water	5	184.2	196.4	185.2	193.4
		9.3	4.6	4.6	3.7
Land	5	182.4	193.6	180.4	194.2
		8.4	6.5	7.8	7.6

[a]Female values significantly ($p<0.001$) less than male.
[b]Post-training values significantly ($p<0.001$) less than pre-training.
[c]Mean
[d]Standard Deviation

The differences between sex were unexpectedly significant ($p<0.01$) with males yielding 3.9% higher HRmax (196.2 bpm) than females (188.8 bpm). These findings were not in agreement with earlier research in which no significant difference was noted in the HRmax between males and females (Burke, 1977; Butts et al., 1984).

Furthermore, the pre-training HRmax (193.3 bpm) was significantly ($p<0.001$) higher than post-training (191.7 bpm) by .8%. This discrepancy could be a result of maturation, from completing the maximal tests once before, or exercise experience and skill development with training. In agreement with the present findings, McArdle et al. (1978) found a 3% decrease in post-training heart rates (from 189.7 bpm to 183.8 bpm) of his subjects. The treadmill test only decreased by 2% while the post training swimming test was 4.6% lower. In contrast, other research has reported no significant difference, although a slight decrease was not unusual. Burke (1977) had no change in females' heart rates (190 bpm pre & 190 bpm post) but males were slightly lower (192 bpm pre & 190 bpm post). Butts et al. (1984) had a decrease in females (183.4 bpm pre & 182.7 bpm post), with a slight increase in the males' heart rates (182.1 bpm pre & 182.6 bpm post).

The present study did not reflect a significant ($p>0.01$) difference in HRmax between the treadmill and pool testing. Obtaining similar HRmax was not extremely unusual since body position and movement patterns for all tests were similar, and the water was maintained at a thermoneutral temperature. Others have noted lower heart rates during rest and submaximal exercise when immersed to the neck in water. McArdle et al. (1978) noted a 13.7% difference in heart rates between treadmill (198.7 bpm) and tethered swimming (174.8 bpm), most likely due to the swimming test requiring a horizontal position.

RERmax

The volume of carbon dioxide produced over the volume of oxygen consumed is referred to as the respiratory exchange ratio (see Table 5). Unity (>1.0) indicates that the energy substrate utilized is primarily carbohydrate. Heavy exercise relys upon carbohydrates since less oxygen is needed to liberate the energy. The RER is also related to ventilation and carbon dioxide production.

Table 5. Means and standard deviations of the respiratory equivalent by sex, training[a], mode[b] and prepost[c]

Training Group	N	Pre-training Pool	Pre-training Tread	Post-training Pool	Post-training Tread
Males:					
Water	6	1.05[d]	1.10	1.08	1.12
		.06[e]	.07	.03	.04
Land	5	1.03	1.09	1.07	1.10
		.05	.07	.09	.05
Females:					
Water	5	1.00	1.13	1.11	1.11
		.06	.03	.06	.04
Land	5	.99	1.07	1.05	1.10
		.04	.04	.05	.06

[a]Land training values significantly (p<.001) less than water training.
[b]Pool values significantly (p<.001) less than treadmill.
[c]Pre-training values significantly (p<.001) less than post-training.
[d]Mean
[e]Standard Deviation

The RERmax was significantly (p<0.01) different between types of training. The group which trained in water had 0.9% greater RER value than the group who trained on land (1.08 vs 1.07 for water & land, respectively). This may possibly be due to a greater tolerance for lactic acid in the one competitive male swimmer who was part of the water training group.

The mode of testing showed significant (p<0.01) difference as well with treadmill (1.10) yielding a 4.8% higher RERmax than the pool (1.05). Although VEmax response was not significantly different between modes of testing, ventilation on the treadmill was higher than in the pool. This variation along with differences in VO_2max could contribute to the significant difference in RERmax.

Finally, the post RERmax was also significantly ($p<0.001$) higher, than the pre-training values of 1.05. These findings conflict with earlier research in which no significant difference in RER was found between pre and post-training (Butts et al., 1984; McArdle et al. 1978). The fairly sedentary subjects in the present study may have been more comfortable with the exercise testing after having experienced the testing process during the pre-trials, as well as completing six weeks of training. Also, the subjects may have been more motivated to do well during the post testing.

<u>VO_2max</u>

Oxygen consumption increases with intensity to meet the metabolic demands of the body. Like heart rate, VO_2 increases linearly with increasing workloads and then plateaus at maximal exercise. Cardiac output is considered the most important determinant of VO_2max, with the major adaptation to training generally accepted as an increase in stroke volume. The degree of improvement in VO_2max depends upon age, sex, initial fitness level, and the type of training incorporated.

Absolute oxygen uptake data, expressed in liters of oxygen per minute (L/min), are provided in Table 6. VO_2max was also calculated relative to body weight so that persons of different size can be compared. Relative oxygen uptake, expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg/min), are presented in Table 7.

Table 6. Means and standard deviations of absolute oxygen consumption (L/min) by prepost[a], training, mode[b] and sex[c]

Training Group	N	Pre-training Pool	Pre-training Tread	Post-training Pool	Post-training Tread
Males:					
Water	6	3.621[d]	4.199	3.759	4.347
		.736[e]	.439	.657	.447
Land	5	3.552	4.270	3.580	4.366
		.892	.832	.634	.845
Females:					
Water	5	1.949	2.489	2.078	2.598
		.305	.217	.240	.348
Land	5	2.127	2.779	2.284	2.886
		.162	.194	.293	.094

[a]Pre-training values significantly ($p<.001$) less than post-training.
[b]Pool values significantly ($p<.001$) less than treadmill.
[c]Female values significantly ($p<.001$) less than male.
[d]Mean
[e]Standard Deviation

Post-training VO_2max (3.240 L/min; 50.1 ml/kg/min) was significantly ($p<0.01$) higher than pre-training (3.123 L/min; 48.43 ml/kg/min) by 3.7%. Although significant, these results did not show as great of an increase as found by previous researchers conducting training programs for males and females. In 1984, Butts et al. showed a 7.9% increase in males along with an 8.7% increase in females after eight weeks of swimming. Burke (1977) revealed a 17% increase in males and 22% increase in females after eight weeks of running. The lower magnitude of improvement in the present study may be a result of the

Table 7. Means and standard deviations of relative oxygen consumption (ml/kg/min) by prepost[a], training, mode[b] and sex[c]

Training Group	N	Pre-training Pool	Pre-training Tread	Post-training Pool	Post-training Tread
Males:					
Water	6	50.3[d]	59.4	52.2	60.2
		8.4[e]	6.4	7.3	3.9
Land	5	47.2	56.1	48.5	58.5
		7.1	4.8	4.2	5.9
Females:					
Water	5	36.7	45.9	38.1	46.9
		4.9	2.6	3.7	4.0
Land	5	39.8	51.4	42.4	53.3
		4.2	4.5	6.2	3.6

[a] Pre-training values significantly ($p<.001$) less than post-training.
[b] Pool values significantly ($p<.001$) less than treadmill.
[c] Female values significantly ($p<.001$) less than males.
[d] Mean
[e] Standard Deviation

shorter duration and lack of increasing the intensity during the six week period. As exercise capacity improved with training the volume of work, or intensity and duration, should have been modified accordingly to maximize continued adaptations. Since the workload was not increased, the training may have become a maintenance program.

The VO_2max values obtained on the treadmill (3.491 L/min; 54.0 ml/kg/min) were significantly ($p<0.001$) higher than those reached in the pool (2.872 L/min; 44.5 ml/kg/min) by 21.5%. This may be due, in part, to the fact that treadmill testing required subjects to support their weight thus activate more muscle fibers. In addition, pool values may be lower due to greater peripheral vasoconstriction in response to altered heat dissipation. In comparison, McArdle et al. (1978) also noted a difference in VO_2max between modes of testing with the treadmill run 19.3% greater than horizontal swimming. They found treadmill values significantly increased due to run training, whereas, the swimming test did not, exemplifying the specificity of training.

Upon analysis of absolute oxygen consumption, the factor of gender was statistically significant ($p<0.001$) with males consuming 65% more oxygen than women (3.964 L/min vs 2.399 L/min). Sparling (1980) stated in his meta-analysis that men typically consume 56% more oxygen than women during maximal exercise. Others have also demonstrated males consume significantly higher volumes of oxygen, ranging from 34.2% to 59% more than females (Burke, 1977; Butts et al., 1984; Ramsbottom et al., 1987). Further analysis revealed that the males, who were rated in a "high" category of cardiorespiratory fitness (American Heart Association, 1972), only improved 2.7% (from 3.910 L/min; 53.4 ml/kg/min to 4.017 L/min; 55.0 ml/kg/min). The women, who fit into the "good" category of fitness, increased by 5.4% (from 2.336 L/min; 43.45 ml/kg/min to 2.462 L/min; 45.2 ml/kg/min).

The same pattern for absolute VO_2max was identified for relative with 22% greater values for males (54.2 ml/kg/min) versus for females (44.3 ml/kg/min). The 22% difference between the sexes is slightly below the range reported for similar populations. Sparling (1980) stated that between the sexes, relative VO_2max is generally 28% greater for males. Ramsbottom et al. (1987) and Butts et al. (1984) both found males to have higher relative VO_2max as well (24% and 13%, respectively).

When VO_2max is matched on the basis of physical activity as well as body weight, the magnitude of variation decreases between gender. Sparling (1980) found a variance in VO_2max between gender of approximately 35%, decreased to 9% when matched for physical activity. In 1977, Burke compared males and females who initially had 22% difference in relative VO_2max which was reduced to an 8% difference after undergoing similar training. The degree of improvement in VO_2max was also less in endurance trained male runners for Priest and Hagan (1987). The experienced runners in their study improved by 5.8% while the novice runners increased by 11.1%.

Summary

The purpose of this study was to compare physiological differences during maximal exercise between college-aged men and women after six weeks of training on land or in water.

Sex

Prior to the study, the majority of the subjects were fairly sedentary, running less than five miles per week, except for a few individuals. The males had significantly higher values for VEmax, HRmax, and VO_2max (L/min and ml/kg/min) than the females. There was no significant difference between gender in RERmax. The values for the present groups were similar to those found for sedentary to moderately trained males and females by past researchers (Burke, 1977; Butts et al., 1984; Maksud et al., 1976; Ramsbottom et al., 1987; Sparling, 1980).

There were no interaction effects between gender, type of training, mode of testing, or prepost values indicating both males and females responded to training in the same fashion. This finding has also been documented by others (Burke, 1977; Butts et al., 1984) and was expected, particularly since energy cost at a given submaximal level is similar for males and females (Maksud et al., 1976; Ramsbottom et al., 1987; Wells et al., 1981).

The degree of variation in VO_2max have been noted to decrease in magnitude when males and females are equated for relative weight, lean body weight, and according to initial fitness levels (Drinkwater, 1973; Iwaoka et al., 1988; Maksud et al., 1976; Ramsbottom et al., 1987), but males are still usually 12-15% greater in oxygen capacity due to differences in heart size, and hemoglobin levels (Sparling, 1980).

Mode of Testing

All subjects were required to complete maximal exercise testing by running on a motor-driven treadmill and in a pool. Both modes of testing were included in an effort to account for the specificity of training. Treadmill values were significantly higher for RERmax and VO_2max (L/min and ml/kg/min) both prior to and after training. No significant difference in VEmax or HRmax was noted. It is recognized that mode of testing significantly affects the outcome (Buchfuherer et al., 1983; McArdle et al., 1978) with non-weight bearing activity yielding lower values. Peripheral vasoconstriction, as noted during immersion in water, would also lower oxygen utilization.

There were no interactions of the factors included in this study. The water training group did not significantly improve in the pool test versus the treadmill, nor did the land training group significantly improve on the treadmill versus the pool test. Specificity of training reflected that the subjects improved their maximal oxygen capacity when running on the treadmill or in the pool.

<u>Prepost</u>

Training for 20 minutes, three times weekly for six weeks by running on land or running in water provided sufficient stress in the male and female subjects to yield physiological adaptations resulting in improved cardiorespiratory fitness. The VEmax, RERmax, and VO_2max (L/min and ml/kg/min) during post-training trials were significantly greater than pre-training.

The combination of frequency, duration and intensity are all important components of a training program. A minimum of three exercise sessions per week (American College of Sports Medicine, 1979; Brynteson & Sinning, 1973; Gettman et al., 1976), for 15 to 30 minutes (American College of Sports Medicine, 1979; Edwards, 1974; Milesis et al., 1976) at 60% - 90% of maximum heart rate reserve (American College of Sports Medicine, 1979) is usually recommended for sedentary individuals. These components can be varied and range from 5-10 minutes at 90%, to 20-30 minutes at 40-70% for improving aerobic capacity, but the former alternative would not be appropriate for sedentary individuals (American College of Sports Medicine, 1986; Pollock, 1978). Altering the frequency and volume so that a minimum of 300 calories expended per session is also noted as a possible method for regulating the training stimulus (Pollock et al., 1972; Pollock, 1978).

The time it takes to make physiological adaptations is considered to be slow by some (Costill, 1986; Gettman et al., 1976; Guyton, 1986). In contrast, Hickson et al. (1981) noted that the adaptation process is actually rather rapid with a half life of less than 11 days, thus the training stimulus should be increased after three weeks or the exercise sessions become a maintenance program with no further gains in VO_2max. In the present investigation, the training intensity was not reevaluated after three weeks. Although the response to training were significantly increased, VO_2max and corresponding physiological variables may have been higher if the intensity had been periodically increased. In addition, training heart rates were based on predicted maximal heart rates, thus lending to possible underprediction of appropriate heart rate intensity. Although, Edwards (1974) found sedentary women had a training threshold of 125 bpm which produced significant increases in VO_2max.

The maximal heart rate was significantly higher during the pre-training trial. An attenuated post-training heart rate response has been noted in other studies as well (Burke, 1977; Butts et al., 1984; McArdle et al., 1978). The possibility exists that this may indicate true maximal oxygen capacity was not achieved during post-testing, although not likely due to the fact that other criteria were satisfactorily met. The decrease in heart rate response was more likely due to increased exercise experience and skill of the subjects.

<u>Training</u>

Although the water training group had significantly higher RERmax values than the land group, there were no significant differences in VEmax, HRmax, or VO_2max (L/min or ml/kg/min) between groups. Running in water provided sufficient exercise stress to produce physiological adaptations to enhance cardiorespiratory fitness while offering the benefits of a non-weight bearing medium.

It was expected that training in water at the same heart rate intensity as on land would provide a greater training stimulus (McArdle et al., 1978) due to hemodynamic alterations made when immersed in water (Arborelius et al., 1972; Begin et al., 1976). Other training studies comparing water versus land cycling, thus non-weight bearing in both mediums, also found that physiological adaptations to training were similar in both mediums (Avellini et al., 1983; Beaudet, 1984; Sheldahl et al., 1986).

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

It has been claimed that running in water allowed specificity of training while reducing stress and minimizing injuries (Evans et al., 1978; Perry, 1986; Williams, 1987). There are only a few studies which have investigated the responses to training while running in water compared to similar training on land. Studies that have been done in water vary in their results due to differences in body position, water temperature, depth of immersion, exercise modalities employed other than running, and training methodology. In addition, studies comparing males and females undergoing training on land and in water are extremely limited.

The purpose of this investigation was to compare the effects of training on land compared to in water. The results of this study were based on a group of males (n=6) and females (n=5) who trained by running in water, and a group of males (n=5) and females (n=5) who trained by running on land. Prior to and after six weeks of training each subject completed a maximal exercise test on a treadmill and in the pool, simulating running while wearing a flotation device.

The males were significantly larger in stature than the females and correspondingly, had higher maximal oxygen capacities. Respiratory exchange ratios were similar between gender, thus the motivation and experience levels were probably similar. Although not significant, the magnitude of improvement was slightly higher for the females, most likely due to the fact that they were initially at a lower fitness level. Based on the fact that there were no interactions between sex, prepost trials, mode of testing or type of training factors, it would be accurate to state that the males and females in this investigation responded similarly to the training.

The training stimulus provided during the investigation was sufficient to warrant a significant improvement in cardiorespiratory fitness. Heart rate response did slightly decrease from pre-training values, most likely because of the experience and maturation of the subjects. Although the increase in VO_2max was significant after the six week training period, it most likely would have been even greater if the training period were longer in duration and the volume, or duration and intensity of each session, had been readjusted to a higher level as the subjects improved their exercise capacity.

Testing on the treadmill produced higher VO_2max than in the pool. This was not surprising in light that treadmill running required supporting one's body weight, thus greater muscle mass activated demanded more oxygen, and peripheral vasoconstriction probably occured during pool testing, thus lowering the pool values. Ventilation was slightly higher, but not significant, on the treadmill, but could have contributed to the significantly higher RERmax on the treadmill. Immersion in water has been noted to induce several hemodynamic alterations which result in lower resting and submaximal heart rates, and lower ventilation as a result of more blood occupying space in the thoracic area. In this study, the head out immersion in water of thermoneutral temperatures during testing did not significantly hinder ventilation or maximal heart rate capacity.

The null hypothesis was accepted in this investigation. Training on land versus in water produced similar physiological adaptations. All subjects improved in their oxygen capacity regardless of the medium in which they exercised.

Based upon the results of this study, running in deep water is a viable alternative exercise for people who are comfortable in water. An injured athlete could benefit by running in water to minimize the effects of detraining. Further study would be necessary to determine if an athlete training in water would increase strength in conjunction with the increased water resistance.

Recommendations

Upon completion of this investigation, it is recommended that a future study be conducted, similar to the present study with the following modifications:

1. Enlarge the sample size.

2. Extend the duration longer than six weeks, optimally 12 to 20 weeks.

3. Update the training intensity every three weeks.

4. Possibly base the training on energy expenditure of each exercise session, in conjunction with heart rate.

5. Include pre and post strength testing.

6. Determine cardiac output during training.

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APPENDIX A

INFORMED CONSENT

INFORMED CONSENT
WATER/LAND RUNNING STUDY

I, ________________________, volunteer to be a subject in a research study to determine what, if any, difference exists between training on land versus training in the water. I understand participation in this project requires that I complete four VO_2max tests, one in the water using the running vest and one on the treadmill both before and after six weeks of training.

Prior to the first pool test, I will be required to practice using the vest in the water while running. In addition I will have to practice running on the treadmill prior to the actual treadmill test. When I feel comfortable with the running vest and can demonstrate adequate skill running on the treadmill I will complete the VO_2max tests in each medium.

The tests will consist of a series of submaximal efforts at varying rates and/or speeds. During these tests my heart rate will be monitored continuously via an ECG. Also I will breathe room air through a mouthpiece so that my exhaled air can be collected. Although these tests will require maximal effort I understand that I can stop the test anytime I wish. As with any exercise, there exists the possibility of adverse changes occurring (i.e., dizziness, difficulty in breathing, etc.) during these tests. In addition, I will probably feel tired at the end of the tests. If any abnormal observations are noted at any time the test will be immediately terminated.

The practice and testing sessions will be scheduled at my convenience. During these periods I will be given specific instructions in order to improve my techniques.

Training activity will be conducted in conjunction with the P.E. 100 course in which I am enrolled. I will attend and participate in all training activities as outlined by the instructor.

I consider myself to be in good health and to my knowledge I am not infected with a contagious disease or have any limiting physical condition or disability, especially with respect to my heart, that would preclude my participation in the exercise tests or training. Furthermore I am not afraid of the water and I have basic swimming skills. I have read the foregoing and understand what is expected from me. Any questions which may have occurred to me have been answered to my complete satisfaction. I, therefore, voluntarily consent to be a subject in this study. Furthermore I know I may withdraw at any time without any type of penalty.

Signed:____ Date:________________

Witness:_______________________________________ Date:________________

APPENDIX B

RATING OF PERCEIVED EXERTION SCALE

PERCEIVED EXERTION SCALE

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	

Borg and Noble (1974)

APPENDIX C

TREADMILL DATA SHEET - MALES

TREADMILL DATA SHEET - MALES

NAME:____________________ DATE:_____ TIME:_____ TEMP:_____ Pbar:_____

_____lbs _____kg _____Height _____age _______birthdate

	WORKLOAD	V_E	ml O_2	ml/kg	V_{CO2}	RER	$FeCO_2$	FeO_2	HR	RPE
1	6.0/0.0									
2	6.0/0.0									
3	6.0/0.0									
4	6.0/0.0									
5	6.0/0.0									
6	7.5/2.5									
7	7.5/2.5									
8	7.5/5.0									
9	7.5/5.0									
10	7.5/7.5									
11	7.5/7.5									
12	7.5/10									
13	7.5/10									
14	8.0/10									
15	8.0/10									
16	8.5/10									
17	8.5/10									
18	9.0/10									
19	9.0/10									
20										

O_2 __________ __________

CO_2 __________ __________

APPENDIX D

TREADMILL DATA SHEET - FEMALES

TREADMILL DATA SHEET - FEMALES

NAME: ______________________ DATE: _____ TIME: _____ TEMP: _____ Pbar: _____

_____lbs _____kg _____Height _____age _________birthdate

	WORKLOAD	V_E	ml O_2	ml/kg	V_{CO2}	RER	$FeCO_2$	FeO_2	HR	RPE
1	5.0/0.0									
2	5.0/0.0									
3	5.0/0.0									
4	5.0/0.0									
5	5.0/0.0									
6	6.0/2.5									
7	6.0/2.5									
8	6.0/5.0									
9	6.0/5.0									
10	6.0/7.5									
11	6.0/7.5									
12	6.0/10									
13	6.0/10									
14	6.5/10									
15	6.5/10									
16	7.0/10									
17	7.0/10									
18	7.5/10									
19	7.5/10									
20	8.0/10									

O_2 __________ __________

CO_2 __________ __________

APPENDIX E

POOL DATA SHEET - MALES

POOL DATA SHEET - MALES

NAME:__________________ DATE:_____ TIME:_____ TEMP:_____ Pbar:_____

_____lbs _____kg _____Height _____age _______birthdate _____Water temp

	WORKLOAD	V_E	ml O_2	ml/kg	V_{CO2}	RER	$FeCO_2$	FeO_2	HR	RPE
1	120 bpm									
2	120 bpm									
3	120 bpm									
4	120 bpm									
5	120 bpm									
6	140 bpm									
7	140 bpm									
8	160 bpm									
9	160 bpm									
10	180 bpm									
11	180 bpm									
12	200 bpm									
13	200 bpm									
14										
15										
16										
17										
18										
19										

O_2 __________ __________

CO_2 __________ __________

APPENDIX F

POOL DATA SHEET - FEMALES

POOL DATA SHEET - FEMALES

NAME:__________ DATE:______ TIME:______ TEMP:______ Pbar:______

______lbs ______kg ______Height ______age ______birthdate ______Water temp

	WORKLOAD	V_E	ml O_2	ml/kg	V_{CO2}	RER	$FeCO_2$	FeO_2	HR	RPE
1	100 bpm									
2	100 bpm									
3	100 bpm									
4	100 bpm									
5	100 bpm									
6	120 bpm									
7	120 bpm									
8	140 bpm									
9	140 bpm									
10	160 bpm									
11	160 bpm									
12	180 bpm									
13	180 bpm									
14	200 bpm									
15	200 bpm									
16										
17										
18										
19										

O_2 ____________ ____________

CO_2 ____________ ____________

APPENDIX G

SUBJECT'S PHYSIOLOGICAL DATA

PHYSIOLOGICAL DATA AT MAXIMAL EXERTION

The following charts include the raw data for four maximal exercise tests per subject. The data are separated into the four groups: Males who trained in water (W_M), males who trained on land (L_M), females in water (W_F), and females on land (L_F). The test codes are as follows: 1 = pre-pool; 2 = post-pool; 3 = pre-treadmill; 4 = post-treadmill. Column abbreviations are used for: subject number (S#), maximal ventilation (VE), oxygen consumption (VO_2), respiratory exchange ratio (RER), and heart rate (HR).

S#	Test	Age (yrs)	Height (cm)	Weight (kg)	VE (L/min)	VO_2 (L/min)	VO_2 (ml/kg)	RER	HR (bpm)
W_M									
01	1	18	175.3	59.4	118.7	3.091	52.0	1.08	183
	2			62.1	114.8	3.273	52.7	1.09	180
	3			59.4	134.0	4.025	67.7	1.05	198
	4			62.6	132.8	3.946	43.1	1.13	188
02	1	18	170.2	67.9	120.1	3.103	45.7	1.03	188
	2			64.6	132.5	3.379	52.3	1.08	201
	3			64.4	142.4	3.812	59.2	1.17	201
	4			65.5	138.5	3.946	60.2	1.10	201
03	1	19	184.2	74.4	131.0	3.230	43.4	1.01	196
	2			76.6	132.4	3.174	41.4	1.07	190
	3			74.6	138.6	3.716	49.8	1.12	203
	4			76.9	147.1	4.128	53.7	1.11	199
04	1	18	180.3	71.7	148.9	4.729	66.0	1.07	203
	2			83.6	142.7	4.383	52.5	1.04	210
	3			87.5	159.6	4.845	55.4	1.17	203
	4			74.1	140.6	4.837	65.2	1.07	201
05	1	20	186.7	87.3	140.2	4.386	50.2	0.98	192
	2			83.6	142.7	4.383	52.5	1.04	210
	3			87.5	159.6	4.845	55.4	1.17	203
	4			83.7	170.8	4.965	59.3	1.17	198
06	1	22	172.7	71.7	121.5	3.184	44.4	1.14	188
	2			71.4	119.7	3.578	50.1	1.07	180
	3			71.2	137.9	4.236	59.5	1.09	195
	4			71.2	145.0	4.258	59.8	1.15	195

S#	Test	Age (yrs)	Height (cm)	Weight (kg)	VE (L/min)	VO_2 (L/min)	VO_2 (ml/kg)	RER	HR (bpm)
L_M									
07	1	20	182.9	87.1	168.7	4.709	54.1	0.99	188
	2			86.6	178.0	4.527	52.3	1.11	176
	3			87.5	185.5	5.509	62.9	1.11	183
	4			87.3	181.0	5.580	63.9	1.05	185
08	1	19	172.7	74.8	142.2	3.858	51.6	1.06	198
	2			73.7	116.4	3.652	49.6	0.97	190
	3			74.8	145.3	4.362	58.3	1.04	212
	4			73.8	157.2	4.697	63.6	1.11	203
09	1	20	167.6	69.8	107.8	2.734	3.91	1.09	207
	2			69.4	110.1	3.017	43.5	1.00	206
	3			70.4	122.0	3.925	55.7	1.00	195
	4			68.5	133.1	4.040	59.0	1.09	188
10	1	18	167.0	64.4	069.0	2.568	39.9	1.01	194
	2			66.9	095.1	2.975	44.5	1.20	200
	3			64.2	100.4	3.220	50.2	1.17	207
	4			66.4	093.3	3.296	49.6	1.08	199
11	1	21	172.7	75.7	120.5	3.893	51.4	0.98	199
	2			71.2	121.9	3.729	52.4	1.06	192
	3			75.3	121.3	4.334	53.5	1.15	204
	4			74.8	123.5	4.219	56.4	1.17	199
W_F									
12	1	18	160.0	48.3	071.8	2.007	41.6	1.05	188
	2			47.9	077.8	2.017	42.2	1.03	185
	3			49.0	087.9	2.402	49.0	1.17	196
	4			48.8	070.1	2.192	45.0	1.10	194
13	1	18	158.8	55.3	090.6	2.132	28.5	1.05	192
	2			57.4	091.7	2.191	38.2	1.14	190
	3			55.0	097.3	2.475	45.0	1.12	201
	4			58.7	102.6	2.624	44.7	1.17	198
14	1	20	160.0	55.6	049.0	1.582	29.5	0.92	169
	2			56.9	065.4	1.903	33.4	1.12	178
	3			56.2	080.8	2.466	43.9	1.12	191
	4			57.6	082.3	2.600	45.1	1.13	192
15	1	20	160.0	49.9	059.2	1.702	34.1	1.03	190
	2			51.7	062.0	1.844	35.7	1.09	188
	3			52.2	085.4	2.256	43.3	1.15	201
	4			53.5	078.9	2.437	45.5	1.05	188
16	1	22	161.3	58.5	087.9	2.322	39.7	0.97	182
	2			59.2	088.7	2.437	41.2	1.18	185
	3			58.7	101.7	2.844	48.4	1.08	193
	4			58.1	109.0	3.138	54.1	1.10	195

S#	Test	Age (yrs)	Height (cm)	Weight (kg)	VE (L/min)	VO_2 (L/min)	VO_2 (ml/kg)	RER	HR (bpm)
L_F									
17	1	18	163.8	52.6	082.7	1.953	37.1	0.98	193
	2			54.0	076.5	1.863	34.5	1.00	170
	3			53.5	105.6	2.786	52.1	1.11	201
	4			54.2	097.1	2.954	54.5	1.04	202
18	1	18	160.7	51.3	086.0	2.296	44.8	0.96	187
	2			51.3	086.5	2.386	46.6	1.01	188
	3			51.3	089.3	2.475	48.3	1.10	195
	4			52.2	098.6	2.755	52.8	1.17	196
19	1	18	160.0	49.2	069.7	2.154	43.8	0.96	176
	2			50.8	093.5	2.567	50.5	1.11	176
	3			49.9	103.4	2.906	58.2	1.03	191
	4			50.3	096.5	2.913	57.9	1.03	184
20	1	18	167.0	64.0	078.9	2.267	35.5	1.04	172
	2			62.8	088.5	2.495	39.7	1.09	180
	3			64.4	092.2	2.980	46.3	1.04	184
	4			62.1	093.1	2.983	48.0	1.12	189
21	1	24	148.6	52.2	077.6	1.965	37.7	1.02	184
	2			51.9	078.2	2.110	40.6	1.02	188
	3			52.8	093.3	2.747	52.0	1.05	197
	4			53.1	100.5	2.826	53.3	1.14	200