EFFECTS OF TEN WEEKS OF DEEP WATER RUNNING OR LAND BASED RUN TRAINING

THESIS

Presented to the Graduate Council of the University of North Texas in Partial Fulfillment of the Requirements For the Degree of

MASTER OF SCIENCE

By

Matthew J. Morrow, B.S.
Denton, Texas
May, 1995
Morrow, Matt J., *Effects of ten weeks of deep water running or land based running training*. Master of Science (Kinesiology), May, 1995, 44 pp, 4 tables, 1 illustration, 41 titles.

Populations that utilize deep water running (DWR) are described in Chapter I. A review of the literature concerning studies comparing peak physiological variables of water exercises (swimming, DWR, & land based running) to land based exercises (cycle ergometer, walking, & running) are presented in Chapter II. The protocols utilized for obtaining peak values on land and in the water along with subject characteristics, statistical methods and description of the training regimen are discussed in Chapter III. The results, presented in Chapter IV, indicate no interaction between any of the variables measured but a main effect for treadmill VO2 peak for the pre- and post testing. Chapter V discusses factors which may limit physiological changes within each training group. Chapter VI contains suggestions for further research.
EFFECTS OF TEN WEEKS OF DEEP WATER
RUNNING OR LAND BASED
RUN TRAINING

THESIS

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE

By

Matthew J. Morrow, B.S.
Denton, Texas
May, 1995
ACKNOWLEDGEMENT

The author would like to thank Excel Sport Science (Eugene, Oregon) for providing ten Aqua Jogger Belts and Dr. Charlotte Sanborn (Texas Woman's University, Denton, Texas) for the meteorological balloons and the use of the Tissot Tank.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATION</td>
<td>vii</td>
</tr>
<tr>
<td>Chapter I: INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Purpose</td>
<td>2</td>
</tr>
<tr>
<td>Definitions</td>
<td>2</td>
</tr>
<tr>
<td>II: REVIEW OF LITERATURE</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Presentation of literature</td>
<td>4</td>
</tr>
<tr>
<td>Specificity of exercise</td>
<td>5</td>
</tr>
<tr>
<td>Training effects</td>
<td>5</td>
</tr>
<tr>
<td>Continuous vs Interval training</td>
<td>6</td>
</tr>
<tr>
<td>Swimming vs Running</td>
<td>7</td>
</tr>
<tr>
<td>Shallow Water Running</td>
<td>7</td>
</tr>
<tr>
<td>Deep Water Running</td>
<td>10</td>
</tr>
<tr>
<td>Physiological Responses to DWR</td>
<td>10</td>
</tr>
<tr>
<td>Responses to DWR Training</td>
<td>11</td>
</tr>
<tr>
<td>Ways of Measuring DWR Intensity</td>
<td>14</td>
</tr>
<tr>
<td>Summary</td>
<td>15</td>
</tr>
<tr>
<td>III: METHODS</td>
<td>16</td>
</tr>
<tr>
<td>Introduction</td>
<td>16</td>
</tr>
<tr>
<td>Subject Characteristics</td>
<td>16</td>
</tr>
<tr>
<td>Measurement of Maximal Tests</td>
<td>17</td>
</tr>
<tr>
<td>Deep Water Running Maximal Test</td>
<td>17</td>
</tr>
<tr>
<td>Treadmill Running Maximal Test</td>
<td>18</td>
</tr>
<tr>
<td>2.4 km Run Performance</td>
<td>19</td>
</tr>
<tr>
<td>Data Collection</td>
<td>19</td>
</tr>
<tr>
<td>Water Max Test</td>
<td>19</td>
</tr>
</tbody>
</table>
LIST OF TABLES

TABLE 1: Measurement of subject characteristics ............................................. 16

TABLE 2: Mean and SD for peak oxygen capacity and time to exhaustion for deep water and land based running groups ........................................ 23

TABLE 3: Mean and standard deviation for 2.4 km performance time for deep water and land based running groups ........................................ 24

TABLE 4: Mean and standard deviation for peak heart rate and RPE values for pre- and post maximal tests ........................................ 24
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>FIGURE 1: Deep Water Testing Apparatus</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

In athletes, the importance of a continuous training program is necessary for success. When an injury occurs, an athlete’s training program is most likely cut back or discontinued until the injury is alleviated. To date, much focus has been on the use of deep water running for an alternative or subsequent mode of exercise in the rehabilitation of athletes and the general population (Abboudi, 1993; Bonnette, 1978; Genuario & Vegso, 1990; Levin, 1991). Recently, there has been more interest in the effects a deep water running program may have as an alternative training mode for maintaining or enhancing fitness and performance in healthy athletes (Eyestone, Fellingham, George, & Fisher, 1993) and non-athletes (Brennan, Michaud, Wilder, & Sherman, 1993; Hertler, Provost-Craig, Sestili, Hove, & Fees, 1993; Michaud, Brennan, Wilder, & Sherman, 1993; Quinn, Sedory, & Fisher, 1994). Two of the previous studies (Eyestone et al. 1993; Hertler et al. 1993) examined the effects of deep water running training on the peak metabolic capacities of the subjects and compared them to the peak metabolic capacities of subjects who trained on land. The other studies (Brennan et al. 1993; Michaud et al. 1993; Quinn et al. 1994) examined the effects a deep water running program would have on individuals for enhancing their peak metabolic capacities.

A weakness of these studies is that all authors based deep water running intensity on treadmill maximal heart rate. It has been reported that maximal heart rate during water exercise is lower than the maximal heart rate achieved on the treadmill (Bishop, Frazier, Smith, & Jacobs, 1989; Butts, Tucker, & Smith, 1991; Green, Cable, & Elms, 1990; Town & Bradley, 1991; Svedenhag & Seger, 1992). If true, it is possible that the intensity
of exercise in the water would be greater than that estimated by maximal values obtained on the treadmill. Therefore, in order to prescribe a “relative” equal intensity for both land and water exercise, each maximal value must be obtained while performing the specific mode of exercise that will be utilized in the exercise program. Assuming that exercise intensity can be equally prescribed between the two training groups (deep water running & land based running), it will then be possible to see if a training effect is present following a 10 week training study.

Purpose

The purpose of this research is to investigate if individuals training in the water while wearing a flotation device [Deep Water Running; DWR], can achieve the same benefits of training as individuals who train on land [Land Based Runners; LBR] at the same intensity.

Definitions

(1) Aqua jogger - flotation belt worn around an individuals lower waist.

(2) Deep Water Running (DWR) - running in deep water so that feet are not coming in contact with the bottom. Done with or without an aqua jogger.

(3) Land Based Running (LBR) - running on land or treadmill.

(4) Mode Specific Peak Heart Rate - the peak heart rate obtained during a specific mode maximal test (water or treadmill).

(5) Peak VO2 - the highest attained amount of oxygen consumed during incremental increases in exercise intensity.

(6) Shallow Water Running (SWR) - running done in water shallow enough so that the feet come in contact with the bottom of the pool with each stride
(7) Time to Exhaustion (TTE) - the amount of time it takes until the subject cannot or will not continue to perform the specific test.
CHAPTER II

REVIEW OF LITERATURE

Introduction

It has been established that the energy cost when exercising in water at a given work rate is greater than the energy cost when exercising on land at the same work rate performing a similar mode of exercise. Costill (1971) showed that subjects exercising on a modified cycle ergometer were capable of performing only from 66.7 to 71.4% as much work in the water as they could on land. In addition, water exercise increased the energy requirement by 33 to 42% for any given power output.

Evans, Cureton, and Purvis (1978) reported that while walking or jogging in waist deep water, only one-half to one-third the speed is needed in order to obtain the same level of metabolic demand as that while walking or jogging on land. However, it was also reported that heart rate at any given level of oxygen uptake in the two environments did not differ significantly. The effects of the hydrostatic forces which cause a decrease in heart rate in individuals submersed in water to their neck (Arborelius, Balldin, Lilja, & Lundgren, 1972; Christie et al., 1990; Gleim & Nicholas, 1989) were probably less pronounced since subjects in this study were only in waist deep water.

Several authors have investigated the physiological responses to water exercise and compared them to treadmill responses. The following literature review will discuss: (1) specificity of exercise; (2) different training protocols; (3) peak metabolic responses during swimming and running; (4) shallow water running; (5) deep water running (submax and maximal testing); (6) deep water training studies; and (7) measurement of intensity.
Specificity of Training

The relationship between specificity and oxygen uptake states that in order to maximize one’s oxygen uptake in a given activity, it is necessary for one to train with that specific activity. This type of specificity has been demonstrated with cycle (Pechar, McArdle, Katch, Magel, & DeLuca, 1974) and swim (Magel, Foglia, McArdle, Gutin, Pechar, & Katch, 1974) training. Magel et al. (1974) reported that swim training was not beneficial for improving VO_{2max} for running.

McArdle et al. (1978) investigated a 10 week training study with 19 subjects placed in a running (n = 11) or control group (n = 8). Subjects exercised for 20 minutes a day, 3 days a week, at the speed that elicited 85% maximal treadmill heart rate. Results indicated a significant 6.3% increase (p<.01) in treadmill VO_{2max} along with a small but statistically significant 2.6% improvement (p<.05) in swimming VO_{2max}. It was suggested that the small increase in swimming VO_{2max} was due to the specificity of leg training as the legs are used to some degree in swimming. These results further support the idea of training specificity and suggest that local adaptations in skeletal muscle contribute to improvements in VO_{2max}.

Training Effects

It has been demonstrated that an individual’s ability to increase VO_{2max} is inversely related to his/her initial fitness level (Saltin, 1969). However, the interactions of intensity, frequency and duration of exercise training are also crucial factors in the effectiveness of a training program. The American College of Sports Medicine (1991) reported that for the enhancement of cardiorespiratory fitness, intensity should be between 40 and 85% VO_{2max} or 55 to 90% maximal heart rate. Duration should be 15 to 60 minutes of continuous or discontinuous activity, and frequency between 3 to 5 d • wk^{-1}. 


Wenger and Bell (1986) analyzed several different studies which investigated the relationship between intensity, frequency and duration of training and their effect on maximum oxygen uptake. Results of the review indicated: (1) when intensity of training was 90 to 100% VO₂max, the greatest improvements in oxygen uptake were seen; and (2) frequencies as low as 2 d • wk⁻¹ can result in improvements in less fit individuals. If VO₂max exceeds 50 ml • kg⁻¹ • min⁻¹, then exercise frequency should be at least 3 d • wk⁻¹.

Wenger and Bell (1986) concluded that gains in maximum oxygen uptake were elicited with training at intensities of 90 to 100% VO₂max, a frequency of 4 d • wk⁻¹ and duration between 35 and 45 minutes.

**Continuous vs Interval Training**

Enhancement of VO₂max can be achieved by interval or continuous training protocols. However, there exists conflicting results as to which method is capable of producing the greatest results.

MacDougall and Sale (1991) suggest that interval training may result in larger increases in VO₂max due to the greater volume of high intensity training (90 to 100% VO₂max). In contrast, when the amount of work per exercise session is equal between the two training groups (continuous & interval), there is no difference in VO₂max attained by the groups (Eddy, Sparks, & Adelizi, 1977; Gregory, 1979).

A cycle ergometer training study comparing high intensity (172 beats per minute, b • min⁻¹) and low intensity (140 b • min⁻¹) continuous training and high (172 b • min⁻¹) and low (140 b • min⁻¹) interval training investigated which mode (interval or continuous) at what intensity (172 or 140 b • min⁻¹) would be most beneficial for increasing VO₂max on the cycle ergometer (Wenger & Bell, 1981). The authors reported that the high intensity continuous training program was most successful for enhancing VO₂max in this sample.
However when evaluated more closely, the continuous mode can not be solely responsible for the increase in VO₂max since the low intensity continuous program also failed to improve VO₂max. Intensity can not be solely responsible since the high intensity interval training did not significantly improve VO₂max either. Smith and Wenger (1981) suggested that the interaction between intensity and mode of training is a major factor in determining the success of a training program for enhancement of VO₂max.

Swimming vs Running

Several studies have compared the physiological responses of swimming and running (Dixon & Faulkner, 1971; Holmer, Lundin, & Eriksson, 1974; Holmer, Stein, Saltin, Ekblom, & Astrand, 1974). While Dixon and Faulkner (1971) reported no difference in VO₂max and cardiac output between swimming and running tests, most authors have concluded that VO₂max is lower during swimming than running. Some of the theories put forth to explain these changes include training status of swimmers, muscle mass utilized, and/or conditions for heat exchange. There may be several factors that come into play. However, at this time, a definite explanation for the limiting factors in swimming is not known.

Shallow Water Running

Previous research on aqua jogging has investigated the physiological responses during maximal and submaximal testing in shallow (feet touching the bottom) and deep water (feet not touching the bottom). Results obtained during aqua jogging exercise were compared to the results obtained during exercise performed at or near the same intensity on the treadmill.

Several authors have investigated the physiological effects of shallow water exercise (Gleim & Nicholas, 1989; Kaminsky, Wehrli, Mahon, Rubbins, Powers, &
Whaley, 1993; Town & Bradley, 1991; Whitley & Schoene, 1987). Whitley and Schoene (1987) compared the heart rate responses while subjects walked at four different speeds in water and on the treadmill to determine if walking in the water or on the treadmill could elicit a cardiorespiratory training effect. The authors hypothesized that subjects would have a greater heart rate in the water compared to that on land. The results showed heart rate to be significantly greater during water walking compared to treadmill walking at all four speeds. Whitley and Schoene (1987) concluded that the increase in heart rate from rest to the fastest speed during water walking (135%) would be sufficient enough to achieve cardiorespiratory fitness in young healthy individuals, while the 19% increase during treadmill walking from rest to the fastest speed would not.

Gleim and Nicholas (1989) investigated the metabolic responses during treadmill walking and walking in water at different depths and temperatures. Subjects were tested at four different depths and once on a dry treadmill (land). A few subjects were also tested in waist deep water at different temperatures. Results indicated that in ankle depth, below the knee, mid-thigh and waist deep water, at speeds greater than or equal to 53.6 m • min⁻¹, the peak oxygen consumption and heart rate obtained during walking/jogging in water was significantly greater than that obtained on the dry treadmill (p <.05). These results were anticipated by the authors knowing that at a given work rate (intensity), the energy cost of exercise in water is greater than that on land (Costill, 1971). However, at speeds greater than or equal to 134.1 m • min⁻¹ there were no differences in oxygen consumption between the two groups. Authors suggested that a prolonged flight phase which occurs during water running in waist deep water could possibly counteract the additional work necessary to move the legs against the resistance of the water. In addition, in waist deep water, heart rate tended to increase with an increase in water temperature. The increase in heart rate was most likely caused by the thermoregulatory demand of the body. This would
suggest that more cardiac work must be performed in hot water for the same whole body
energy expenditure.

Town and Bradley (1991) investigated maximal metabolic responses to DWR and
SWR in trained runners and compared them to maximal treadmill measures. DWR was
performed in water at a depth of 2.5 to 4 meters with the subject not wearing a vest. SWR
was performed in water at a depth of 1.3 meters with the subjects not wearing a vest.
Treadmill VO2max was significantly greater than both SWR and DWR VO2max, while
SWR VO2max was significantly greater than DWR VO2max (p < .05). The heart rate
response was highest during treadmill running. However, there was no difference
between heart rate responses to SWR and DWR (p > .05). A suggested explanation by the
authors is the increased utilization of muscle mass. During DWR, the antigravity muscles
are not needed to maintain posture to the same extent as during LBR.

Butts, Tucker, and Greening (1991) suggest the increase in active muscle mass
normally involved during LBR, but absent during DWR might be responsible for the
decrease of metabolic work seen during DWR. Town and Bradley (1991) suggested that
VO2max might be influenced more by utilization of active muscle mass rather than heart
rate. Also, there was a higher oxygen-pulse during the DWR test the LBR test. This
increased oxygen-pulse indicates that a greater heart during DWR is needed to achieve the
same VO2max between the two modes of testing. The authors suggest this increased
oxygen-pulse seen in the DWR test might be influenced by a decrease in efficiency brought
on by atypical movements of both arms and legs during DWR. A similar example of this is
when we compare arm and leg exercise. Toner et al. (1990) reported that for any level of
oxygen consumption or percent of VO2max, the physiological strain (heart rate, ventilation
and RPE) is greater in arm exercise than leg exercise.

Kaminsky et al. (1993) attempted to estimate maximal aerobic power from results
of a SWR test. Performance times from a 457 meter shallow water run and a 2.4 km land run were correlated to maximal aerobic power. Results indicated that maximal aerobic power obtained during a maximal treadmill test correlated well with both the 2.4 km land run and the 457 meter water run \( r = -.89 \) and \( r = -.80 \) respectively. Kaminsky and colleagues concluded that the 457 meter shallow water run test can provide a reasonable estimate of an individual's treadmill maximal aerobic power.

Deep Water Running

In the past, there have been a number of studies performed to determine the physiological responses to treadmill running and DWR (Bishop et al. 1989; Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Green et al., 1990; Svedenhag & Seger, 1992). More recently, there has been a growing interest evaluating the effectiveness of DWR as a training mode (Brennan et al., 1993; Eyestone et al., 1993; Hertler et al., 1993; Michaud et al., 1993; Quinn et al., 1994).

Physiological Responses to DWR

Svedenhag and Seger (1992) evaluated the physiological differences between responses to running on treadmill and running in the water. They reported submaximal and maximal heart rates and VO2max to be lower while exercising in the water than on land. Authors of this study and others on DWR (Bishop et al., 1989; Butts, Tucker, & Smith, 1991; Green et al., 1990) are in agreement that the physiological responses are different during DWR than in LBR. Lower maximum heart rates and a lower VO2max have consistently been reported during DWR. Theories to explain the differences are: (1) hydrostatic effects of water which can increase central and cardiac blood volume leading to baroreflex response (Green et al., 1990); (2) body position and depth of subject in water; and/or (3) active muscle mass utilized (Butts, Tucker, & Smith, 1991).
Butts, Tucker, and Smith (1991) investigated the maximal responses obtained during treadmill running and DWR (with a vest) in competitive high school female cross country runners. Results indicated no significant differences in peak ventilation (VE), rating of perceived exertion (RPE), or respiratory exchange ratio (RER) between the treadmill running and water running values. However, maximum heart rate and VO2max were lower during DWR. The reported differences between the two modes of exercise for VO2max (7.9 ml • kg⁻¹ • min⁻¹ or 17%) and maximum heart rate (17.6 b • min⁻¹ or 8%), are similar to those found in swimming studies (Holmer, Lundin, & Eriksson, 1974; Holmer, Stein, Saltin, Ekblom, & Astrand, 1974; Magel & Faulkner, 1967; McArdle, Magel, Delio, Toner, & Chase, 1978).

Bishop et al. (1989) tested seven well trained, uninjured runners and found that maximum VE, VO2max and maximum RER were significantly higher during treadmill running while heart rate and perceived exertion were not significantly different between the LBR and the DWR groups. However, two of the athletes with a high initial VO2 (values not given), were capable of achieving a high VO2max for both exercise modes. The authors speculated that water running may help lessen the rate of deconditioning of injured athletes. However, the ability for increasing fitness level in athletes had yet to be tested.

Responses to DWR Training

Is it possible for DWR to elicit an intensity great enough to increase metabolic responses? To date, there have only been a few studies which have investigated DWR as a possible training mode of exercise (Brennan et al., 1993; Eyestone et al., 1993; Hertler et al., 1993; Michaud et al., 1993; Quinn et al., 1994).

Quinn and colleagues (1994) investigated the effects of a 4 week DWR training program following a 10 week land based running program. The purpose was to
investigate if the DWR program was capable of maintaining the oxygen uptake established during the previous 10 weeks of LBR. The authors concluded that DWR was not capable of maintaining VO$_2$max. In fact, a 7% decrease (p<.05) in VO$_2$max was reported following the 4 weeks of DWR. A possible problem with this study is the prescription of intensity for exercise in the water. As reported from previous research (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Svedenhag & Seger, 1992) that heart rate obtained during DWR is at least 10 b·min$^{-1}$ lower than that obtained during LBR, Quinn and colleagues prescribed water intensity as 80% of heart rate reserve minus 10 b·min$^{-1}$. The authors suggest it was possible that this intensity during DWR was not sufficient enough to maintain VO$_2$max.

Eyestone et al. (1993) compared the effectiveness of training programs involving DWR (with a vest), cycling, and running on land for maintaining VO$_2$max and 3.2 km run performance in 32 trained runners over a 6 week training period. All three groups trained at similar intensities (based on a percentage of their treadmill VO$_2$max), durations and frequencies over a 6 week period. Results indicated all three groups had similar significant decreases in treadmill VO$_2$max (4.9%, 3.25%, and 4.22%) respectively, but no change in 3.2 km performance time. Eyestone and colleagues gave no suggestions for the decrease in treadmill VO$_2$max, but concluded that VO$_2$max would decrease the same regardless of the training mode selected. Furthermore, 3.2 km performance times were not affected differently by any of the three modes. Therefore, DWR proved to be as successful as LBR and cycling for maintaining VO$_2$max.

Michaud et al. (1993) attempted to determine if DWR training could enhance peak metabolic values measured on land. Ten untrained, healthy subjects (8 females & 2 males) volunteered for an 8 week aqua jogging program to taking place in deep water while wearing an Aqua jogger flotation belt around their waist. Initial fitness was determined by
a pretraining maximal treadmill test. The mean \( VO_2\text{max} \) for the group \((n = 10)\) was \(29.3 \pm 8.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \). After 8 weeks of aqua jogging interval training, 3 days • week\(^{-1}\) at 63-82% maximal treadmill heart rate, the posttraining maximal test showed \( VO_2\text{max} \) had increased by \(3.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}\) or 10.6\% \( (p < .01) \). It was concluded that regular DWR performed at frequencies, intensities, and durations recommended by the ACSM (1991) produces cardiovascular stimuli of significant specificity and magnitude to improve LBR \( VO_2\text{max}/\text{cardiovascular fitness} \).

The effectiveness of a DWR program as a replacement or alternative mode of exercise for maintaining peak oxygen uptake and leg strength in runners was investigated by Hertler et al. (1993). All subjects trained on land for 4 weeks at the same intensity (established from treadmill maximum tests). After this initial 4 weeks of training, all subjects were evaluated for \( VO_2\text{max} \) and several leg strength exercises, including maximal concentric and eccentric contractions of the knee, ankle plantar flexion, ankle dorsiflexion and knee flexion. Subjects were placed into one of two groups. One group \((n = 7)\) continued to train on land, while the other group \((n = 6)\) participated in DWR (while wearing an Aqua jogger buoyancy belt), at the same intensity (measured by RPE) and duration as the on land group. Results revealed no significant differences \((p > .05)\) in \( VO_2\text{max} \) or any of the strength measures between groups as a result of the training protocol. The authors concluded that deep water training with this specific protocol was successful in maintaining \( VO_2\text{max} \) and leg strength over a 4 week period in this particular group of runners.

Brennan et al. (1993) investigated the changes in cardiovascular fitness/DWR \( VO_2\text{max} \) brought about by an 8 week interval type DWR (with vests) program. Results indicated that posttraining \( VO_2\text{max} \) in the water was significantly greater \((4.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \) or 19.6\%) than pretraining \( VO_2\text{max} \) \((p < .01)\). The authors conclude that DWR
VO2max can be increased if appropriate intensity, frequency and duration are maintained.

Ways of Measuring DWR Intensity

The ability to estimate VO2 in the water from heart rate values obtained on the treadmill is questionable (Arborelius et al., 1972; Green et al., 1990). This degree of uncertainty suggests that maximal heart rate values from the treadmill should not be used to determine intensity of exercise in water. Therefore, if deep water exercise is to be used as the mode of exercise, the appropriate training heart rate should be determined in the pool or during water exercise.

Mercer, Jensen and Fromme (1994) investigated the reliability of a DWR maximal test and compared peak responses obtained in the water to those obtained on the treadmill. Reliability of the DWR test was established by intraclass correlation for peak VO2 ($r = .95$, $p < .05$) and peak HR ($r = .86$, $p < .05$). A paired t-test revealed that peak VO2 and peak HR for the water test were significantly lower than those values obtained on the treadmill ($p < .01$). Estimation of peak HR on the treadmill is often obtained by using $220 - \text{age}$. When this same technique was used to estimate peak HR for DWR, results indicated $R = 0.39$, suggesting its accuracy for predicting DWR peak HR is questionable.

Another method used to measure the intensity of exercise for aqua jogging is the use of cadence. Wilder, Brennan, and Schotte (1993) determined the relevance of cadence as a measure for exercise prescription. Results indicated that cadence and heart rate were highly correlated ($r = 0.73$, $p < .01$), and that cadence may be used as a measure of exercise prescription for aqua jogging. Although the use of cadence has proven to be a good predictor of intensity for aqua jogging, the ability to accurately measure and maintain a particular cadence frequency and stride length in the water is difficult. This difficulty limits its usefulness as a gauge of intensity.
Ritchie and Hopkins (1991) compared the intensity of “hard” DWR to a “normal” and “hard” treadmill run and a “hard” outdoor run. The intensity of exercise was based on the subjects' perception of hard and normal feeling. The results showed that VO2max for the hard deep water run was 73% of the hard outdoor run and was not significantly different from that of the hard treadmill run (78%), but was significantly higher than that of the normal treadmill run (62%). It was concluded that DWR can be performed at a sufficient intensity for a sufficient period to make it an effective endurance training technique.

Summary

A review of the literature has established that a difference exists between VO2max and heart rate values obtained during water exercise and those obtained during land exercise. The exact reason for the difference is unknown at this time. Most studies suggest that maximum HR during water exercise is approximately 10 - 20 b • min-1 less than values seen on the treadmill (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Mercer et al., 1994; Svedenhag & Seger, 1992; Town & Bradley, 1991). With this wide range of variability, the accuracy of predicting a safe and effective intensity for water exercise from treadmill values is questionable. In fact, it has been advised that extreme caution be taken when prescribing intensity of exercise in water from treadmill values (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991).

Of the DWR training studies reviewed, all investigators prescribed intensity of water exercise from treadmill values. With this in mind, the accuracy of the prescribed intensity for the training groups is questionable. Any differences that occurred between the land based runners and the deep water runners might not be due to the differences between the training modes, but to the differences in training intensity.
CHAPTER III

METHODS

Introduction

In this chapter, subject characteristics along with methods and procedures utilized for the collection of peak values during all testing (treadmill, water, & 2.4 km runs) will be discussed. The statistical methods employed for the analysis of data will also be explained.

Subject Characteristics

Subjects in the present study included volunteers from the University of North Texas student body (14 males & 10 females). Of the 24 subjects who began the study, only 11 subjects (6 males & 5 females) successfully completed the study by meeting the necessary criteria. Subject group characteristics are displayed in Table 1. Individual values are in Appendix A.

Table 1
Mean and Standard Deviation of Subjects’ Characteristics

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Stature (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>University students (N = 11)</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>23 ± 3</td>
<td>174 ± 9</td>
</tr>
</tbody>
</table>

Prior to any testing, all subjects read and signed an informed consent form (Appendix B) which was in appliance with the policy statements of the ACSM (1991). The
Institutional Review Board of the University of North Texas. Subjects were put into one of two groups, Land Based Runners (n = 5) or Deep Water Runners (n = 6). Both groups trained at the same relative intensity (determined by mode specific graded exercise test), three times per week for 10 weeks. Following 10 weeks of training, subjects were evaluated for peak oxygen uptake on the treadmill and in the water as well as performance time for the 2.4 km land run.

Measurement of DWR and Treadmill Running Maximal Tests

Deep Water Running Maximal Test

The DWR tests took place in a tank measuring 1.8m x 1.8m x 1.8m. The water temperature of the tank was maintained as close as possible to that of the pool where the DWR subjects trained. The water temperature of the pool was 26.6 °C while the average temperature of the tank was 27.2 ±1.5 °C.

During DWR testing, the subject wore an Aquajogger Belt (Excel Sports, Eugene, Oregon) around his or her waist to help maintain an upright erect position while in the water. A rope was attached to the back of the Aquajogger Belt. It extended horizontally behind the subject running through one pulley, up the wall, through a second pulley over the subject’s head, then down through a third pulley and attached to a bucket suspended 0.63 m above the deck of the tank (Fig. 1).

The water test protocol was continuous and consisted of 1 minute stages (Mercer et al., 1994). To provide a graded response, a 0.57 kg weight was added to the bucket at the beginning of each stage. The added weight had the effect of pulling the subject backwards if the propulsive force was not increased. Additional weight was added each minute until the subject could no longer keep the bucket from coming in contact with the pool deck.
Treadmill Running Maximal Test

All subjects were required to perform one maximal treadmill running test before and after the training program. The protocol for the treadmill test was continuous and consisted of 1 minute stages (Mercer et al., 1994). The first stage began at 0% grade and 4.8 km • hr⁻¹. After stage one was complete, speed remained at 4.8 km • hr⁻¹ and the grade was increased to 7.5%. For stages three and four, grade was kept constant at 7.5% and the speed was increased 1.6 km • hr⁻¹ at the beginning of each minute. During stage five and all subsequent stages, speed was increased 0.8 km • hr⁻¹ at the beginning of each minute until the subject could no longer continue.
2.4 km Run Performance

All subjects completed three 2.4 km runs during the course of the study. Two were done before training while the third was done after training. To establish the reliability of the 2.4 km run, an additional 22 students from a University jogging class (N = 46) ran two 2.4 km runs. All runs took place on an outdoor track. In order to eliminate any pacing effects, subjects ran with the same individual or group of individuals as they did in the pretraining runs.

Data Collection

DWR Peak Oxygen Uptake Test

Expired gases were collected in 120 liter meteorological balloons every 30 seconds for the last 2 minutes of the test by using a low resistance three-way valve. Values were expressed in ml • kg • min\(^{-1}\). Expired gas fractions of oxygen and carbon dioxide were analyzed with a metabolic cart (Medical Graphics CPX, St. Paul, Minnesota) while gas volumes were determined using a Tissot gasometer. Heart rate was measured before and immediately after the test by palpation of the carotid artery for 15 seconds.

Treadmill Running Peak Oxygen Uptake Test

Oxygen consumption and other ventilatory volumes were determined and recorded every 30 seconds and expressed in ml • kg • min\(^{-1}\) through the use of a metabolic cart (Medical Graphics CPX, St. Paul, Minnesota). Ventilatory calibration was performed daily using a calibrated 3 liter syringe. Prior to each test, O\(_2\) and CO\(_2\) analyzers were calibrated using known gases. Heart rate was obtained before and immediately after the test by palpation of the carotid artery.
Training

The training program consisted of 10 weeks of training, 3 d • wk⁻¹, for 35 minutes each day. Intensity was 70% mode specific peak heart rate for the first two weeks and 80% for the remaining 8 weeks. Intensity for each individual was determined from the mode specific maximum test (water or treadmill) depending on which group the individual was in. Intensity, in both LBR and DWR, was monitored by the subject every 10 minutes of the workout through palpation of carotid artery.

If a subject missed five or more training sessions, the subject was dropped from the study. However, subjects were allowed to make up any missed sessions if done within 48 hours of the missed session. Training logs were kept by each subject and evaluated weekly by the investigator. All training for LBR took place on area roads and on the university track, while the DWR took place in the university diving well. The training took place between 8:00 and 10:00 a.m on Monday, Wednesday and Friday mornings.

Testing Procedures

Tests were performed on separate days and all posttesting was done at the same approximate time of day as the pretest. The subjects were instructed not to participate in any strenuous activity the day of testing. Ambient air temperature for pretraining maximal tests (water and treadmill) was 22 °C, and 22.5 °C posttraining. Water temperature for all pretraining water tests was 27 °C, and 27 °C posttraining. Due to the change in seasons, the pre/posttraining temperatures for the 2.4 km runs were significantly different, 24.5 °C vs 11.5 °C respectively. Upon arrival at the laboratory prior to testing, each subject was weighed and had blood pressure taken. All subjects were familiarized with the testing apparatus, and instructed on proper technique. Determination of VO₂peak was when: (a) subject could no longer maintain the current intensity; or (b) rating of perceived exertion
(RPE) of 17 or greater.

Statistical Analysis

A 2 (DWR/LBR) by 2 (pre/post) repeated measures analysis of covariance with gender as the covariate was used to analyze the data. The dependent variables were (1) performance time in the 2.4 km run; and (2) VO2peak for both treadmill and water tests. Means and standard deviation were calculated for the dependent variables under the conditions for which they were measured. Statistical significance was set at .05.
CHAPTER IV

RESULTS

Pilot testing of the 2.4 km performance run (N = 46) indicated reliability was high (r = .95), with the mean difference between the trials being 14.5 s (p>.05). Of the subjects who completed the study (N = 11), analysis of variance with repeated measures indicated the means between the first 2.4 km run (M = 850.5 s) and the second 2.4 km run (M = 850.5 s) were not significantly different F(1, 10) = .003, p>.05. Therefore, for statistical purposes, the values obtained during the two pretraining 2.4 km runs were averaged, and this mean served as the criterion value for time in the 2.4 km run.

Two-Factor ANCOVA with gender as the covariate was done to establish if an interaction between the training mode (DWR or LBR) or the time of testing (pre/post) was present. Results indicated there were no interaction effects on treadmill VO2peak F(1, 9) = .20, p = .66, water VO2peak F(1, 9) = 2.95, p = .12, or 2.4 km performance time F(1, 9) = .02, p = .89. Results also indicated there was a main effect for treadmill VO2peak for pre- to post-testing F(1, 9) = 9.68, p = .01, and a tendency towards a main effect on 2.4 km performance time pre and post testing F(1, 9) = 4.47, p = .06. The main effect for pre to post treadmill VO2peak indicates there was an increase in VO2peak in all subjects (DWR & LBR) considered together. The mean values for all measured variables within each group are presented in Tables 2 and 3. Individual data are presented in Appendix C.
Heart rate and RPE were also recorded pre- and post-testing on the treadmill and in the water. Results indicated that there were no significant differences (p>0.05) in pre- and post-peak heart rate and RPE within each group (LBR & DWR). Results can be seen in Table 4.

Table 2
Mean and SD for Peak Oxygen Capacity and Time to Exhaustion for Deep Water and Land Based Running Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>DWR (n = 6)</th>
<th>LBR (n = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Treadmill Max</td>
<td>41</td>
<td>43</td>
</tr>
<tr>
<td>(ml • kg • min⁻¹)</td>
<td>10.3</td>
<td>11.7</td>
</tr>
<tr>
<td>Treadmill TTE (s)</td>
<td>405</td>
<td>435</td>
</tr>
<tr>
<td></td>
<td>137.3</td>
<td>157.5</td>
</tr>
<tr>
<td>Water Max</td>
<td>38</td>
<td>42</td>
</tr>
<tr>
<td>(ml • kg • min⁻¹)</td>
<td>10.8</td>
<td>13.0</td>
</tr>
<tr>
<td>Water TTE (s)</td>
<td>480</td>
<td>545</td>
</tr>
<tr>
<td></td>
<td>156.2</td>
<td>147.7</td>
</tr>
</tbody>
</table>

Note.
DWR: Deep water running group
LBR: Land based running group
TTE: Time to exhaustion
Table 3
Mean and Standard Deviation for 2.4 km Performance Time for Deep Water and Land Based Running Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre (s)</th>
<th>Post (s)</th>
<th>%Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>DWR (n = 6)</td>
<td>903 ± 196</td>
<td>853 ± 237</td>
<td>-5.5%</td>
</tr>
<tr>
<td>LBR (n = 5)</td>
<td>788 ± 1118</td>
<td>731 ± 139</td>
<td>-7.1%</td>
</tr>
</tbody>
</table>

Table 4
Mean and Standard Deviation for Peak Heart Rate and RPE Values for Pre- and Post Maximal Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>LBR (n = 5)</th>
<th>DWR (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Treadmill HR (b • min⁻¹)</td>
<td>189 ± 11</td>
<td>180 ± 14</td>
</tr>
<tr>
<td>Treadmill RPE</td>
<td>17 ± 1</td>
<td>17 ± 2</td>
</tr>
<tr>
<td>Water HR (b • min⁻¹)</td>
<td>171 ± 19</td>
<td>161 ± 24</td>
</tr>
<tr>
<td>Water RPE</td>
<td>18 ± 1</td>
<td>17 ± 1</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION

Introduction

An interpretation of the results and the significance they may have is presented in this chapter. Possible explanations as to why these results were found will hopefully provide a better understanding of the effects a DWR training program may have on an individual. With frequency, intensity, and duration of exercise being equal, the results of this study indicate that the training response to DWR did not differ from LBR. Therefore, DWR may be used as a training method as effectively as LBR.

Treadmill Peak Oxygen Uptake

The fact that there has been minimal research done comparing the physiological differences between DWR and LBR (Eyestone et al., 1993; & Hertler et al., 1993), it is hard to evaluate the results of this study. The significant main effect for treadmill VO2peak indicates that both training modes (DWR or LBR) were successful for increasing VO2peak.

Michaud et al. (1993) reported a 10.6% increase (p<.05) in treadmill VO2peak following 8 weeks of DWR training. This 10.6% increase was larger than either of the groups in the present study (5.6% DWR or 7% LBR). Some explanations could include beginning fitness level of the current subjects (41.4 ± 10.3 ml • kg⁻¹ • min⁻¹ vs 29.3 ± 8.2 ml • kg⁻¹ • min⁻¹) and, also type of training (continuous vs interval). As reported by Saltin (1969), improvements in oxygen uptake are inversely related to the subject’s
initial fitness level. In the study by Michaud and colleagues (1993), the initial oxygen uptake for the water runners was approximately 10 ml • kg$^{-1}$ • min$^{-1}$ less than that of the deep water runners in the present study. Also, the fact that Michaud et al. (1993) used interval training whereas the present study used a continuous training protocol might account for the differences in the results (MacDougall & Sale, 1991).

Although no interaction was seen between groups, results from the LBR group indicated a 7.3% increase in treadmill VO$_2$peak, while Eyestone et al. (1993) reported a significant 4.22% decrease in treadmill VO$_2$peak ($p<.01$). In the present study, the DWR group had a 5.6% increase in treadmill VO$_2$peak while Eyestone and colleagues reported a significant 4.9% decrease ($p<.05$) in VO$_2$peak for deep water runners. The discrepancy between the results in the current study and that by Eyestone and colleagues (1993) could possibly be due to initial fitness level (41.40 ml • kg$^{-1}$ • min$^{-1}$ vs 56.87 ml • kg$^{-1}$ • min$^{-1}$) of the subjects at the beginning of training (Saltin, 1969), the frequency of training (3d • wk$^{-1}$ vs. 3-5 d • wk$^{-1}$), intensity of training (2 wks @ 70% & 8 wks @ 80% VO$_2$peak vs 1 wk @ 75% & 5 wks @ 80% VO$_2$peak) and duration of training (35 min • d$^{-1}$ for 10 wks vs 27.5 min • d$^{-1}$ for 6 wks) respectively. Furthermore, because the subjects in the study by Eyestone and colleagues were already trained, it is very possible that the intensity and frequency of training was not sufficient enough to maintain VO$_2$peak.

In contrast to the results of the present study, Quinn et al. (1994) reported that following 10 weeks of LBR, a 4 week DWR training program was not capable of maintaining treadmill VO$_2$peak. In fact, they reported a 7% decrease ($p<.05$). Because initial fitness level was similar (41.40 ± 10.38 vs 42.9 ± 3.2 ml • kg$^{-1}$ • min$^{-1}$), differences are most likely due to the intensity level prescribed during the DWR (80% treadmill maximum heart rate - 10 b • min$^{-1}$). Quinn et al. (1994) suggested that the
intensity of exercise during the 4 weeks of DWR training might not have been intense enough to maintain the VO2peak achieved during the previous 10 weeks of LBR.

Furthermore, specificity of exercise may have also played an important role. It was noted by Quinn and colleagues that the deep water runners used a running style which was more representative of a "bicycle" motion than a running motion. In the present study, deep water runners used a running motion very similar to that seen on land. If local adaptations in skeletal muscle do indeed play an important role for improvements in oxygen uptake (McArdle et al., 1978), then it is possible that the difference in running styles between the study by Quinn et al. (1994) and the current study might influence the ability to improve or maintain treadmill VO2peak.

**Water Peak Oxygen Uptake**

In the DWR and LBR groups, the increase in water VO2peak of 9.3% and 0% respectively was smaller than the 19.6% (p<.01) reported by Brennan et al. (1993). Some suggestions for the differences could be exercise prescription, type of training (continuous vs interval), and or differences in initial fitness levels. Whereas Brennan and colleagues prescribed intensity of water exercise from peak treadmill values, intensity for water exercise in the present study was prescribed by maximum water values. Assuming that peak heart rate in water is less than that obtained on land (Butts, Tucker, & Greening, 1991; Butts, Tucker, & Smith, 1991; Svedenhag & Seger, 1992), it is possible that the "water subjects" in the study by Brennan and colleagues (1993) were training at a higher intensity than believed. Therefore, while training at an intensity between 63 - 82% peak treadmill heart rate, they may actually have been training at an intensity between 67 - 86% their peak DWR heart rate. Whether or not this difference is large enough to cause or influence the discrepancy is unknown.
Different training protocols could also account for some of the differences in improvement of DWR VO2peak. Brennan et al. (1993) used an interval training program which utilized 16 - 36 minute exercise sessions at 63 - 82% peak treadmill heart rates. On the other hand, the current study used a continuous training protocol at an intensity of 70 to 80% of peak water heart rates. The greater increase in VO2 during interval training programs have been suggested to be due to a greater volume of high intensity training (MacDougall & Sale, 1981). It is difficult to compare the total volume of high intensity training in the study by Brennan and coworkers to the current investigation because the actual time of the interval work/rest ratio in the former study was not reported. Therefore, it is possible that the differences in the training protocols could be responsible for the differences seen in peak water values of the deep water runners.

A third explanation and the one most likely responsible for the biggest difference is initial fitness level of subjects at the beginning of the study. In the study by Brennan et al. (1993), the sample used was composed of 8 females and 2 males. It has been reported that VO2peak for women is typically 15 to 30% below scores for men (Hermansen, & Anderson, 1965). The initial fitness level as measured on the treadmill was 41.40 ± 10.38 ml • kg\(^{-1}\) • min\(^{-1}\) in the present study, and 29.3 ± 8.2 ml • kg\(^{-1}\) • min\(^{-1}\) in the study by Brennan et al. (1993). Knowing that improvements in VO2 are inversely related to the subject's initial fitness level (Saltin, 1969), it is likely that the difference in VO2peak between the two studies had a large impact on the degree of improvement.

In the land based runners, results indicated there was no change between the pre- and post-training water VO2peak values (37.55 ± 8.1 ml • kg\(^{-1}\) • min\(^{-1}\) vs 37.33 ± 4.07 ml • kg\(^{-1}\) • min\(^{-1}\)). There appears to have been no previous studies in which individual's VO2peak during DWR pre- and post-training on land have been evaluated. However, a study by McArdle et al. (1978) reported that running produced a general training adaptation
that resulted in a 2.6% increase in swimming VO2max. On the other hand, Magel et al. (1974) reported no significant improvement in treadmill VO2max following 10 weeks of swim training in recreational athletes. In the present study, a possible explanation for why VO2peak in the LBR group did not improve while that in the DWR group improved by 9.3% (4.0 ml • kg\(^{-1}\) • min\(^{-1}\)) could be due to specificity of training and/or skill level of subjects.

If local adaptations of skeletal muscle or specificity are determining factors for the different training modes, then one would expect the DWR group not to improve their treadmill VO2peak. However, this was not the case in the current study, where DWR group increased treadmill VO2peak by 5.6% (2.47 ml • kg\(^{-1}\) • min\(^{-1}\)) which was not significantly different than that of 7.3% (3.3 ml • kg\(^{-1}\) • min\(^{-1}\)) seen in the LBR group.

It has also been reported that skill level is an important factor for achieving a higher VO2peak in experienced deep water runners (Svedenhag & Seger, 1993; Yamaji, Greenleg, Northey, & Hughson, 1990). Therefore, the 9.3% change in water VO2peak for the DWR group could be a result of the skill level obtained over the previous 10 weeks of DWR. If this is true, it helps explain why the LBR group could not improve their water VO2peak, but were able to improve their treadmill VO2peak. It is likely that the difference in VO2peak obtained in the water is dependent on both skill level and specificity. However, it must also be recalled that although physiologically different, there was no statistical group by pre/post test interaction in the current study.

2.4 km Run Performance

The ANCOVA for the 2.4 km run indicated no main effect however it was very close \(F(1, 9) = 4.47, p = .06\). Both the LBR group and the DWR group 2.4 km performance times demonstrated a tendency towards improvement, however it was not
statistically significant. It is interesting to note that the decrease in performance time for the 2.4 km run for LBR (7%) and the DWR (5%) is very similar to the increase in treadmill peak oxygen consumption of 7.3% for the LBR and 5.6% for the DWR. Ambient temperature may also have played a role in 2.4 km performance. The temperature was about 25 ± 3 °C and 12 ± 2 °C during the pre- and post-test respectively. It is possible that this difference could have had a positive or negative effect on the subjects however the exact effect can not be determined.

Conclusion

The primary purpose of this study was to determine if deep water running could enhance VO2peak as well as land based running. Results indicated there was no interaction for any of the variables measured. However, there was a main effect for treadmill VO2peak, suggesting both groups had an improvement in treadmill VO2peak following 10 weeks of training. For the other variables measured, there was no main effect. The most likely reason for lack of a main effect was the small sample size of 11 subjects. However, a second possibility is that due to the high initial fitness level of the subjects (41.65 ± 10.13 ml • kg^{-1} • min^{-1}), the frequency, intensity, and duration of exercise may have not been sufficient enough to enhance VO2peak in this sample.
CHAPTER VI

RECOMMENDATIONS FOR FUTURE RESEARCH

The study of deep water running is a relatively new field. There are many variables, most of which are unexplained, that may affect the physiological responses during exercise in water. Therefore recommendations for future research in this field are unlimited.

1) Further analysis of the effects of water on submaximal and maximal aerobic uptake.

2) More training studies involving larger samples and different populations.

3) Effects of different types of training (continuous & interval), along with different frequencies, intensities, and durations.

4) Further analysis of the importance of skill level and the effect it may or may not have on submaximal or maximal aerobic uptake.

5) Investigation of deep water running with and without a flotation device.

6) Further analysis of the effectiveness of deep water running for the enhancement of land based aerobic uptake.
APPENDIX A

SUBJECT CHARACTERISTICS
APPENDIX A
Subject Characteristics

<table>
<thead>
<tr>
<th>Subject</th>
<th>Group</th>
<th>Gender</th>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DWR</td>
<td>F</td>
<td>26</td>
<td>167</td>
<td>70.5</td>
</tr>
<tr>
<td>2</td>
<td>DWR</td>
<td>M</td>
<td>30</td>
<td>187</td>
<td>92.0</td>
</tr>
<tr>
<td>3</td>
<td>DWR</td>
<td>F</td>
<td>23</td>
<td>169</td>
<td>70.0</td>
</tr>
<tr>
<td>4</td>
<td>DWR</td>
<td>M</td>
<td>23</td>
<td>175</td>
<td>68.0</td>
</tr>
<tr>
<td>5</td>
<td>DWR</td>
<td>M</td>
<td>22</td>
<td>173</td>
<td>67.0</td>
</tr>
<tr>
<td>6</td>
<td>DWR</td>
<td>F</td>
<td>23</td>
<td>168</td>
<td>69.0</td>
</tr>
<tr>
<td>7</td>
<td>LBR</td>
<td>M</td>
<td>23</td>
<td>175</td>
<td>68.0</td>
</tr>
<tr>
<td>8</td>
<td>LBR</td>
<td>F</td>
<td>19</td>
<td>165</td>
<td>47.0</td>
</tr>
<tr>
<td>9</td>
<td>LBR</td>
<td>M</td>
<td>19</td>
<td>168</td>
<td>76.0</td>
</tr>
<tr>
<td>10</td>
<td>LBR</td>
<td>F</td>
<td>20</td>
<td>175</td>
<td>71.0</td>
</tr>
<tr>
<td>11</td>
<td>LBR</td>
<td>M</td>
<td>24</td>
<td>193</td>
<td>89.0</td>
</tr>
</tbody>
</table>

Mean

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.0</td>
<td>174.0</td>
<td>72.0</td>
</tr>
</tbody>
</table>

SD

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0</td>
<td>9.0</td>
<td>12.0</td>
</tr>
</tbody>
</table>
APPENDIX B

SUBJECT CONSENT FORM
University of North Texas
Department of Kinesiology
Written Consent Form

Water Based Running vs. Land Based Running: A Training Study

Subject Name (print): ___________________________________________________________________

1. I hereby volunteer to participate as a subject in a 10-week training study. I understand that this testing is part of a study entitled: “Deep Water Running vs. Land Based Running”. The purpose of this study is to compare VO2max and 1.5 mile performance time between Deep Water Running and Land Based Running.

I hereby authorize Matt Morrow, Chad Peace and/or assistants as may be selected by themselves to perform the following procedures:

a. To have me exercise twice in the water, twice on the treadmill, with the work rate increasing every minute until I can no longer continue.

b. To have me run three 1.5 mile runs and three 200 meter dashes on the University of North Texas track.

c. To have me perform two maximal strength tests (10 contractions) of my arms and legs.

d. To train for 10-weeks in one of the two exercise modes; Deep Water Running, or Land Based Running.

I understand that during the maximal exercise tests (a) I will be breathing through a mouthpiece, which will be attached to a metabolic cart or meteorological balloons which will analyze the air I exhale, and that my nose will be pinched shut.

2. The procedures outlined above have been explained to me by Matt Morrow and/or Chad Peace.
3. I understand that the procedure described in paragraph 1 (a & b) involve the following risks and discomforts: temporary muscle pain and soreness is expected. There is a possibility of abnormal changes in my heart beat or blood pressure or even a heart attack during the tests. However, I understand that my heart rate will be monitored during all laboratory testing procedures and that I can terminate any test at any time at my discretion.

4. I have been advised that aside form the educational benefit of learning about aerobic testing there will be no benefits from my participation in this study.

5. I understand that Matt Morrow, Chad Peace and/or appropriate assistants as may be selected by them will answer any inquiries that I may have at any time concerning these procedures and/or investigations.

6. I understand that all data concerning myself will be kept confidential and available only upon my written request. I further understand that in the event of publication, no association will be made between the reported data and myself.

7. I understand that there is no monetary compensation for my participation in this study.

8. I understand that in the event of physical injury directly resulting from participation, compensation cannot be provided. I understand that there will not be a medically certified physician or defibrillator present during the tests. However, medical treatment will be available at the University Health Center and the laboratory has an outside telephone line to the city of Denton emergency services (911). All investigators are certified in Cardio Pulmonary Resuscitation (CPR).
9. I understand that I may terminate participation in this study at any time
without prejudice to future care or any possible reimbursement of expenses,
compensation, or employment status.

10. I understand that I may contact the chairperson of the Kinesiology
Department's Committee on the Use of Human Subjects in Research, Dr. Allen
Jackson on any matters concerning my participation in this study or if I feel
that there is infringement on my rights.

Subject's Signature: ________________________________

Witness: ____________________________ Date: ____________
APPENDIX C

SUBJECT RAW DATA
APPENDIX C
Raw Data

<table>
<thead>
<tr>
<th>ID</th>
<th>DW&lt;sup&gt;a&lt;/sup&gt;</th>
<th>DW&lt;sup&gt;a&lt;/sup&gt;HR</th>
<th>DW&lt;sup&gt;b&lt;/sup&gt;</th>
<th>DW&lt;sup&gt;b&lt;/sup&gt;HR</th>
<th>TM&lt;sup&gt;a&lt;/sup&gt;</th>
<th>TM&lt;sup&gt;a&lt;/sup&gt;HR</th>
<th>TM&lt;sup&gt;b&lt;/sup&gt;</th>
<th>TM&lt;sup&gt;b&lt;/sup&gt;HR</th>
<th>1.5&lt;sup&gt;a&lt;/sup&gt;</th>
<th>1.5&lt;sup&gt;b&lt;/sup&gt;</th>
<th>TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.30</td>
<td>170</td>
<td>21.52</td>
<td>160</td>
<td>27.40</td>
<td>179</td>
<td>30.00</td>
<td>160</td>
<td>1226</td>
<td>1252</td>
<td>1050</td>
</tr>
<tr>
<td>2</td>
<td>41.80</td>
<td>177</td>
<td>47.86</td>
<td>160</td>
<td>47.40</td>
<td>176</td>
<td>54.30</td>
<td>184</td>
<td>736</td>
<td>640</td>
<td>1050</td>
</tr>
<tr>
<td>3</td>
<td>37.82</td>
<td>185</td>
<td>38.07</td>
<td>170</td>
<td>35.00</td>
<td>170</td>
<td>34.60</td>
<td>175</td>
<td>937</td>
<td>922</td>
<td>1085</td>
</tr>
<tr>
<td>4</td>
<td>49.50</td>
<td>182</td>
<td>57.40</td>
<td>176</td>
<td>54.70</td>
<td>201</td>
<td>57.60</td>
<td>200</td>
<td>690</td>
<td>670</td>
<td>980</td>
</tr>
<tr>
<td>5</td>
<td>47.90</td>
<td>180</td>
<td>54.00</td>
<td>170</td>
<td>48.60</td>
<td>184</td>
<td>51.00</td>
<td>179</td>
<td>832</td>
<td>688</td>
<td>980</td>
</tr>
<tr>
<td>6</td>
<td>37.40</td>
<td>150</td>
<td>39.00</td>
<td>164</td>
<td>35.30</td>
<td>190</td>
<td>35.70</td>
<td>170</td>
<td>995</td>
<td>943</td>
<td>945</td>
</tr>
<tr>
<td>7</td>
<td>35.73</td>
<td>185</td>
<td>36.28</td>
<td>175</td>
<td>36.70</td>
<td>201</td>
<td>41.40</td>
<td>195</td>
<td>742</td>
<td>663</td>
<td>1050</td>
</tr>
<tr>
<td>8</td>
<td>25.20</td>
<td>172</td>
<td>32.86</td>
<td>162</td>
<td>34.00</td>
<td>180</td>
<td>39.40</td>
<td>180</td>
<td>895</td>
<td>888</td>
<td>980</td>
</tr>
<tr>
<td>9</td>
<td>44.28</td>
<td>140</td>
<td>38.00</td>
<td>130</td>
<td>53.70</td>
<td>175</td>
<td>54.10</td>
<td>160</td>
<td>617</td>
<td>590</td>
<td>980</td>
</tr>
<tr>
<td>10</td>
<td>37.15</td>
<td>170</td>
<td>35.67</td>
<td>180</td>
<td>37.00</td>
<td>194</td>
<td>35.70</td>
<td>180</td>
<td>821</td>
<td>873</td>
<td>945</td>
</tr>
<tr>
<td>11</td>
<td>45.39</td>
<td>186</td>
<td>43.82</td>
<td>168</td>
<td>48.40</td>
<td>198</td>
<td>55.70</td>
<td>196</td>
<td>862</td>
<td>641</td>
<td>1050</td>
</tr>
</tbody>
</table>

Mean 38.32 172.5 40.41 164.1 41.65 186.2 44.50 179.2 850 797 1008

Note.
ID = Subject Identification Number

DW<sup>a</sup> = Pre Deep Water VO₂ Test
DW<sup>b</sup> = Post Deep Water VO₂ Test
TM<sup>a</sup> = Pre Treadmill VO₂ Test
TM<sup>b</sup> = Post Treadmill VO₂ Test
1.5<sup>a</sup> = Pre 1.5 Mile Run Time (Minutes)
1.5<sup>b</sup> = Post 1.5 Mile Run Time (Minutes)
TT = Total Training Time (Minutes)
REFERENCES


