COMPARISON OF HEART RATE AND PERCEIVED EXERTION ON AN UNDERWATER TREADMILL VERSUS A LAND-BASED TREADMILL

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TABLE OF CONTENTS

CHAPTER PAGE

I: INTRODUCTION....1

Problem Statement....4
Deliminations....4
Limitations....5
Assumptions....5
Null Hypotheses....6
Justification....6
Definition of Terms....7

II: REVIEW OF RELATED LITERATURE....9

Physiological Changes....10
Circulatory System....10
Pulmonary System....12
Musculoskeletal System....13
Ratings of Perceived Exertion (RPE)....14
Similar Studies....15
Support of Methodology....17
Summary....18

III: METHODOLOGY....20

Setting....20
Subjects....20
Research Design....21
Testing Procedures....23
Land-Based....23
Underwater....24
Statistical Analysis....25

IV: MANUSCRIPT....26

V: CONCLUSION....34

REFERENCES....37

APPENDICES……………………………………………………………………...…42
APPENDIX A—IRB APPROVAL……………………………………………...…43
APPENDIX B—BORG'S RPE SCALE……………………..………………..45
APPENDIX C—INFORMED CONSENT……………………..…………...….47
APPENDIX D—MEDICAL HISTORY QUESTIONNAIRE…..……….………50
APPENDIX E—WITHIN SUBJECTS ANOVA SUMMARY TABLE.……….54
APPENDIX F—SIMPLE MAIN EFFECTS POST-HOC ANALYSIS……...…..56
APPENDIX G—PHYSIOLOGICAL DATA: HEART RATE.…………………58
APPENDIX H—MEAN HEART RATE GRAPH………….....………………..60
APPENDIX I—PHYSIOLOGICAL DATA: RPE…….…..……………………62
APPENDIX J—MEAN RATINGS OF PERCEIVED EXERTION GRAPH…...64
APPENDIX K—MEAN HR vs. RPE GRAPH…………………………………66

LIST OF ABBREVIATIONS

BL: blood lactate

bpm: beats per minute

DWR: deep water running

g/m: gallons per minute

Kg: kilograms

km/h: kilometers per hour

m/min: meters per minute

ml: milliliters

mmol: millimoles

MPH: miles per hour

RPE: rating of perceived exertion

UT: underwater treadmill

UTR: underwater treadmill running

LIST OF TABLES

Table | Page

1. Testing Protocol……………………………………………………………………..25
2. Demographic Data……………………………………………………………………..30
3. Simple Main Effect: Condition X Response Summary Table………………………31
4. Mean Heart Rate, Difference, Percent Difference…..……………………………....32
5. Mean RPE Value, and Difference Between Conditions …..…………………..…….32

Chapter I

INTRODUCTION

Several stories and events, some of which date back to the dawn of time, revolve around the mystical powers of water. One such event is relayed in II King 5:14, "So he went to dip himself in the Jordan River seven times, as the man of God had instructed him. His skin became healthy again like a little child's skin." (II Kings, 1993) This story gives insight to humanity's belief of the healing power to which is attributed to water. In the Bible, water was viewed as a cleansing agent capable of bringing renewed life, which is evident in this passage as well as in the story of Noah's arc and the Great Flood. In Greek mythology there are similar reflections as to the mystical powers bestowed upon water. The story of Achilles, the greatest Greek warrior of the Trojan War, takes root on the banks of the river Styx. In hopes of making her son immortal his mother, Thetis, held her infant son by a heel and dipped him into the waters. Myth has it that everything that the sacred waters touched became invulnerable. This quest for immortality happened to be Achilles' doom, because where is mother held him became his only weakness and an arrow to his heel caused his death (Greek Mythology, 2001).

Eureka Springs, Arkansas grew up from a small hot spring located in the Ozark Mountains to an economical boomtown during the turn of the 19th century. Until the white man settled the region, local Indian tribes believed this site was sacred ground and attached several stories of healing to these venerated waters. An insightful doctor and entrepreneur used this "miraculous water" at his hospital during the civil war and shortly after he began marketing this "healing water" to the public. In the late 1800's several groups of individuals would flock to Eureka Springs to be healed by the powerful waters. Eureka Springs still claims its hot springs as a natural attraction, but no longer do they attempt to heal individuals (Eureka Springs, 2001).

With the changing times came the change in the beliefs associated with water. It is longer believed that water can "heal" an individual from what ails them, at least not in the way that it was believed in earlier times. Water is capable of bringing about therapeutic effects that can ease and even improve an individuals everyday life. Aquatic therapy is not, by any means, a revolutionary discovery. Spas and bathhouses are noted in cultures that are located on every settled continent. The strides that aquatic therapy has taken in recent history are enormous. Many of these advancements are secondary to civilizations increased knowledge of the physiological effects that immersion in water has on the human body as well as the technological advances that have accompanied this newfound knowledge.

Archimedes was one of the first philosophers to delve into the untapped potential of aquatic properties. From this we get Archimedes principle, which states that when a body is fully or partially submerged in a fluid at rest, it experiences an upward thrust, equal to the weight or the fluid displaced (Bates & Hanson, 1996). Since Archimedes discovery, several other advances have been made in regards to the understanding of aquatic physiology and with them recently, there have been numerous technological advances. We have evolved from rivers to spas, from spas to recreational pools, and from recreational pools to functioning therapeutic pools.

Aquatic therapy, by today's standards, had been limited to sharing time at recreational pools. Fortunately the benefits of aquatic therapy were realized and began to take hold and later spread through the rehabilitation community. Physical rehabilitation clinics around the world are beginning to implement these custom therapeutic pools into their design and construction in order to meet the demands and requirements of their clientele. These therapeutic pools range from small inexpensive whirlpools to elaborate in ground pools with supporting state-of-the-art computer software that can monitor multiple facets of each therapy session.

These technologically advanced pools place a myriad of opportunities at the therapists' fingertips. With the knowledge of the physiological effects of immersion in water accompanying these therapeutic pools, the only limit to the possibilities is the therapists' imagination and resourcefulness.

Recently, a number of studies have been performed that deal with the comparison of deep water running to treadmill running on land in an attempt to form a basis of the cardiovascular changes the body undergoes when submerged. While these are viable studies when dealing with deep water running, they are not as reliable when dealing with running on an underwater treadmill. While the two modes of cardiovascular exercise are similar, they are also very different. Running on an underwater treadmill incorporates different muscles as well as a different muscle activation pattern than deep water running. In this aspect, comparing deep water running to underwater treadmill running is like comparing apples to oranges, they are both similar but when it comes down to it they are very different.

There has not been as much research done on underwater treadmill running as there has been on other forms of aquatic exercise. Therefore, there is no foundation of knowledge as to exactly how the body physiologically responds to this training medium. Currently, there is only one manufacturer of pools that incorporate an underwater treadmill directly into their design. Several professional athletic teams, universities, hospitals, and physical rehabilitation clinics have added this type of pool to their facilities in order to benefit their athletes or clients from a sports medicine standpoint.

Problem Statement

This study was designed to assess the differences between on land treadmill running versus underwater treadmill running based on heart rate response and rate of perceived exertion.

Delimitations

The design of this experiment poses certain delimitations or boundaries that could affect the collection and interpretation of the data.

1. The subjects were competitive collegiate athletes residing in the Stillwater, Oklahoma area and participating on a voluntary basis.
2. Only male subjects were included in this study in order to keep certain variables regarding the properties of water on a similar level.
3. The mileage each subject ran on a weekly basis will not be regulated. All subjects were nearing the end of their competitive season therefore, their

exercise regimes were similar, but not a variable that was within the control of this experiment.

4. The water level in the Hydroworx cannot be manipulated; therefore the level of immersion varied slightly from subject to subject.

Limitations

The effect of the delimitations and the ability to expand the scope of inference beyond the sample population influences the limitations. Generalizations made from the results are compromised by the following limitations:

1. The results of this experiment cannot be applied to those who are not well-trained cross-country runners.
2. Using only experienced athletes limited the scope of inference to the population because of the athletes' advanced physiological status.
3. Generalizing the results to females could not be made since the physiological properties of water may produce differences between genders.

Assumptions

Assumptions regarding the research design of this study include:

1. Patients were compliant with the instructions given on how to rate their level of perceived exertion.
2. Subjects had no withheld anxiety about water, which could adversely affect the heart rate response.
3. The level of perceived exertion given by each subject was dependent upon motivation, competitive spirit, and willingness to reply honestly. For many

athletes performing in front of an audience may influence how they wish to appear to their audience, which may cause them to rate their level of exertion below the actual level. To avoid the consequences of this, the subjects were tested with as few witnesses as possible.

4. The jets of the Hydroworx were maintained in the same relative position for each subject.
5. The calibration, in regards to speed, is the same for the Hydroworx treadmill and the land based treadmill used in this study.

Null Hypotheses

H_{o1}: There will be no significant differences between the RPE of running in water compared to running on land at comparable workloads.

H_{o2}: There will be no significant differences between the heart rates of running in water compared to running on land at comparable workloads.

Justification

Past studies have compared deep water running that took place in a swimming pool while the individual was suspended in the water by a flotation device to land based running. While the two modes of exercise are similar, biomechanically several discrepancies can be noted: no stance phase, a longer muscle activation pattern, a more upright body posture, and the floatation device alters upper body motions. These discrepancies restrict therapists from having a validated baseline to monitor a patients perceived exertion when using an underwater treadmill. To date, studies comparing underwater treadmill running to running on land are very scarce. Borg's Rating of

Perceived Exertion (RPE) scale (Borg, 1970) allows a comparison to be made between an exercising individual's rating of perceived exertion to a correlated HR. For example, a RPE of 16 on Borg's 6-20 scale would correlate to a HR of 160 bpm for land-based activities. This same correlation when exercising in water, more specifically when exercising on an underwater treadmill, does not exist. This study may provide therapists with valuable information that that may serve as a guide when monitoring a patient's workload while exercising in water.

Definition of Terms

- Aquatic Therapy—the union of aquatic exercise and physical therapy. It is a comprehensive therapeutic approach that uses aquatic exercises to aid in the rehabilitation of various conditions (Bates & Hanson, 1996).
- Buoyancy—Archimedes' principle states that when a body is fully or partially submerged in a fluid at rest, it experiences an upward thrust equal to the weight of the fluid displaced (Bates & Hanson, 1996).
- Deep Water Running—is simulated running in the deep end of a swimming pool, avoiding contact with the bottom of the pool. To maintain body position and keep the head above water, a floatation device is worn. The participant may use a tether to remain stationary or may elect to move through the pool (Bushman, 1999).
- Hydrostatic Pressure—Pascal's law of hydrostatic pressure states that a fluid exerts a pressure equally on all surfaces of an immersed body at rest at any given depth. Hydrostatic pressure increases with the depth and density of the fluid (Fuller, 1998).

- Rating of Perceived Exertion—the integration of various information, including the many signals elicited from the peripheral working muscles and joints, from the central cardiovascular and respiratory functions, and from the central nervous system into a configuration or "gestalt" of perceived exertion (Borg, 1982).
- Specific Gravity—property that determines whether an object will sink or float in water. The specific gravity of water equals 1; therefore, if the specific gravity of an object is greater than 1, the object will sink, and if it is less than 1 the object will float (Fullers, 1998) If a floating object's specific gravity is 0.96, 96% of the body must be submerged to displace enough water so that the upward force of buoyancy will equal the downward force of gravity (Bates 1996).
- Underwater Treadmill Running—running on a stationary treadmill, which is located within a therapeutic pool (Hydroworx, 2000).
- Viscosity—the friction that occurs between molecules of a liquid and causes resistance to flow of the liquid (Fullers, 1998).

Chapter II

REVIEW OF RELATED LITERATURE

The current status of studies that are aimed at investigating running on an underwater treadmill is limited at best. The majority of research that has compared running in an aquatic environment to running on land has used the modality of deep water running (Bishop, Frazier, Smith, & Jacobs 1989; Brown, Chitwood, Beason, & McLemore, 1996; Butts, Tucker, & Green, 1991; DeMaere & Ruby, 1997; Glass, Wilson, Blessing, & Miller, 1995; Green, Cable, & Elms, 1990; Svedenhag & Seger, 1992; Yamaji, Greenley, Northey, Hughson, 1990). While deep water running is biomechanically similar to running on land, there is also a pronounced difference: deep water running requires the individual to be totally suspended in the water and completely non-weight bearing. In essence this requires the individual to "simulate" the normal running biomechanics. Further biomechanical analysis of deep water running is needed to determine the similarity of deep water running to treadmill running (Mercer 2001). With deep water running there is an altered running technique as well as an altered muscle activation pattern, most notably an absence of the support phase, and a longer absolute muscle contraction time (Svedenhag & Segar, 1992). Running on an aquatic treadmill erases this difference and allows the individual to use the same biomechanics in the water as on land. With running on an underwater treadmill, one gets all the biomechanical benefits of running on a land based treadmill as well as all of the hydrostatic benefits provided by the physical properties of the water.

Physiological Changes

Immersion in an aquatic environment has profound physiological effects, which affect all of the homeostatic systems in the body. With the altered physiology associated with exercising in an aquatic environment, the question of whether or not aquatic exercises are as effective as traditional land based exercise is raised. Because every system in the body is placed in a state other than normal homeostasis, the overall energy output of the body is certain to be affected.

Circulatory System

In the circulatory system there are several changes that take place, in part because venous return is very sensitive to external pressure changes such as the compression provided by water immersion. It is reported that there is a 60% increase in central blood volume which represents an increase of approximately 0.7 liters with immersion to the neck (Becker & Cole, 1997; Svedenhag & Seger, 1992) or a 27-44% increase as noted in another study (Christie, 1990). Cardiac volume also shows an increase of 27-30% with immersion to the neck (Becker & Cole). With this increase in cardiac volume, there is also a marked increase in stroke volume from 71ml/beat to about 100ml/beat, an increase of 25ml/beat or 25%(Becker & Cole; Svedenhag & Seger). As stroke volume increases with the increased depth of immersion, heart rate typically drops (Dowzer, Reilly, Cable, Nevill, 1999) with reports up to 15% in thermoneutral temperatures (Becker& Cole). Although in a study comparing water walking to land walking, one group found there to be a significant higher heart rate at all intensities in the water when compared to the same intensities on land (Whitley& Schoene, 1987). It is worth noting that in this study, the subjects were only waist deep in the water so the full hydrostatic effects were not present. Maximal Oxygen uptake (VO_{2max}) is the product of both maximal cardiac output and arterial-venous oxygen difference (American College of Sports Medicine: 6th ed). Therefore with the increased stroke volume and the lowered heart rate associated with immersion, there is going to be a variation between VO_{2max} on land and in water. In a study performed by Green, Cable, and Elms (1990) comparing running in an aquatic environment to running on land, results showed that in men there was a higher predicted VO_{2max}. Although, several studies (DeMaere & Ruby, 1997; Harvey, 2001; Dowzer, Reilly, Cable, & Nevill, 1999; Svedenhag& Seger, 1992; Nakanishi, Kimura, & Yokoo, 1999; Butts, Tucker, & Greening, 1991; and Glass, Wilson, Blessing, & Miller, 1995) all showed there to be a decreased VO_{2max} associated with aquatic running. It was also noted by Becker and Cole (1997) that studies have consistently demonstrated that VO_{2max} increased with training in a water environment, provided that sufficient intensity, duration, and frequency parameters are met.

Since cardiac output is a product of stroke volume and heart rate, immersion to the neck increases cardiac output by 30% (Becker & Cole, 1997). With immersion, venous pressure is also shown to decrease because less vascular tone is required to support the venous system. It is worth noting that the heart rate and VO_2 relationship during water exercise parallels that of land exercise, although the water heart rate averages 10 bpm less (Becker & Cole). These changes in the circulatory system have been noted to be very temperature dependant, with temperatures below thermoneutral conditions (30-34°C) resulting in inhibition of the heart rate response and temperatures above thermoneutral conditions resulting in enhances heart rates and cardiac outputs (Becker & Cole). It is also worth noting that when immersed in water below the core body temperature, persons loose body heat approximately 27 times faster than when on land (Harvey, 2001).

An important indicator of the workload accomplished is by blood lactate [BL] levels. With DWR Nakanishi, Kimura, and Yokoo (1999) found BL to be significantly lower when compared to land, 13.8 mmol/L to 9.2 mmol/L. In opposition to this finding Svedenhag and Seger (1992) found that the BL curve shifted to the left when comparing water to land running. At a VO_2 of 3.0 l/min BL levels were 5.02 mmol/L to 1.33 mmol/L in water versus land, respectively (Svedenhag & Seger, 1992). Similar findings were present for DWR compared to land running at intensities of 70% VO_{2max}, 4.57 mmol/L to 1.47 mmol/L respectively (Svedenhag & Seger, 1992). Svedenhag and Segers (1992) findings would support the theory of there being an increased workload present with DWR.

Pulmonary System

The changes present in the pulmonary system as a result of immersion are partly due to the central shift of the blood supply as well as the increased hydrostatic pressure that occurs. This combined effects alters pulmonary function and increases the work of breathing. The increased pressure (2 mm Hg/in) exerted on the rib cage accounts for a 10% decrease in the circumference of the rib cage (Becker & Cole, 1997). Vital capacity is noted to decrease with immersion; there is a slightly reduced diffusion capacity, as well a reduced blood oxygen concentration (Becker & Cole). Overall, these physiological deep water running. This benefit in combination with traditional rehabilitation techniques provides a new and alternative treatment avenue for patients that are suffering from certain types of orthopedic injuries. Dr. Andrew Cole, MD is quoted as "Aquatic Therapy allows people to rehabilitate more effectively because they can do things in water that they can't do on land," (Levin, 1991. pg 119).

Ratings of Perceived Exertion (RPE)

In order for each subject to rate their perceived exertion, Borg's 6-20 rating scale for perceived exertion was used (Appendix B). In a study by Borg (1970) it was confirmed that on land, a correlation of 0.85 existed between heart rates and ratings of perceived exertion. The scale Borg constructed ranged form 6-20 and can be used to denote heart rates ranging from 60-200 bpm. Borg's initial findings were supported in a study by Brown, Chitwood, Beason, & McLemore (1996b) in which a correlation of 0.87 existed between heart rate and perceived exertion. A study performed by Robertson (1998) supported Borg's earlier findings. The study indicated that rating of perceived exertion is physiologically valid and an easily applied measure for assessing functional aerobic power and prescribing intensity of exercise for a use in a variety of sport, pedagogical, experimental and clinical settings. Russell (1997) also concluded that subjective perceptions of effort sense or exertion are systemically related to objective means by which physical work is performed, and therefore, the RPE scale is a clear, concise, and effective means of measurement for this relationship.

Abadie (1996) conducted a study in which the effects of viewing the RPE scale on the ability to make ratings of perceived exertion were examined. Seven subjects performed four exercise sessions of which viewing an RPE scale was manipulated. The results suggest that monitoring exercise of moderate to high intensity with the RPE scale without the scale being viewed may result in an underestimation of exertion.

Similar Studies

Several studies exist on the status and effects of deep water running and how the physiological changes compare to running on land. However, few studies exist that actually compare underwater treadmill running to land based treadmill running. Gleim and Nichols (1989) reported the metabolic costs and the heart rate responses to treadmill walking in water at different depths and temperatures. Six men and five women were monitored while walking in water at varying speeds and varying depths: no water, ankle level, knee level, mid thigh level, and waist level. What this study reported was that with increasing water depth, there was a corresponding increase in the work of walking and jogging. Oxygen consumption was the highest at all speeds when the water level was at mid thigh. When the water was at ankle, knee and mid thigh level produced rates of oxygen consumption were higher than control. Contrary to what the study reported, when the water was at waist level there was a remarkable response. Up until treadmill speeds of 80.4m/min the rate of oxygen consumption was parallel to the other water groups, from 80.4 m/min to 134 m/min the rate of oxygen consumption leveled off while the other test groups continued to climb. At 134m/min the rate of oxygen consumption was in fact lower than that of the control group. It can be assumed that this variation is secondary to the likely effects of buoyancy as well as hydrostatic pressure. This study does, however, recognize the lack of existing literature on the efficacy of underwater treadmill walking/jogging and states that there appears to be significant usefulness in the rehabilitation of a number of orthopedic patients.

Whitley and Schoene (1987) conducted a study that compared actual underwater walking to treadmill walking. While this is not the exact same as underwater treadmill running, walking in a pool does incorporate the same muscular response as well as the same muscle activation pattern. This study used 12 female college students, with a mean height and weight of 165.9 cm and 60.2 Kg respectively, as subjects and had them walk on a land-based treadmill and in a 25m pool at a uniform depth of 0.92 m or 36 inches. Subjects were tested at four different speeds: 2.55 km/h, 2.77 km/h, 3.02 km/h, and 3.31 km/h. In order to maintain the same workload in the pool as on the treadmill, the subjects were instructed at what pace to complete each lap, and during each lap informed of their lap times. At each speed, the heart rate response in the water was significantly higher than the heart rates during the treadmill portion. While this study does show there to be an elevated heart rate at all workloads, there is no differentiation between where the water level was on each given subject. This factor could explain why the heart rate response was higher at each speed: if the water level is below the umbilicus the effects of buoyancy and hydrostatic pressure would not have any effect on the heart rate.

The present study requires that all subjects be male. The reason for this is that body composition is a variable that affects buoyancy. Since adipose tissue is less dense than either muscle or bone, having a higher percentage of body fat would lower an individuals' relative density. Lean body mass, which includes bone, muscle, connective tissue, and organs, has a typical density near 1.1, whereas fat mass, which includes both essential body fat in excess of essential needs, has a density of about 0.9 (Becker & Cole, 1997; Bates & Hanson, 1996). Water has a specific gravity of 1, therefore anything with a specific gravity less than 1.0 will float and anything with a specific gravity greater than

1.0 will sink. Healthy, fit, and muscular males tend to have a relative density greater than 1.0 whereas a female of similar fitness will always have a lower relative density and therefore a higher percentage of body fat due to fundamental anatomy. During deep water running, the interaction between body composition on VO_2 and heart rate is complicated due to the buoyancy and insulating properties of fat (Mercer, 2001).

Brown, Chitwood, Alvarez, Beason, & McLemore (1997) conducted a study comparing genders and oxygen consumption during deep water running. As would be expected the female subjects had a higher percentage of body fat than the male subjects, 23.2% to 14.1% respectively. The results showed that at all heart rates and running cadences, the oxygen consumption was higher for males than for females. The conclusion that this study reported was that there is a linear relationship between maximal VO_2 and heart rate and that there are distinct gender differences when both heart rate and running cadence were used to predict max VO_2. This would most likely be the result of the varying relative densities between the two groups and the varying level of effort required for each subject group to stay afloat.

Support of Methodology

Stoudemire, Wideman, Pass, McGinnes, & Weltman (1996) published a study in which blood lactate concentration during running was validated in accordance to ratings of perceived exertion. The treadmill protocol that was used in this study proved to be the basis of the protocol that will be used in this study. The initial treadmill velocity was 130m/min (4.8 mph) and was increased by 10 m/min (0.4 mph) every three minutes. The test was performed until each subject achieved volitional exhaustion. This elicited a heart rate response that was positively sloped and linear. The major finding of this study indicates that RPE is a valid tool for prescribing exercise intensities when blood lactate of 2.5 mmol and 4.0 mmol are used as the criterion measures for exercise prescription.

Due to the treadmill in the Hydroworx being limited to 7.8 mph, there will need to be a manipulation of jet percentages in order to increase the workload to a level that will elicit an increase in heart rates. In an attempt to determine the percentage of the jets in the Hydroworx as well as the grade of incline on the treadmill, a pilot study was performed in which these two variables were manipulated. Initially, a grade of 2.0° was equal to the jets being set at 20%. This relationship was found not to obtain the desired heart rate response. What was discovered, however, was that jet percentages of 30%, 60%, 70%, 80% and 85% were comparable to 2.0°, 4.0°, 6.0°, 8.0°, and 10.0° on the treadmill and, furthermore, elicited the heart rates that were needed.

Brown, Chitwood, Beason, & McLemore (1996b) compared ratings of perceived exertion for both treadmill running and deep water running twenty-four subjects (12 males and 12 females). The treadmill protocol that was followed consisted of seven stages, which were 3 minutes in length, beginning at 42 m/min and concluded at 126 m/min. The grade of the treadmill was kept at 0% in order to match the deep water running protocol. The results showed that at every stage, the RPE in the water averaged 3.5 points higher than on the land. It was also found that peak heart rate was significantly greater during exercise on the treadmill than during deep water running.

<u>Summary</u>

When a body is immersed to chest level in water, several physiological changes take place in all systems of the body and result in an increased stroke volume and therefore a decreased heart rate. An individual exercising on an underwater treadmill will benefit from all of these physiological changes, plus have the benefit of a more normal running pattern than if they were participating in DWR exercise. With ratings of perceived exertion, several studies have found a high correlation between HR and RPE values. However, when looking at RPE in an aquatic environment, many studies have used DWR as their basis.

Chapter III

METHODOLOGY

The major objective of this study was to assess the heart rate and rating of perceived exertion while working at corresponding workloads in both an underwater and land-based treadmill. Those who took part in this study performed the same workout protocol on both a land-based treadmill and an underwater treadmill and then rated their perceived exertion. This study employed a counter-balanced design with subjects either being tested on the land-based or underwater treadmill, depending on their group assignment. Seven days after the first testing session, each subject performed the same protocol in the other testing medium.

Setting

The testing was performed during four testing sessions at the Oklahoma State University Athletics Facility in Stillwater, Oklahoma. The first session in both the Hydroworx as well as the land-based treadmill were for familiarization and no data was collected.

Subjects

The subjects were male college cross-country runners who were in training near the end of the competitive season. These subjects were asked to participate in this study. To be eligible to take part in this study, certain parameters regarding demographics of the subjects needed to be set in order to provide accurate testing results. Subjects were male, and needed to be between the heights of 67" and 75". These parameters insured that all subjects were under a similar influence of buoyancy and therefore were experiencing similar workloads. Similar experience, based on years of running, as well as prior experience of training in the Hydroworx was also required for all subjects. Subjects were selected on a basis of availability from members of the Oklahoma State University cross-country team. A copy of the active roster was obtained and names were placed in order based upon the last four digits of their phone numbers. Then, individual were called going from the top of the list and the first 15 to agree were selected as subjects. The main incentive for participation was that subjects received information and experience in an alternative form of training. Those individuals who were identified as possible subjects first were asked to participate in the study and then as prospective subjects were required to read, understand, and sign an informed consent form (Appendix C) and also were given the opportunity to withdraw from this study at any time without consequence to themselves. Inclusion in the study also required each subject complete a medical history questionnaire (Appendix D). Any indication of a possible health problem that might compromise the safety of the subjects or the validity of the study constituted grounds for exclusion.

Research Design

This study was experimental in nature and followed a counter-balanced design. The first testing session took place in one of the two testing mediums followed in one week by the second testing session. Comparisons between the heart rate and perceived

Testing Procedure

Each subject completed a total of four treadmill tests, two on a land-based treadmill and two on an underwater treadmill. The first session on both the land based treadmill and the underwater treadmill were for the subject to become familiarized with running on these modalities. Data collection only occurred during each subjects second session on both treadmills. All tests entailed the use of the same workout protocol. There was at least one week between tests in order to limit the amount of fatigue that may occur, resulting in a total of four weeks to conclude the testing.

Heart rate was monitored during both testing sessions using a Polar Heart Rate Monitor (Woodbury, NY). The recording portion of the heart rate monitor was positioned and fit snuggly across the sternum so that it did not move during the test. The individual administering the test, in order to monitor and record the heart rate, kept the monitoring portion of the heart rate monitor.

During the final fifteen seconds of each stage, both heart rate and an RPE score was obtained from each subject. Borg's scale for ratings of perceived exertion was displayed within the subjects view (Abadie, 1996) during each testing session. Prior to beginning each session, subjects were given verbal instructions as to the RPE scale.

Land-Based (Table 1)

A True 750 S.O.F.T. model treadmill located in the Gallagher-Iba Athletic Center was used for this session of the testing due to convenience. Prior to taking the land-based treadmill test, a basal heart rate was recorded for five minutes prior to beginning exercise while the subject was not performing any activity. The subject was then given the opportunity to stretch for two minutes. Following the stretching, there were eight (8) stages, each of which lasted for three (3) minutes. A heart rate and RPE score was obtained during the last fifteen seconds of each stage. The first stage of the test began at 4.8 mph followed by stage two at 5.6 mph and stage three at 7.6 mph (Stoudemire, Wideman, Pass, McGinnes, Gaesser, & Weltman, 1996). From this point on, the grade of the treadmill was manipulated while the speed remained at 7.6. Stage four had a 2% grade, stage five a 4% grade, stage six a 6% grade, stage seven an 8% grade and finally stage 8 with a 10% grade. Upon the completion of the test, the subject was given a five-minute cool-down stage at a pace of their choosing. At no time during the test was the subject allowed to use the handrails other than to regain balance.

Underwater (Table 1)

Subjects performed this portion of the test in a Hydroworx 1000 model therapy pool, which was accompanied by the supporting computer software for this model. The depth of the water was maintained at 4 ½ feet for all subjects. Prior to beginning the underwater portion of the test, a basal heart rate was recorded after the subject entered the water up to chest level for five minutes, while the subject was inactive. The subject was then given the opportunity to stretch for two minutes. Following the stretching, there were eight (8) stages each of which lasted for three (3) minutes. The heart rate and the rating of perceived exertion was recorded for the last fifteen seconds of each stage. The first stage of the test began at 4.8 mph followed by stage two at 5.6 mph and stage three at 7.6 mph. From stage four on, the speed of the treadmill remained at 7.6 mph and the jets of the pool were manipulated to increase workload. Stage four had the jets at 30% (93 g/m), stage five 60% (186 g/m), stage seven 70% (217 g/m), and finally stage eight at

85% (263.5 g/m). Having the jets at 100% is equal to 310 gallons/minute. Upon completion of the test, the subjects were allowed to cool down at their own pace for five-minutes. At no time during this test were subjects allowed to use the handrails other than to regain balance.

(MPH)	Stage 1 3 min	Stage 2 3 min	Stage 3 3 min	Stage 4 3 min	Stage 5 3 min	Stage 6 3 min	Stage 7 3 min	Stage 8 3 min
Land	4.8	5.6	7.6	7.6 (2°)	7.6 (4°)	7.6 (6°)	7.6 (8°)	7.6 (10°)
Water	4.8	5.6	7.6	7.6 (30%)	7.6 (60%)	7.6 (70%)	7.6 (80%)	7.6 (85%)

Table 1 - Overview of protocol for underwater and land-based treadmill tests.

Statistical Analysis

In order to follow the counter balanced design, subjects performed their tests in a varying order based upon their group inclusion. Health history questionnaires provided the raw data needed to describe mean, standard deviation and range calculations of the demographic information.

Each testing session consisted of measuring heart rate and perceived ratings of exertion using the Borg 15-point scale for the final fifteen seconds of each stage. The two testing sessions were compared using a 2 x 2 multivariate analysis of variance (MANOVA).

The dependant variables in this study were heart rate and perceived exertion. The independent variables of this study are testing medium and workload. A repeated measure analysis of variance was used for the primary analysis. A separate analysis was performed for each variable. The alpha level was set at $p \leq 0.05$ for all analyses.

Chapter IV

MANUSCRIPT

Comparison of Heart Rate and Perceived Exertion on Underwater Versus Land-Based Treadmill Running

The correlation between heart rate (HR) and rating of perceived exertion (RPE) has been found to be rather high for land based training, 0.85 (Borg, 1970) and 0.87 (Brown, Chitwood, Beason, & McLemore, 1996b). Many studies up to this point that have dealt with exercise in an aquatic environment investigated deep water running (DWR). What has been found is a correlation between HR and RPE. That is, at similar RPE's, heart rates are lower when exercising in water (Brown, Chitwood, Beason, & McLemore, 1996a). With deep water running there is an altered running technique as well as an altered muscle activation pattern, most notably an absence of the support phase, and a longer absolute muscle contraction time (Svedenhag & Segar, 1992). However, there is little research dealing with running on an underwater treadmill, which more closely resembles the normal running biomechanics than DWR. Hydroworx International, Inc. (Middletown, PA) manufactures a complete line of fitness pools which incorporate an underwater-treadmill into their designs allowing for all the benefits of waters physical properties plus the ability to run with more normal body mechanics.

Exercising while immersed allows the body to benefit from all the physiological changes that occur due to the physical properties of water. In the circulatory system, there is a 60% or 0.7L increase in central blood volume (Becker & Cole, 1997; Svedenhag & Segar, 1992), a 27-30% increase in cardiac volume (Becker & Cole), a 25% increase in stroke volume (Becker & Cole; Svedenhag & Segar), up to a 15% decrease in heart rate (Becker & Cole; Dowzer, Reilly, Cabel, Nevill, 1999), and a 30% increase in cardiac output (Becker & Cole). The changes in this system are in part due to the fact that venous return is very sensitive to external pressure changes such as the compression provided by water immersion. Water exerts a pressure of 22.4 mm Hg/foot of depth, which translates to 1 mm Hg/0.54 inches of water depth (Becker & Cole).

Within the pulmonary system there is a 10% decrease in rib cage circumference, a decreased vital capacity, a reduced diffusion capacity, and a reduced blood oxygen concentration (Becker & Cole). All of these changes combined for a 60% increase in the overall work of breathing (Becker & Cole). In the musculoskeletal system, an "unloading" of the joints occurs due to the buoyancy provided by the water and decreases the body weight by up to 90% when immersed to the neck (Becker & Cole; Thein, Thein-Brody, 1998).

Borg's 15-point scale for rating perceived exertion provides a method to subjectively measure the perception of effort and translate that into an objective value. Borg (1982) stated, "…perceived exertion is the single best indicator of the degree of physical strain" (pg. 377). This scale ranges from 6-20 and can be used to denote heart rates ranging from 60-200 bpm. However, this relationship was not intended to be taken too literally because the meaning of a certain heart rate value as an indicator of strain depends upon age, exercise type, environment, anxiety, and several other factors. Ratings of perceived exertion provide much of the same information regarding assessment of exercise tolerance and regulation of exercise intensity as do physiological responses such as oxygen uptake, heart rate, pulmonary ventilation, and lactic acid concentration (Robertson, Goss & Metz, 1997). In order for subjects to accurately rate their level of exertion, it is best to have a visible copy of Borg's scale present (Abadie, 1996).

The purpose of this study is to assess the effects that similar workloads in different testing mediums have on heart rate in regards to perceived exertion and to determine if there is any correlation between the two. We hypothesized that at similar workloads to land based running, heart rate and ratings of perceived exertion will be lower when running in an aquatic environment.

Methods

The testing took place during a 4-week period in February following the cross-country season at a large Midwestern University. The subjects were members of the cross-county team who were in the process of training for their national indoor competition and incorporated the testing into their workouts.

Fifteen male subjects (age = 21.07 ± 2.05 years, ht = 69.8 ± 2.15 inches, wt = 145.00 ± 13.62 lbs) reported to the testing site at approximately the same time of day each week, and were dressed appropriately depending on testing medium. Subjects were instructed to remove their shirts and were fitted with the sensor portion of a Polar S410 Heart Rate Monitor (Woodbury, NY). A basal HR was obtained prior to any activity with the subject standing on the treadmill, followed by a two-minute stretching period, if subjects chose to stretch. Following this, the testing protocol began.

The same protocol was used for both testing mediums, with either changes in the grade or the percentages of jets, depending on the medium. Each stage lasted for three minutes, with the HR and RPE being recorded during the last 15 seconds of each stage. The first stage was at 4.8 mph followed by stage two at 5.6 mph and stage three at 7.6 mph. Stages four thru eight were maintained at 7.6 mph, but in stage four the land-treadmill (LTM) was inclined to a 2° grade and the jets were set at 30% in the underwater-treadmill (UTM). In stage five the LTM was inclined to a 4° grade and the jets were set at 60% in the UTM. In stage six the LTM was inclined to a 6° grade and the jets were turned up to 70% in the UTM. Stage seven had the LTM inclined to an 8° grade and the jets were set at 80% in the UTM. Finally, in stage eight the LTM was inclined to 10° and the jets were set at 85% in the UTM. Upon completion of the protocol, a three-minute cool-down stage was implemented at a pace of each subjects choosing. At no time during any testing session were the subjects allowed to use the handrails other than to regain balance, nor were the subjects allowed to cup their hands while in the water.

Experimental Design and Statistical Analysis

This study was experimental in nature and followed a 2 x 2 multivariate analysis of variance design for both heart rate and rating of perceived exertion. The alpha level was set at $p \leq 0.05$ for all analyses.

In order to follow the counter balanced design, subjects performed their tests in a varying order based upon their group inclusion. Health history questionnaires provided the raw data needed to describe mean, standard deviation and range calculations of the demographic information.

The dependant variables in this study were heart rate and perceived exertion. The independent variables of this study are testing medium and workload. A multivariate analysis of variance was used for the primary analysis. A simple main effect post hoc strategy was used to perform follow up testing.

Results

Specific subject data is described in Table 2 as well as in Appendices G and I. Prior to participating, all subjects read and signed an informed consent form as well as completed a medical history questionnaire in accordance with guidelines set forth by the University Review Board.

	Age	Height	Weight	Miles per Week	Years of Running Experience
Range	18.0-26.0	67.0-75.0	130.0-180.0	30.0-90.0	5.0-15.0
Mean	21.07	69.80	145.00	64.33	7.87
Std. Dev.	2.05	2.15	13.62	16.68	2.62

Table 2. Demographic data.

The response of HR and RPE does depend upon whether the subject is running on land or in water, based upon the significant interactions located in the ANOVA summary table (Appendix E). No statistical significance was determined to exist between subject and condition or condition and stage. Significance was determined to exist between subject and response ($F_{(14,98)}p<.001=2.78$), condition and response ($F_{(1,98)}p<.001=11.4$), response and stage ($F_{(7,98)}p<.001=3.77$) and subject and stage ($F_{(98,98)}p<.05=1.25$). Of those areas that contained significance, the focus of this research was between the conditions (land vs. water) and the responses (HR vs. RPE).

After plotting the mean values for the interaction between condition and response (Appendix F) it was determined that an ordinal interaction was present, and that a simple main effect was the post-hoc strategy that should be used to determine where the significance was located (Keppel, 1991). A simple main effect post-hoc analysis was performed between condition and response which determined there to be a significant difference in HR between land and water ($F_{(1,98)}p<.001=44.384$), but not a significant difference in RPE between land and water ($F_{(1,98)}p>.05=0.046$).

Comparison	df	MS	F	p-value
HR (LINE 1)	1	5036.489	44.384	0.0001
RPE (LINE 2)	1	5.242	0.046	0.8251

Table 3-- Simple Main Effect: Condition versus Response Summary Table

The mean HR on land was 151.43 $\pm$ 13.7 bpm compared to the mean HR in water that was 125.65 $\pm$ 16.84 bpm, a difference of 25.78 bpm. When looking at the subjects basal HR, it is worth noting that between land and water there was a 21% lower HR in the water, 77.87 $\pm$ 10.17 bpm versus 61.80 $\pm$ 11.33 respectively. For the RPE values, the mean value on land was 12.55 $\pm$ 1.2 compared to the mean value in the water of 11.54 $\pm$ 1.87.

When looking for a correlation between HR and RPE, investigators have shown a high correlation ranging from 0.85-0.87 (Borg, 1970; Brown, Chitwood, Beason, and McLemore, 1996b). In this study, no significant correlation was found in either testing condition.

Discussion

Exercising in an aquatic environment is known to elicit several physiological changes; the most easily measured change is heart rate. This decrease in HR is related to the increase in stroke volume resulting in an increased cardiac volume (Dowzer, Reilly, Cable & Nevill, 1999: Svedenhag & Seger, 1992). This decrease in HR has been shown to be as much as 15% (Becker & Cole, 1997). In this present study, resting HR was found to be 21%, or 16.1 bpm, lower when subjects were immersed to chest level. Overall, there was an average decrease of 24.7 bpm, or 18%, for all stages of the test (Table 4).

	Basal	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
Land	77.87	114.47	121.73	139.67	147.73	158.00	169.13	177.14	183.54
Water	61.80	93.93	98.53	111.80	115.93	132.53	140.73	154.13	157.57
Diff.	16.07	20.53	23.20	27.87	31.80	25.47	28.40	23.01	25.97
% diff.	21	18	19	20	21	16	18	13	14

Table 4- Mean heart rate, difference, and percent difference between conditions

Results show that there is a significantly lower HR when running in water when there is a comparable workload to land based running. Individuals are able to perform the same running workout in water as on land, but maintain a lower HR (Appendices G, H). Peak HR was also found to be higher on land than in the water, 183.54 bpm to 157.57 bpm respectively.

Borg's 15-point scale for Ratings of Perceived Exertion (Borg, 1970) is a clear, concise, and effective means of measuring the subjective perception of effort and relating that to an objective value (Abadie, 1996; Russell, 1997; Brown, Chitwood, Beason & McLemore, 1996b). In earlier investigations it was noted that under comparable workloads during DWR, RPE values in water were on average 3.5 points higher than on land (Brown, Chitwood, Beason & McLemore). In this study, RPE values were on average 1.01 points lower in water when compared to land (Table 5).

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
Land	7.00	8.07	10.67	11.87	13.33	15.13	16.43	17.92
Water	6.93	8.00	10.00	10.67	12.47	13.40	15.00	15.86
Diff	0.07	0.07	0.67	1.20	0.87	1.73	1.43	2.07

Table 5- Mean RPE value, and difference between conditions

No significant correlation was found to exist between HR and RPE in this study, in either land or water running. Correlations of 0.87 (Brown, Chitwood, Beason & McLemore, 1996b) and 0.85 (Borg, 1970) have been reported for land based running. It is worth noting that during the first four stages, this difference in RPE values was 0.50 points while during the final four stages the difference was 1.52 points, both having water values lower than land. (Table 4) (Appendices I, J). Overall, the lower stages had reported RPE values that were closer together (Stage 1: land=7.00 versus water=6.93), and the higher stages had a greater difference in RPE values (Stage 8: land=17.92 versus water =15.86) (Appendices I, J). However, in regards to this information, no significant correlation was determined to be present between HR and RPE at any individual stage in either medium (Appendix K).

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

Individuals who use aquatic exercise as a mode of cardiovascular exercise, will benefit from the physiological effects of immersion. The present study offers the first physiological investigation on underwater treadmill running while immersed to the chest. This study was designed to investigate the differences between heart rate and rating of perceived exertion between land-based treadmill running and underwater treadmill running.

There were two null hypotheses for this investigation. The first null hypothesis was that there would be no significant differences between the RPE of running in water compared to running on land at comparable workloads. The second null hypothesis was that there would be no significant differences between the heart rates of running in water compared to running on land at comparable workloads. The null hypothesis for HR was rejected, but this investigation failed to reject the null hypothesis for RPE. This investigation found heart rates to be significantly lower when running in the Hydroworx, but there was no significant difference in the RPE values (Appendix E). Meaning that when running in the Hydroworx subjects maintain a lower heart rate, but perceive their level of work to be equivalent to that on land. No significant correlation between HR and RPE was found in this study for either land-based treadmill running or underwater treadmill running. Therefore, the results of this investigation lead to the conclusion that running on an underwater treadmill will result in a lowered HR but a similar RPE value when running at a corresponding workload to land based treadmill running.

The following recommendations are made based on the realization that this study could have been conducted differently in many ways. Further, research warranted in this area includes but is not limited to, a larger sample size, the use of male and female subjects, untrained subjects, intrinsically measuring physiological responses, and multiple data recording sessions.

Future research needs to be performed to compare the biomechanical differences between running on a land-based treadmill and running on an underwater treadmill. Many subjects in this study felt that toward the latter stages, when the jet percentages were at and above 70%, their form fell apart and a majority of their effort was in maintaining their balance. With this in mind, some of their energy output may be directed more toward their upper-body and trunk motions that are not present when running on a land-based treadmill. Future study should be made where other physiological data, such as VO_2 as well as blood lactate concentration levels are measured which will more closely indicate actual levels of work.

Another possible avenue of future research in this area could be to select a different or even untrained subject population. This study incorporated the use of cross-country runners based on the assumption that this subject population tends to be more "in-tune" with how their body feels in regards to heart rate and workload. While this may be true, this subject population ran an average of 64.3 ± 16.7 miles per week. They might have underestimated their RPE level for the lower stages of the protocol. However, this could be reduced and even eliminated by using a different subject population or a more difficult protocol. In future research of cross-country runners, controlling for the number of miles each subject will run each, or even grouping subjects based upon their mileage, may produce differing results than this study reported.

In the future, it would also be interesting to look at the long term cardiovascular effects of running in the Hydroworx compared to a control group that ran exclusively on a land-based treadmill. This would be beneficial to individuals whom are unable, for whatever reason, to train in a full weight-bearing atmosphere.

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APPENDICES

APPENDIX A

IRB APPROVAL

Oklahoma State University
Institutional Review Board

Protocol Expires: 1/10/03

Date: Thursday, January 17, 2002 **IRB Application No** ED0261

Proposal Title: COMPARISON OF HEART RATE AND PERCEIVED EXERTION ON UNDERWATER VERSUS LAND-BASED TREADMILL RUNNING

Principal Investigator(s):

Brandon Hetzler
701 S Wicklow #608
Stillwater, OK 74074

Jack Ransone
429 Willard
Stillwater, OK 74078

Reviewed and Processed as: Expedited

Approval Status Recommended by Reviewer(s): Approved

Dear PI :

Your IRB application referenced above has been approved for one calendar year. Please make note of the expiration date indicated above. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved projects are subject to monitoring by the IRB. If you have questions about the IRB procedures or need any assistance from the Board, please contact Sharon Bacher, the Executive Secretary to the IRB, in 203 Whitehurst (phone: 405-744-5700, sbacher@okstate.edu).

Sincerely,

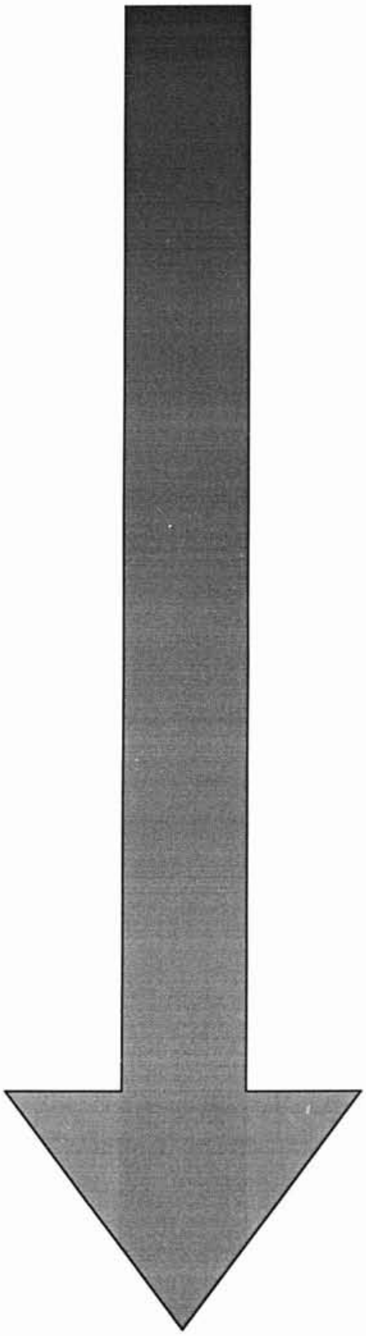
Carol Olson

Carol Olson, Chair
Institutional Review Board

APPENDIX B

BORG'S RATING OF PERCEIVED EXERTION SCALE

BORG'S RATING OF PERCEIVED EXERTION SCALE



6	No exertion at all
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard, heavy
16	
17	Very hard
18	
19	Extremely hard
20	MAXIMAL EXERTION

APPENDIX C

INFORMED CONSENT

OKLAHOMA STATE UNIVERSITY HHP RESEARCH CONSENT FORM

Comparison of Heart Rate and Perceived Exertion on Underwater Versus Land-Based Treadmill Running

I, ____________________________hereby authorize Brandon Hetzler and Dr. Jack Ransone to perform an experimental study conducted through Oklahoma State University, comparing perceived exertion between running on a standard land-based treadmill to a Hydroworx underwater treadmill. I will come dressed in comfortable clothing that will allow me to perform the following test. I understand that the purpose of this study is to assess the differences between on-land treadmill running and underwater treadmill running on heart rate and perceived exertion. I will undergo the same testing protocol in the two different training environments and my rating of perceived exertion will be compared at corresponding heart rates. Water level for the underwater portion will be maintained at chest level.

I understand I will perform the same testing protocol four times: twice in the Hydroworx and twice on a land-based treadmill. Each test will last between 20 and 30 minutes depending on my heart rate. A resting heart rate will be recorded for five minutes prior to beginning exercise while I am not performing any activity. I will then be allowed to warm up for five minutes at 4.8 mph. After stage one, the speed of the treadmill will be increased to 5.6 mph for stage 2 and 7.6 mph for stage 3-stage 8. From stage 4 to stage 8, the grade of the treadmill will be increased to 2°, 4°, 6°, 8° and 10° for the land-based testing and the jets will be increased to 30%, 60%, 70%, 80% and 85% of 300 gallons per minute for the underwater portion of the test. My heart rate and rating of perceived exertion for the last minute of each stage will be recorded. Upon the completion of the test, I will be given a three-minute cool-down stage at a pace of my choosing. I understand that the entire testing procedure will last four weeks.

I understand that the procedures explained in Paragraph 1 may have the following potential benefits to myself and/or humankind as a whole: 1) I may be exposed to exercise conditions that I may not have otherwise experienced on my own. 2) I will be able to see how my cardiovascular fitness varies between two training mediums, which may allow me to enhance my level of training. I understand that the procedure explained in Paragraph 1 may involve the following potential risks or discomforts: 1) I may experience muscle fatigue or cramping, as with any form of exercise. 2) I may experience dizziness. 3) I may experience temporary shortness of breath.

I understand that I will be a volunteer and that no medical services or compensation will be provided to myself by Oklahoma State University if an injury occurs from participation in this research. I understand that I have the opportunity to withdraw from this study at any time without penalty and that I have not given up any of my legal rights.

The data collected during this study will be kept confidential by assigning a subject a number by which to be recorded. This number will be used for tracking my records throughout the study. I will be identified by number only and the assigned numbers will be kept confidential and secure. The principal investigators will keep all data in an area of restricted access. Names will not be associated with any data, analysis, or presentation. Materials related to the identification number will be kept in a locked cabinet and will be destroyed immediately after the study is completed.

I understand that I (or my legally authorized representative) may have questions and request information about this research project at any time. By signing this consent I acknowledge that I have been afforded the necessary opportunities to pose any questions, which I may have, and that they have been answered to my satisfaction. The medical terms used have been explained to me and I understand them. Dr. Ransone or Brandon Hetzler will acknowledge any questions or problems that arise. Dr Ransone may be reached in his office by calling 405-744-9439, and Brandon Hetzler may be reached at 405-744-7823.

I understand that participation is voluntary and that I will not be penalized if I choose not to participate. I also understand that I am free to withdraw my consent and end my participation in this project at any time with no penalty after I notify Dr. Ransone at 405-744-9439. I may also contact Sharon Bacher, IRB Executive Secretary, 3056 Whitehurst, Oklahoma State University, Stillwater, OK 74078; telephone 4405-744-5700.

I have read and fully understand the consent form. I sign freely and voluntarily. A copy has been given to me.

Date:________________ Time:______________(a.m./p.m.)

Name:__________________________________

Signature:______________________________
(Please Print)

I certify that I have personally explained all elements of this form to the subject or his representative before requesting the subject or his representative sign it.

Signed:____
Project director or authorized representative

APPENDIX D

MEDICAL HISTORY QUESTIONNAIRE

Medical History Sheet

Today's Date___________

PERSONAL INFORMATION:

NAME____

(Last) (First) (MI)

AGE___ HEIGHT________ WEIGHT__________

LEVEL IN SCHOOL: FR SO JR SR GR

HOW MANY YEARS OF RUNNING EXPERIENCE DO YOU HAVE?_________

HOW MUCH EXPERIENCE DO YOU HAVE RUNNING IN THE HYDROWORX?

NONE VERY LITTLE MODERATE A LOT

IF YOU ANSWERED ANYTHING OTHER THAN NONE, PLEASE EXPLAIN?

____

____

____

HOME PHONE__________________________

WHAT DAY(s) OF THE WEEK ARE BEST FOR YOU TO PARTICIPATE IN THIS STUDY?____________________

WHAT TIME OF DAY IS BEST FOR YOU TO PARTICIPATE IN THIS STUDY?

Morning Midday Afternoon

MEDICAL HISTORY

Please circle YES or NO for *ALL* the questions listed below and explain any "yes" answers in the space provided.

General

Have you ever been advised by a medical doctor not to participate in strenuous activities?

Yes No

For what reasons?_________

Are you under a physicians care for any reason at this time?

Yes No

If yes, for what?___________

Have you ever had heat or muscle cramps?

Yes No

Have you had any other medical problems?

Yes No

If yes, what?______________

Are you afraid of water?

Yes No

Disease/Illness

Have you ever experienced an epileptic seizure or been informed you might have epilepsy?

Yes No

Have you ever been treated for Diabetes?

Yes No

Have you ever passed out during or after exercise?

Yes No

Have you ever been dizzy during or after exercise?

Yes No

Have you ever had chest pain during or after exercise?

Yes No

Have you ever had high blood pressure?

Yes No

Musculoskeletal

Have you ever had a fracture?

Yes **No**

If yes, when & where?______________

Have you ever had an injury to…

Your hip R or L **Yes** **No**

Your knee R or L **Yes** **No**

Your ankle R or L **Yes** **No**

Your foot R or L **Yes** **No**

Have you ever had an injury to your back?

Yes **No**

Do you experience frequent pain in your back?

Yes **No**

Explain in detail any "yes" answered in this section:

____

____

____

Have you had or do you have any other medical problems or injuries not listed on this form?

____

____

____

Do you have any medical or health problems that you are currently receiving medical treatment for?

____

____

____

Have you ever suffered from an injury in which you trained in the Hydroworx pool in the main athletic training room? ☐ **Yes** ☐ **No**

Are there any additional health problems that you feel is pertinent to your health that you would prefer to discuss privately with the investigator? ☐ **Yes** ☐ **No**

APPENDIX E

WITHIN SUBJECTS ANOVA SUMMARY TABLE

Within Subjects ANOVA Summary Table

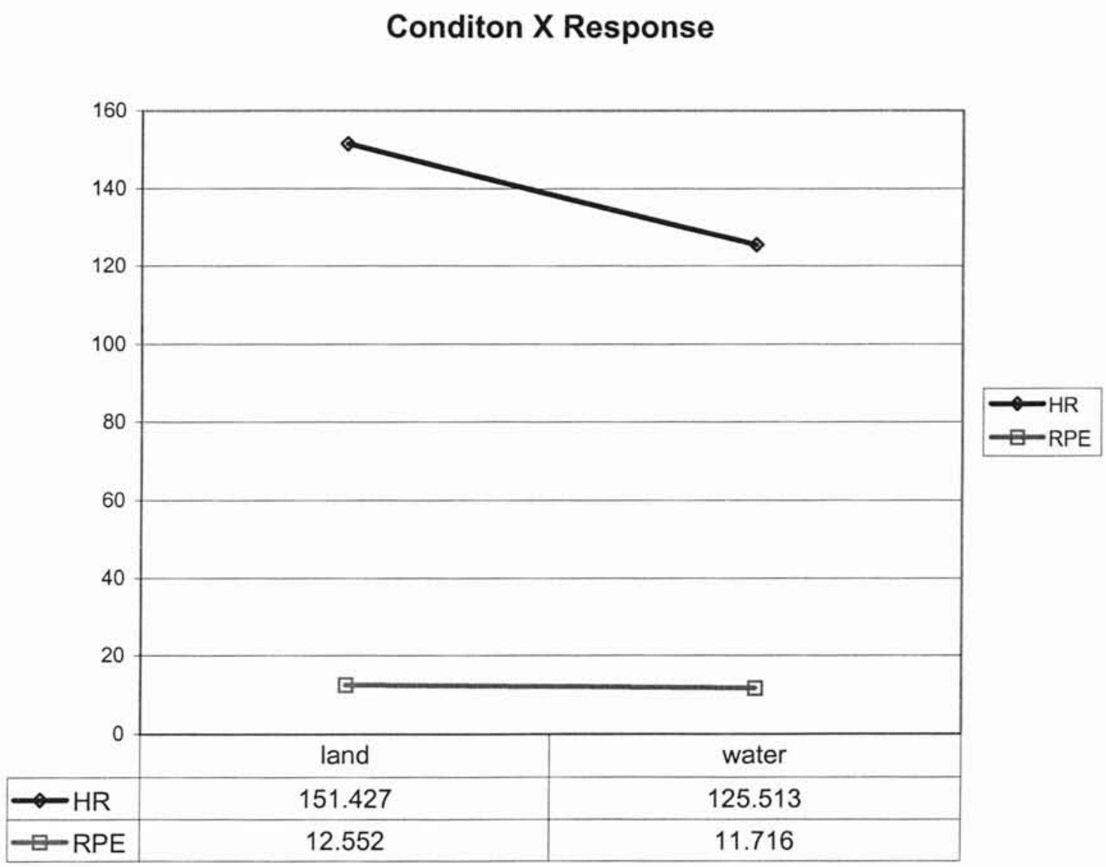
Source	SS	df	MS	F	
Condition {C}	19114.126	1	19114.126	201.657	a
Response {R}	1892471.763	1	1892471.763	19965.845	a
Stage {W}	78181.938	7	11168.848	117.833	a
Subjects {S}	23021.578	14	1644.398	17.349	a
S x C	2181.96	14	155.854	1.644	
S x R	21764.767	14	1554.626	16.402	a
C x R	16690.515	1	16690.515	176.087	a
C x W	1109.602	7	158.515	1.672	
R x W	42697.03	7	6099.576	64.351	a
S x W	11582.244	98	118.186	1.247	b
S x C x R	1747.627	14	124.831	1.317	
C x R x W	1064.249	7	152.036	9.502	
S x C x W	9320.072	98	95.103	1.003	
S x R X W	11120.536	98	113.475	1.197	
S x C x R x W	9288.975	98	94.785	1.000	
TOTAL	2141356.982	479			

a = significance to the .001 level
b = significance to the .05 level

APPENDIX F

SIMPLE MAIN EFFECT POST-HOC ANALYSIS

POST-HOC ANALYSIS



APPENDIX G

PHYSIOLOGICAL DATA: HEART RATE

Land Heart Rate

	Basal	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
1	93	134	146	170	175	184	186	*	*
2	77	118	128	140	153	157	164	175	186
3	73	113	122	139	145	161	167	175	184
4	82	103	107	133	144	155	166	175	186
5	69	93	98	114	118	125	132	143	153
6	83	112	108	113	125	149	167	182	180
7	80	107	111	125	135	147	157	163	172
8	84	119	126	140	147	155	166	174	184
9	66	120	130	149	155	158	170	172	185
10	67	108	112	132	141	150	165	173	181
11	86	102	111	137	152	162	180	184	196
12	62	111	120	140	156	161	168	174	182
13	66	129	136	167	172	185	194	200	204
14	93	141	155	174	174	185	193	199	*
15	87	107	116	122	124	136	162	191	193
Average	77.87	114.47	121.73	139.67	147.73	158.00	169.13	177.14	183.54

Water Heart Rate

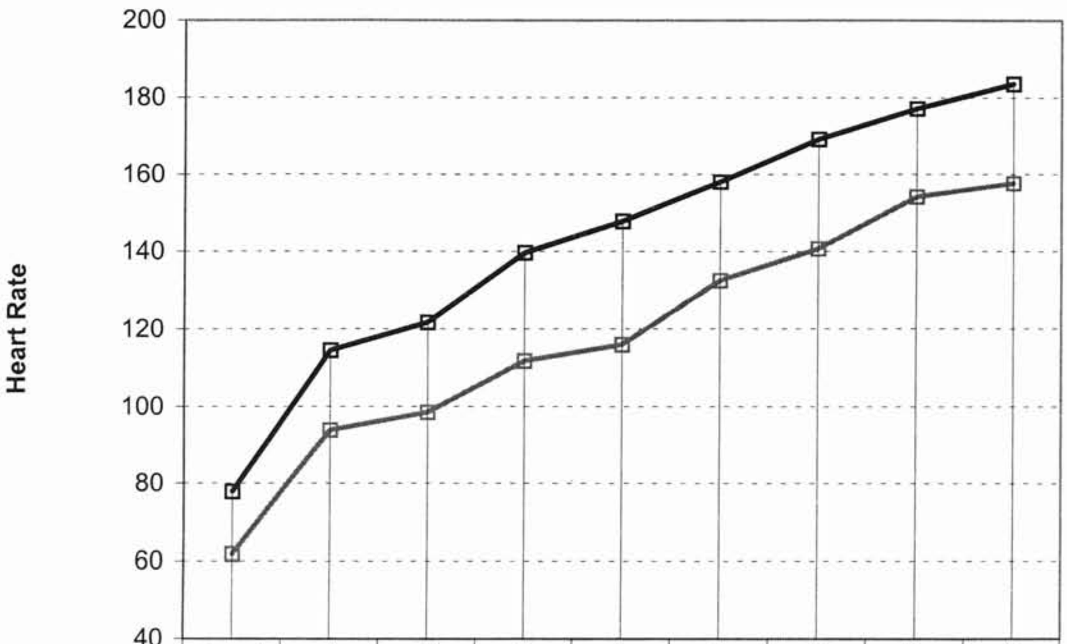
	Basal	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
1	80	116	124	153	154	173	183	195	*
2	54	95	110	129	132	142	142	152	165
3	68	98	97	100	111	118	116	130	144
4	48	91	90	111	110	123	142	160	156
5	56	78	72	75	84	84	96	114	130
6	66	90	91	104	109	134	146	159	159
7	73	94	99	100	108	110	115	137	125
8	66	99	104	124	127	138	136	143	149
9	60	93	91	102	111	127	153	166	166
10	57	95	103	115	117	128	132	154	159
11	50	84	94	110	104	143	138	157	185
12	50	79	86	97	102	117	126	133	127
13	48	94	102	121	126	149	168	167	177
14	83	114	119	128	137	181	185	188	192
15	68	89	96	108	107	121	133	157	157
Average	61.80	93.93	98.53	111.80	115.93	132.53	140.73	154.13	156.50

* denotes a stage the subject was unable to complete

APPENDIX H

MEAN HEART RATE GRAPH

Mean Heart Rate



	Basal	1	2	3	4	5	6	7	8
land	77.8667	114.466	121.733	139.666	147.733	158.000	169.133	177.142	183.538
water	61.8000	93.9333	98.5333	111.800	115.933	132.533	140.733	154.133	157.571

Stage

APPENDIX I

PHYSIOLOGICAL DATA: RPE

Land RPE Values

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
1	7	7	12	15	16	20	*	*
2	6	7	8	9	11	13	15	18
3	8	9	12	13	14	15	17	18
4	9	11	13	14	15	16	17	19
5	7	7	10	11	12	14	15	16
6	7	8	10	11	13	15	17	18
7	6	6	9	10	13	15	17	19
8	6	8	12	12	13	16	18	19
9	7	7	8	10	12	13	14	16
10	7	8	11	12	13	14	16	17
11	7	8	10	11	12	13	13	15
12	9	11	13	15	16	17	18	20
13	6	8	11	12	14	16	17	19
14	7	8	10	11	12	15	19	*
15	6	8	11	12	14	15	17	19
Average	7.00	8.07	10.67	11.87	13.33	15.13	16.43	17.92

Water RPE Values

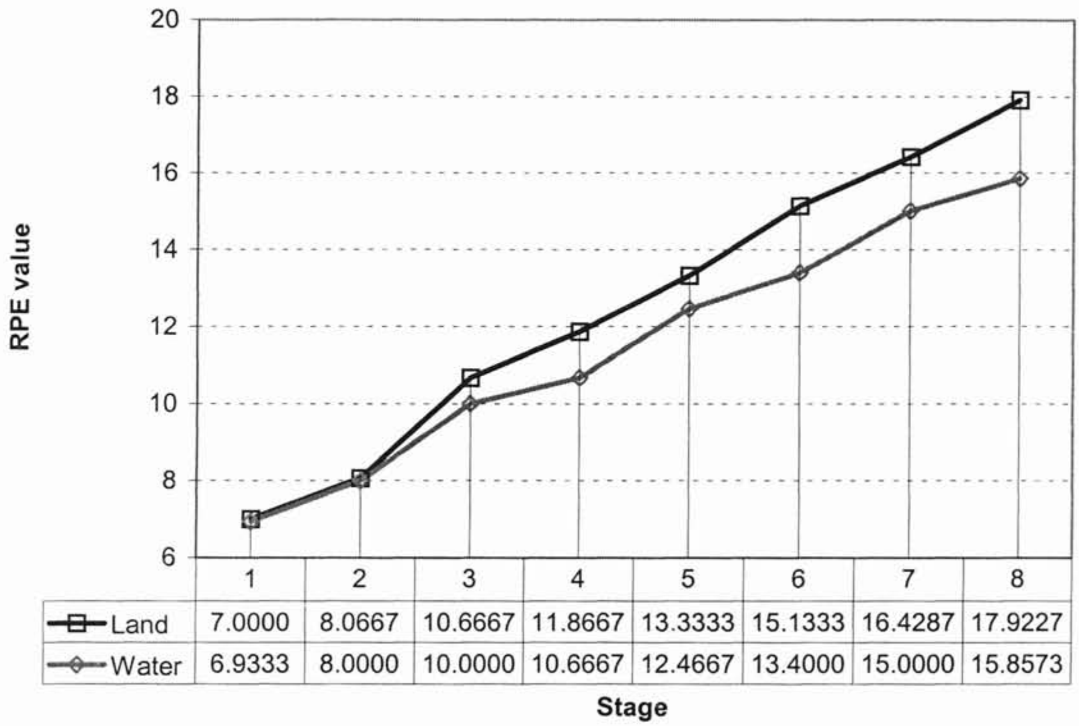
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
1	9	10	11	12	14	15	17	*
2	6	7	9	10	12	12	13	15
3	7	9	12	12	13	15	17	18
4	7	9	11	12	14	16	18	19
5	7	8	9	10	11	12	12	14
6	7	9	12	12	14	15	16	17
7	6	6	6	6	7	8	13	9
8	7	9	12	13	14	15	16	17
9	6	6	6	7	7	9	12	14
10	8	9	13	14	15	15	17	18
11	7	9	11	12	13	14	15	15
12	6	7	12	13	16	17	17	18
13	7	9	12	12	14	17	16	17
14	7	7	8	8	12	12	13	15
15	7	8	10	11	13	14	16	18
Average	6.93	8.13	10.27	10.93	12.60	13.53	15.20	16.00

* denotes a stage the subject was unable to complete

APPENDIX J

MEAN RATINGS OF PERCEIVED EXERTION GRAPH

Mean Ratings of Perceived Exertion

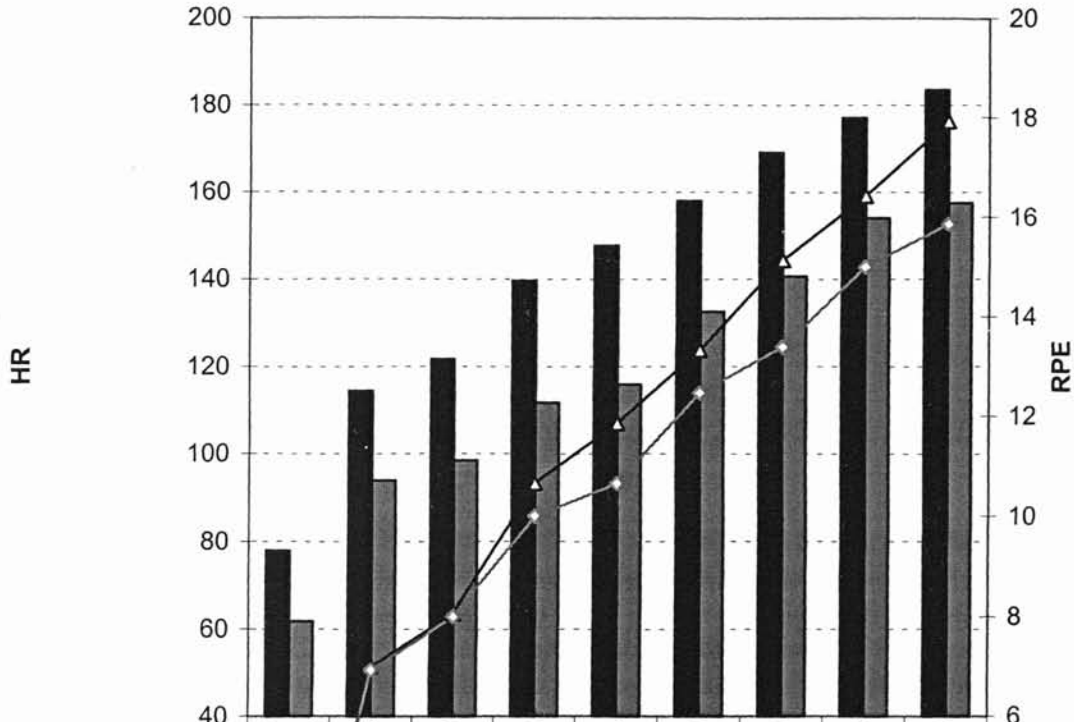


	1	2	3	4	5	6	7	8
Land	7.0000	8.0667	10.6667	11.8667	13.3333	15.1333	16.4287	17.9227
Water	6.9333	8.0000	10.0000	10.6667	12.4667	13.4000	15.0000	15.8573

APPENDIX K

MEAN HEART RATE vs.
RATING OF PERCEIVED EXERTION GRAPH

Heart rate vs. Rating of perceived exertion



	Basal	1	2	3	4	5	6	7	8
land HR	77.86	114.4	121.7	139.6	147.7	158.0	169.1	177.1	183.5
water HR	61.80	93.93	98.53	111.8	115.9	132.5	140.7	154.1	157.5
land RPE	0	7.000	8.066	10.66	11.86	13.33	15.13	16.42	17.92
water RPE	0	6.933	8.000	10.00	10.66	12.46	13.40	15.00	15.85

Stage

γ

VITA

Brandon S. Hetzler

Candidate for the degree of

Master of Science

Thesis: COMPARISON OF HEART RATE AND PERCEIVED EXERTION ON AN UNDERWATER TREADMILL VERSUS A LAND-BASED TREADMILL

Major Field: Health, Physical Education and Leisure

Biographical:

Personal Data: Born in Quincy, Illinois, on December 24, 1977, the son of Keith and Shirley Hetzler.

Education: Graduated from Highland High School, Ewing, Missouri in May 1996; received a Bachelor of Science Degree in Sports Medicine/Athletic Training from Southwest Missouri State University, Springfield, Missouri in May 2000. Completed the requirements for the Master of Science Degree with a major in Health and Human Performance at Oklahoma State University, Stillwater, Oklahoma in May 2002.

Experience: Employed at Titan Wheel International, Inc. during high school; acted as a student athletic trainer at SMSU; employed by various sporting camps during the summers; employed by OSU, Department of Athletics as a graduate assistant athletic trainer with the football team, 2000 to present.

Professional Memberships: National Athletic Trainer's Association, District 5 Athletic Trainer's Association, Mid-American Athletic Trainer's Association.