

THE CARDIOVASCULAR RESPONSES OF RUNNING ON AN UNDERWATER
TREADMILL AT TWO DIFFERENT WATER TEMPERATURES COMPARED TO
LAND BASED RUNNING

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CHAPTER I

INTRODUCTION

Obesity is a health condition and an epidemic affecting many people, including children and the elderly. This condition occurs when the amount of calories consumed exceeds the amount of calories expended over a long period of time (American College of Sports Medicine, 2013). Not only does this condition decrease quality of life and life expectancy, but also progresses into detrimental health complications and conditions (Alberston, Cadore, Pinto, Tartaruga, Silva & Kruehl, 2010). Obesity has been linked to cardiovascular disease, diabetes, and cancer (Butts, Tucker & Greening, 1991).

Additionally, having excessive amounts of stored adipose tissue increases the amount of stress and load placed on skeletal joints (Alberston, Cadore, Pinto, Tartaruga, Silva & Kruehl, 2010). This increase in axial load can make it difficult to do daily tasks of living and lead to degeneration of the joints resulting in painful conditions, such as arthritis (Hall, Macdonald, Maddison & O'Hare, 1997). Obesity is a condition, which left untreated, can escalate into many other deteriorating health conditions and diseases.

Obesity is a very preventable and treatable condition (Hall, Macdonald, Maddison & O'Hare, 1997). One of the most common prescriptions to prevent and treat obesity is exercise (Denning, Bressel & Dolny, 2010). According to the American College of Sports Medicine (ACSM), an individual should engage in moderate physical activity

three to five times a week for at least thirty minutes. Moreover, data supports that sedentary people can gain health benefits from exercising one time a week for thirty minutes (American College of Sports Medicine, 2013). Exercise increases the strength of the cardiac muscle, regulates hormone activity, and improves mood (American College of Sports Medicine, 2013). Additionally, exercise strengthens the muscles, joints, and bones in the body and this helps the body perform daily tasks of living. Through enhancing these mechanisms of the body, exercise provides people with the ability to sustain a good quality of life.

Exercise is commonly prescribed to prevent and treat obesity; however, many individuals can't perform land-based exercise. Land-based exercise can cause discomfort on an individual's joints and musculoskeletal injuries and soreness. Fortunately aquatic exercise, which is defined as physical activity in the water, enables many individuals to gain similar physiological benefits as land-based exercise (Hall, Macdonald, Maddison & O'Hare, 1997). Water exercise is as effective as land-based exercise in developing muscular and cardiovascular strength and endurance (Binkley & Schroyer, 2002). Water immersion decreases axial loading of the spine and through the effects of buoyancy, allows the performance of movements that are normally difficult or impossible on land (Waller, Lambeck, & Daly, 2009). The buoyancy and drag properties of the water can create resisted movements to suit individuals' needs and functions (Waller, Lambeck, & Daly, 2009). Buoyancy opposes the load of an individual's weight and this decreases the amount of stress and load on the axial spine (Waller, Lambeck, & Daly, 2009). In addition to buoyancy, drag creates resistance and this resistance increases the muscular strength of the body. (Alberston, Cadore, Pinto, Tartaruga, Silva & Krueel, 2010).

Furthermore, aquatic exercising creates a stronger exercise adherence because warm water promotes sensory input, decreases pain sensation and muscle spasms, while increasing muscle relaxation (Wang, Belza, Thompson, Whitney, & Bennett, 2007).

Recent research has examined the effects that water temperature produces on aquatic exercise. Specifically, the effects that water temperature have on individuals' physiological responses, such as rating of perceived exertion (RPE), oxygen consumption, and heart rate. In addition, comparison of physiological responses of aquatic and land-base exercise has been examined. Results have shown that individuals gain the same physiological benefits with aquatic exercise as they do in land-based exercise (Binkley and Schroyer, 2002). However, there is paucity of data that evaluates the heat stresses of warm-water immersion (Craig & Dvorak, 1966). Therefore, a lack of data exists on the physiological responses that occur when running on an underwater treadmill in warm water and how these responses compare to running on a land-base treadmill.

The question of whether heart rate is the same while running in water and on air, at similar levels of energy expenditure, is important since heart rate is often used for prescription of exercise intensity (Evans, Cureton, and Purvis, 1978). Therefore, the purpose of this study was twofold: (1) to compare rating of perceived exertion, oxygen consumption, energy expenditure, and heart rate while running on an underwater treadmill in 95°F and 104°F water, and (2) to determine if running on an underwater and land-base treadmill produced similar responses in rating of perceived exertion, oxygen consumption, energy expenditure, and heart rate.

Research Question 1: Does water temperature of 95°F increase heart rate, rating of perceived exertion, oxygen consumption, and energy expenditure on healthy college-aged adults while running on an underwater treadmill when compared to running in 104°F water?

Research Question 2: Does aquatic running increase heart rate, rating of perceived exertion, oxygen consumption, and energy expenditure on healthy college-aged adults when compared to running on a land-base treadmill?

CHAPTER II

REVIEW OF LITERATURE

Aquatic exercise has been used for many years in the management of musculoskeletal problems, including low back pain, which has a high contribution to disability (Waller, Lambeck, & Daly, 2009). An 8-week water-aerobic program found that knee-flexion, knee-extension, and shoulder extension strength increased (Binkley & Schroyer, 2002). At moderate-intensity exercise on land and in water, measuring oxygen consumption and heart rate can be useful for conditioning, therapeutic, and rehabilitation programs (Binkley & Schroyer, 2002). Important relationships have been shown at submaximal intensities during underwater treadmill running between perceived exertion, heart rate, and oxygen consumption and these responses tend to be lower during underwater treadmill running than land-based running (Wilder & Brennan, 1993). However, aquatic exercise produces inconsistent results in regards to physiological responses produced from performing upright exercises such as walking and jogging in water (Evans, Cureton, & Purvis, 1978). Additionally, little research has examined the physiological responses that occur when exercising in water temperature greater than 95°F (Buck, McNaughton, Sherman, Bentley & Batterham, 2001).

Water temperature is maintained at many different degrees, but the body's thermoneutral temperature, which is the body's natural temperature, is 86°F (Buck,

McNaughton, Sherman, Bentley & Batterham, 2001). Any water temperature below 83°F causes peripheral vasoconstriction, which shunts blood flow to the core of the body and stimulates the musculoskeletal system to shiver and produce heat (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). Water temperature above 86°F causes physiological stress on the human body causing vasodilatation, which allows heat to escape from the body (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). Responses to thermal stresses involve adjustment of heat production, alterations of the circulation, and changes in water vaporization from the surface (Craig & Dvorak, 1966). An individual's ability to adjust a range of atmospheric conditions is measured by temperature, humidity, and air movement (Craig & Dvorak, 1966).

A study by Buck *et al* (2001), examined physiological responses in six college-aged adults while walking on an underwater treadmill in 86°F, 95°F, and 104°F. The measured variables were blood lactate concentration, heart rate, maximum oxygen consumption, rating of thermal sensation, and RPE. Buck *et al* (2001) concluded that walking on an underwater treadmill at increasing speeds, in increasing water temperatures, increased the physiological stress. Another study examined how increasing walking speeds on an underwater treadmill impacted heart rate and rating of perceived exertion in 20 healthy middle-aged and elderly women in 86°F water (Shimizu, Fujishima, & Kosaka, 1998). The results of this study indicated that heart rate and RPE have a strong linear relationship when walking on an underwater treadmill because both heart rate and RPE increased as speed increased. Further, a study done by Shimizu and Fujishima (2003) compared how reversing the order of water temperature effected eight healthy males' physiological responses on rectal temperature, heart rate, and maximum

oxygen consumption when walking for sixty minutes in 77°F, 86°F, and 95°F water in comparison to 95°F, 86°F, and 77°F water on an underwater treadmill. This study found that sequence of water temperature had no impact or influence on the above mentioned variables for this population (Shimizu & Fujishima, 2003).

Brubaker *et al* (2011) performed a study that compared physiological responses of running on an underwater treadmill to running on a land-base treadmill. This study consisted of examining heart rate, ventilation, tidal volume, breathing frequency, RPE, and oxygen consumption on eleven collegiate athletes while running on an underwater treadmill in 82°F water and running on a land-base treadmill. The aquatic and land-base trials used similar protocols, but minor adjustments were implemented between the two trials. The underwater treadmill trial consisted of having participants rest in water for five minutes and then complete seven stages, with each stage lasting two minutes at increasing speeds. The underwater treadmill speeds were as listed: 1.5, 3.0, 4.5, and 6.0 miles per hour (mph). After stage four, water jets were turned on and the jet speeds increased every two minutes. However, the treadmill speed stayed constant at 6.0 mph while the jet speeds increased in two minute increments. The jet velocities were as listed: 30, 40, and 50% resistance. The land-base treadmill trial followed the same protocol as the underwater treadmill trial, but instead of using water jets for the last three stages the land-based treadmill was inclined. The following inclines were utilized for the last three stages: 1, 2, and 4% incline (Brubaker, Ozemek, Gonzalez, Wiley & Collins, 2011). As mentioned by Brubaker *et al* (2011), the underwater treadmill jet speeds and the land-base incline treadmill were used as comparable exercise intensities. The results of this study indicated that no significant differences were observed for oxygen consumption,

heart rate, ventilation, tidal volume, breathing frequency, or RPE when compared to underwater and land-based treadmill running.

The Brubaker *et al* (2011) study produced no significant results between underwater and land-base treadmill running; however, this study should be replicated with minor adjustments for the following reasons. First, Brubaker *et al* (2011) had limited participant selection. The purpose for selecting the eleven participants was to represent uninjured collegiate athletes, but these athletes were used to represent various sports including, men's soccer (2 participants), women's soccer (3 participants), women's volleyball (1 participant), women's field hockey (1 participant), football (1 participant), baseball (1 participant), men's track and field (1 participant), and women's track and field (1 participant). Eleven participants is hardly an adequate representation of collegiate athletes. In addition to the small sample size, Brubaker *et al* (2011) allowed participants to either walk or jog during stage four of both the underwater and land-base trials. The inconstant biomechanical procedures could have skewed the data for this stage and had to be excluded when comparing the results of all three trials.

The minor adjustments this research study made was using a larger and broader population sample, adding uniformity to the fourth stage of both the underwater and land-base treadmill trials, adding an additional underwater treadmill trial, and using different water temperatures. Having a larger and generalized sample of participants, which aren't college athletes, will provide new information when comparing physiological responses to underwater and land-base treadmill running. In addition to increasing the sample population size, uniformity was added to stage four of both the underwater and land-base treadmill trials. For this study participants were required to jog in the fourth stage of both

the underwater and land-base treadmill trials. Lastly, this study compared how water temperatures of 95°F and 104°F affected heart rate, RPE, oxygen consumption, and energy expenditure. In conjunction to comparing the physiological responses created in the two aquatic trails, a comparison between physiological responses of underwater treadmill running and land-base running was done.

The reason for selecting 95°F and 104°F water temperatures for this study was in responses to a statement made by Buck *et al* (1998), which was, "unfortunately, there are limited studies that have investigated the effect on water temperature above thermoneutral temperature and so a direct comparison of water temperatures of 95°F and 104°F is difficult." Furthermore there are differing opinions between water and land-base running and further research should apply these applications (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). To add to the existing research on the physiological benefits between land and underwater treadmill running, this study examined the effects of running on an underwater treadmill in 95°F and 104°F water and compared the physiological responses to underwater treadmill running and land-base treadmill running.

CHAPTER III

RESEARCH DESIGN AND METHODS

Participants

Seventeen recreationally active individuals between the ages of 20 and 30 years old who were moderately active as defined by American College of Sports Medicine as (30-min of moderate intensity exercise 3-5-d/wk) were recruited. Each participant had to complete a Godin-Leisure-Time Exercise Questionnaire form to determine physical activity level. Participants were recruited from The University of Akron's campus through the use of electronic mail and word of mouth. Individuals that were pregnant, suffering from musculoskeletal injuries, smoke, have a phobia of water, or present cardiovascular or respiratory conditions were deemed ineligible to participate in this study due to health risks and conditions. Additional contradictions for participating in this study were participants' suffering from infections, open wounds, fever, chronic disease, abnormal blood pressure, and gastrointestinal disorders (Binkley & Schroyer, 2002). Resting abnormal blood pressure was defined as systolic over 260mmHg and diastolic over 160mmHg (Bocalini, Serra, Murad & Levy, 2008). Participants were instructed to wear a swimsuit, which included swimming trunks for men and a one-piece swimming suit for women. All participants signed an informed consent form and all procedures were approved by The University of Akron's Institution Review Board (IRB).

Table 1

Subject Characteristics

<i>Demographics</i>	<i>Mean</i>	<i>SD</i>
<i>Age</i>	21.7(y)	± 1.7
<i>Weight</i>	76.6 (kg)	± 11.3
<i>Height</i>	176.6 (cm)	± 7.1

Note. Values are an average of the seventeen subjects' that participated in the trials. Avg= average, Age= numbers of years old, Weight=kilograms, Height=centimeters, ±SD= standard deviation.

Research Design

Participants reported to the Exercise Physiology laboratory to perform a familiarization sessions before starting the study. At the familiarization session participants received an informed consent (Appendix A), PAR-Q & YOU form (Appendix B), Godin Leisure-Time Exercise Questionnaire (Appendix C), and the RPE scale (Appendix D). Each participant was required to complete a PAR-Q & YOU form, which provided an overview of his or her health history. Answering yes to any question on the PAR-Q & YOU eliminated participants from the study due to health risks. Also, during the familiarization session participants were informed about their role in the study, their ability to discontinue participation at any time, testing protocols, and all other pertinent information. Furthermore, participant's demographics were obtained during the familiarization session, which included age, weight, and height. During the familiarization session, participants walked on the HydroWorx 1200 (HydroWorx, Middletown, PA) underwater treadmill for two minutes at 1.5 miles per hour (mph) in 86°F water. This allowed participants to become acclimated with the underwater treadmill. The familiarization session occurred 72 hours before starting the study trials, which ensured that participants had enough time to read and complete the informed

consent, PAR-Q & YOU, and Godin Leisure-Time Exercise forms. Testing procedures were alike for each participant and all participants underwent three trials, which were running on a land-base treadmill trial, 95°F underwater treadmill trial, and 104°F underwater treadmill trial. It's important to note the exact temperature of the water was unknown to the participants. The study began with participants completing the land-base treadmill trial. The first stage consisted of standing in place for five minutes on the treadmill. Following this stage, participants began walking on the treadmill at 1.5 (mph). Participants' heart rate were measured using a Polar Heart Rate monitor (Polar, USA), RPE using a 20-point Borg scale (Borg, 1982), and oxygen consumption and energy expenditure measured using a ParvoMedics TrueOne 2400 Metabolic Measurement System (Sandy, UT) every minute. Participants walked at 1.5 mph for two minutes before the treadmill speed increased to 3.0 mph. After two minutes were completed at 3.0 mph the treadmill speed increased to 4.5 mph and participants completed two minutes at this speed. After two minutes were completed, the treadmill speed increased to 6.0 mph. Participants completed two minutes at this speed. For the remainder of the trial, the treadmill speed stayed constant at 6.0 mph, but the treadmill inclined every two minutes. After two minutes were completed at 6.0 mph, the treadmill inclined to 1%. After two minutes were completed, the treadmill inclined to 2%. When two minutes had been completed, the treadmill inclined to 4%. When two minutes have been completed at this incline, a cool-down was implemented. The cool-down consisted of having participants walk at 1.5 mph at 0% incline until their heart rate was within or under 100 beats per minute. A rest period of at least 48 hours took place before participants reported back to the Exercise Physiology laboratory to run on the underwater treadmill in 95°F water. To

begin, participants stood at rest for five minutes on the underwater treadmill in the 95°F water. After standing in place for five minutes, the underwater treadmill speed increased to 1.5 mph. The same procedures were used for the underwater trials as the land-base trial. However, the last three stages of the underwater treadmill trials used water jets; instead, of inclining the treadmill, like the land-base trial. Water jet velocities of 30, 40, and 50% resistance and were increased every two minutes. The following table displays the procedures for the trials:

Table 2

Land and Water Treadmill Protocol

Stage	Speed (mph)	Land Treadmill Incline	Water Jet Velocity	Time (min)
Rest	0	0	0	5
1	1.5	0	0	2
2	3.0	0	0	2
3	4.5	0	0	2
4	6.0	0	0	2
5	6.0	1%	30%	2
6	6.0	2%	40%	2
7	6.0	4%	50%	2

Statistical Analysis

A 3X7 with repeated measures ANOVA was used to determine if there was a significant difference between heart rate, rating of perceived exertion, maximum oxygen consumption and energy expenditure. All trials were compared to one another (Land X 95°F X 104°F). Post-hoc Bonferroni analysis, when appropriate, was then performed to determine where differences occurred. Statistical significance was set *a priori* at $p < 0.05$. All data was analyzed using with SPSS V. 19.0 software.

CHAPTER IV
RESULTS

RATING OF PERCEIVED EXERTION (RPE)

Overall, the group showed a significant difference in all three trials as shown in table three. A significant difference within subjects was observed for all trials ($p=0.019$) and time X trials ($p=0.000$). There was a direct correlation between rating of perceived exertion and time, as time increased so did the rating of perceived exertion. There is no significant difference for land and 95°F trials ($p=0.113$), and no significant difference for land and 104°F ($p=0.092$). Furthermore, there was no significant difference observed for 95°F and 104°F ($p=0.994$). It is important to mention that the heat of the water has an effect on the process of homeostasis and on most occasions the subjects' consider the tests in warmer water to be extremely uncomfortable because the higher temperature leads to dehydration and may have led to shift in electrolytes balance and fluid distribution (Buck, McNaughton, Sherman, Bentley & Batterham, 2001).

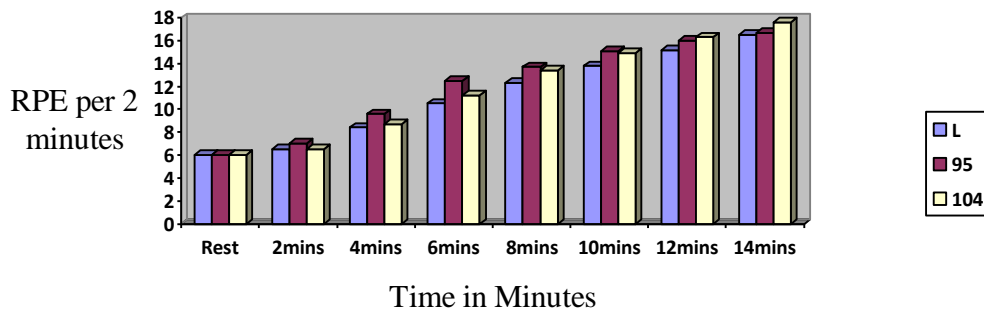
Table 3

Rating of Perceived Exertion

<i>Time</i>	Rest	2mins	4mins	6mins	8mins	10mins	12mins	14mins
<i>L</i>	6.0±0.0	6.5±.64	8.4±1.50	10.5±2.17	12.3±2.37	13.8±2.07	15.2±1.92	16.5±2.02
<i>95°F</i>	6.0±0.0	7.0±.96	9.6±2.16	12.5±2.13	13.7±2.11	15.1±1.56	16.0±1.49	16.7±1.71
<i>104°F</i>	6.0±0.0	6.5±2.05	8.7±2.55	11.2±2.44	13.4±2.09	14.9±1.86	16.3±1.73	17.6±1.73

Note. Values are presented as mean \pm SD. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree water on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

Figure 1



Note. Values are presented as mean \pm SD. Mins = two minute stages, L= running on land treadmill, 95 = running in ninety five degree on aquatic treadmill, 104 = running in one hundred four degree water on aquatic treadmill.

Table 4

Change in perceived exertion per stage

Time	2mins	4mins	6mins	8mins	10mins	12mins	14mins
L	.5	1.9	2.1	1.8	1.5	1.4	1.3
95°F	1	2.6	2.9	1.2	1.4	.9	.7
104°F	.5	2.2	2.5	2.2	1.5	1.4	1.3

Note. Numbers represent the changes in value per stage. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree water on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

OXYGEN CONSUMPTION

Overall, the group showed a significant difference in all three trials as shown in table five. A significant difference within subjects was observed for all trials ($p=0.000$) and time X trials ($p=0.000$). As time increased throughout the trials, oxygen consumption also increased. When oxygen consumption and time were compared to land and 95°F a significant difference was observed ($p=0.001$). Moreover, there was a significant difference between land and 104°F ($p=0.000$). Furthermore, there was a significant

difference between 95°F and land ($p=0.001$), as well as, 104°F and land ($p=0.000$).

However, there was no significant difference between 95°F and 104°F ($p=1.000$).

Additionally, there was no significant difference between 104°F and 95°F ($p=1.000$).

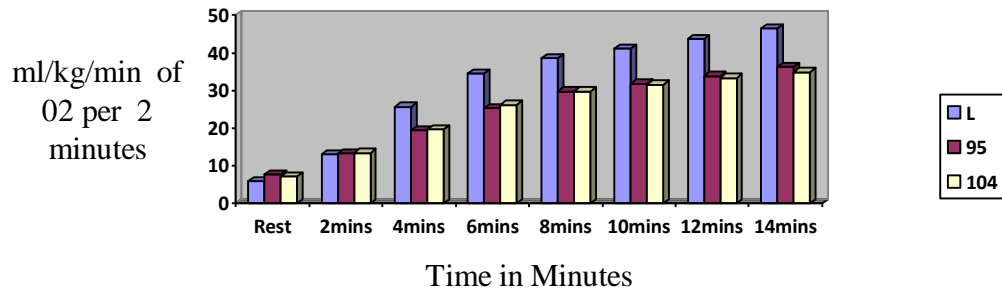
Table 5

Oxygen Consumption (ml/kg/min)

Time	Rest	2mins	4mins	6mins	8mins	10mins	12mins	14mins
L	5.89±1.86	13.0±1.34	25.6±3.35	34.4±2.90	38.5±3.11	41.1±3.59	43.7±3.35	46.4±4.00
95°F	7.56±2.58	13.2±3.40	19.3±4.10	25.2±5.89	29.7±5.16	31.8±5.70	33.8±5.50	36.2±6.30
104°F	7.05±2.55	13.4±2.45	19.6±3.38	26.2±4.36	29.7±5.09	31.5±5.14	33.3±5.30	34.8±5.40

Note. Values are presented as mean ± SD. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

Figure 2



Note. Values are presented as mean ± SD. Mins = two minute stages, L= running on land treadmill, 95 = running in ninety five degree on aquatic treadmill, 104 = running in one hundred four degree water on aquatic treadmill.

Table 6

Change in oxygen consumption per stage (ml/kg/min)

Time	2mins	4mins	6mins	8mins	10mins	12mins	14mins
L	7.11	12.6	8.8	4.1	2.9	2.6	2.7
95°F	5.64	6.1	5.9	4.5	2.1	2	2.4
104°F	6.35	6.2	6.6	3.5	1.8	1.8	1.5

Note. Numbers represent the changes in ml/kg/min per stage. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree water on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

ENERGY EXPENDITURE

Overall, the group showed a significant difference in all three trials as shown in table seven. A significant difference within subjects was observed for all trials ($p=0.001$) and time X trials ($p=0.000$). As time increased throughout the trials, energy expenditure also increased. When energy expenditure and time were compared for land and 95°F a significant difference was observed ($p=0.018$). Moreover, when land and 104°F were compared to one another there was a significant difference of ($p=0.005$). A significant difference between 95°F and land is clear ($p=0.018$). The significant difference between 104°F and land is strong ($p=0.005$). However, there was no significant difference between 95°F and 104°F ($p=1.00$), as well as, 104°F and 95°F ($p=1.000$).

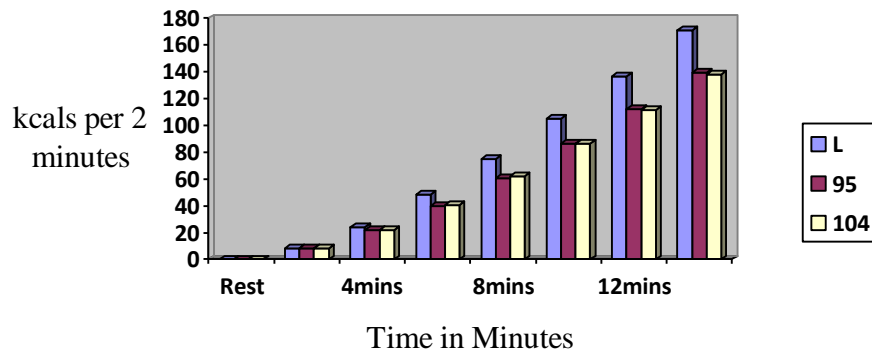
Table 7

Energy Expended (kcal)

<i>Time</i>	Rest	2mins	4mins	6mins	8mins	10mins	12mins	14mins
<i>L</i>	0±0.0	8.4±1.45	24.2±3.82	48.4±6.81	75.2±11.80	104.9±15.79	136.7±20.57	171.2±26.29
<i>95°F</i>	0±0.0	8.4±3.10	21.7±7.05	40.0±13.03	60.3±21.54	86.7±26.44	112.5±33.33	139.7±40.90
<i>104°F</i>	0±0.0	8.5±2.20	22.0±5.15	40.4±9.22	62.2±14.28	86.1±19.68	111.2±25.21	138.0±30.69

Note. Values are presented as mean ± *SD*. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

Figure 3



Note. Values are presented as mean \pm SD. Mins = two minute stages, L= running on land treadmill, 95 = running in ninety five degree on aquatic treadmill, 104 = running in one hundred four degree water on aquatic treadmill.

Table 8

Change in energy expenditure per stage (kcal)

Time	2mins	4mins	6mins	8mins	10mins	12mins	14mins
L	8.4	15.8	24.2	26.8	29.7	31.8	34.5
95°F	8.4	13.3	18.3	20.3	26.4	25.8	27.2
104°F	8.5	13.5	18.4	21.8	23.9	25.1	26.8

Note. Numbers represent the changes in kcal per stage. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree water on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

HEART RATE

Overall, the group showed a significant difference in all three trials as shown in table nine. A significant difference within subjects was observed for all trials ($p=0.000$) and time X trials ($p=0.000$). As time increased throughout the trials, heart rate also increased. When heart rate and time were compared for land-based and 104°F a significant difference was observed ($p=0.002$). Moreover, when 95°F and 104°F water trials were compared to each other there was a significant difference of ($p=0.000$). A significant difference between 104°F and land is clear ($p=0.002$). The significant

difference between 104°F and 95°F is strong ($p=0.000$). However, there was no significant difference between land and 95°F ($p=0.142$). Additionally, there was no significant difference between 95°F and land ($p=0.142$). Therefore, these results suggest that as duration of the trials is increased, so is the physiological response of heart rate. In conclusion the duration of these trials directly impact the response of the individuals' heart rate.

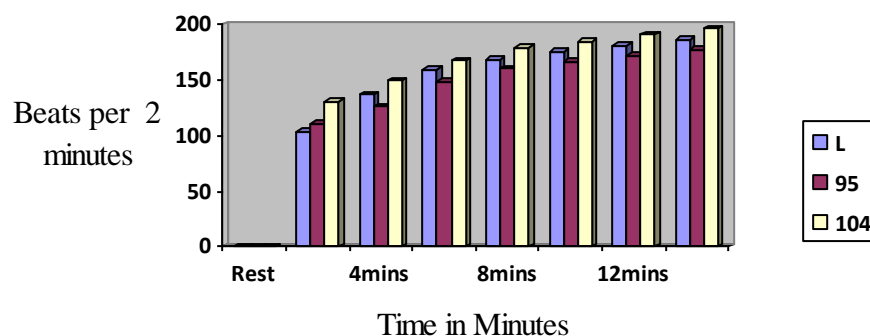
Table 9

Heart Rate (bpm)

Time	Rest	2mins	4mins	6mins	8mins	10mins	12mins	14mins
L	Na	103.0±13.5	136.8±14.0	158.9±12.6	169.0±13.0	175.3±13.2	180.8±12.7	186.2±12.6
95°F	Na	110.4±9.3	126.1±8.2	149.3±12.0	160.1±11.1	167.2±12.3	172.1±10.2	177.2±11.5
104°F	Na	130.0±7.06	149.5±8.51	167.6±11.08	178.7±8.83	184.9±10.34	190.7±11.0	196.2±11.17

Note. Values are presented as mean ± SD. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill, Na= values were not obtained for that stage.

Figure 4



Note. Values are presented as mean ± SD. Mins = two minute stages, L= running on land treadmill, 95 = running in ninety five degree on aquatic treadmill, 104 = running in one hundred four degree water on aquatic treadmill.

Table 10

Change in heart rate per stage (bpm)

<i>Time</i>	2mins	4mins	6mins	8mins	10mins	12mins	14mins
<i>L</i>	103.0	33.8	22.1	10.1	6.3	5.5	5.4
<i>95°F</i>	110.4	15.7	23.2	10.8	7.1	4.9	5.1
<i>104°F</i>	130.0	19.5	18.1	11.1	6.2	5.8	5.5

Note. Numbers represent the changes in bpm per stage. Mins = two minute stages, L= running on land treadmill, 95°F = running in ninety five degree water on aquatic treadmill, 104°F = running in one hundred four degree water on aquatic treadmill.

CHAPTER V

DISCUSSION

This study compared the physiological responses of apparently healthy college-aged individuals when running on an underwater and land-based treadmill at matched levels of intensity. The ideology of the study was inspired by Buck *et al* (2001), “which stated there are conflicting opinions about the differences between water and land based treadmill running.” In regards to this study, the underwater and land-based treadmill running produced significant differences for energy expenditure, oxygen consumption, and heart rate, with no significant differences in RPE. These findings are in conjunction with previous studies that have shown oxygen consumption decreases when running on an underwater treadmill compared to land-based treadmill running (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). Brubaker *et al* (2011) explains that with the lower oxygen consumption observed during the underwater treadmill trial is associated with a greater mechanical efficiency and reduced metabolic cost secondary to the buoyancy provided by hydrostatic pressure and different muscle groups being activated. Eliminating the weight bearing movements while underwater treadmill running likely causes the larger muscle groups of the lower extremities to not work as much, in comparison to the increased proportion of work done by the upper extremities (Wilder & Brennan, 1993). Consequently, the decrease of oxygen consumption in underwater treadmill running is possibly due to cardiovascular drift induced by the hot, humid

environment created in the underwater trials and prolonged exercise at sub-maximal intensity (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). In addition, there is a significant difference between heart rate responses produced between underwater and land-based treadmill running (Brubaker, Ozemek, Gonzalez, Wiley & Collins, 2011). Fujishima *et al* (2003) suggested that higher heart rates during water exercise could be the result of having a greater venous return, lower stroke volume, and higher cardiac output.

However, no significant differences were found when comparing the physiological responses of 95°F and 104°F. Surprisingly, no significant difference exists between water temperatures and heart rate responses. Previous studies have suggested no difference exists because of an increase in arterial blood volume, which results in a reflex increase in heart rate to combat an expected reduction in heart rate (Buck, McNaughton, Sherman, Bentley & Batterham, 2001). The Buck *et al* (2001) study further explained that the thermal stimulus to increase heart rate overpowers the effect of a centrally shifted blood volume and when the environment is hot, heart rate changes in parallel with the change in core body temperature. Therefore, in warmer water heart rate increases, which increases cardiac work for the same energy expenditure.

The current limitations of this study are the small (n=14) and homogeneous (healthy college individuals) sample size. Therefore, these findings cannot be generalized to populations other than healthy college-aged individuals; however, this population was intentionally recruited because limited data currently exists on healthy college-aged individuals and underwater treadmill running. Another limitation of this study was the correlation that running on an incline and running against water-jet velocities is 100%

compatible (Brubaker, Ozemek, Gonzalez, Wiley & Collins, 2011). Pilot test have determined equivalency between the two modalities, different biomechanical efficiency were used and these differences can increase the metabolic demands differently (Brubaker, Ozemek, Gonzalez, Wiley & Collins, 2011). Lastly, participant's body composition wasn't measured, which is important due to adipose tissue acting as an insulator.

Even though it wasn't the intent of this study, future research should further evaluate the biomechanical differences in locomotion during underwater and land-based treadmill running because the human eye detects differences between the two modalities (Brubaker, Ozemek, Gonzalez, Wiley & Collins, 2011). Additionally, it is suggested that future studies examine the effects that water devices have on physiological responses. Various water devices are used when aquatic exercising and investigating the different physiological responses that are produced when using different devices can help prescribe aquatic conditioning, therapeutic, and rehabilitation programs.

Conclusions

Due to the uniformity of all stages during these trials, data was compared for each stage of the trials. This data comparison is unique from any other data collection because of the warm water temperatures that were used and requiring participants to run during stage four. In comparison, participants in previous studies would walk or jog during this stage and the inconstancy in mechanical movement created incomparable data. In conclusion, due to a lack of significant differences between underwater treadmill running in 95°F and 104°F it is recommended that individuals exercise in a lower water

temperature. In addition, individuals' seeking a high-intensity exercise should run on a land-base treadmill, rather than, an underwater treadmill due to physiological responses being more intensified when exercising on land. Therefore, expansion of this study should include examining if different running motions while running on an underwater treadmill create different physiological responses.

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APPENDICES

APPENDIX A
INFORMED CONSENT FORM



Department of Sport Science and Wellness Education
College of Education
Akron, OH. 44325-5103
330-972-7738 Office
330-972-5293

PROTOCOL TITLE: THE CARDIOVASCULAR RESPONSES OF RUNNING ON AN UNDERWATER TREADMILL AT TWO DIFFERENT WATER TEMPERATURES COMPARED TO LAND BASED RUNNING

Informed Consent Form

DESCRIPTION: Fourteen subjects will take part in this research study in which you have been asked to volunteer. The study consists of comparing the effects of underwater treadmill jogging in 35 and 40-degree Celsius water to jogging outside of the pool on a regular treadmill. To evaluate the impact that temperature water has on aerobic fitness, your heart rate, rating of perceived exertion, oxygen consumption, and energy expenditure will be measured.

PROCEDURES: Forty-eight hours prior to beginning the research study, you will participate in a familiarization session. During this session your resting heart rate and blood pressure will be obtained along with your demographics, which include height, weight, and age. After this information has been recorded, you will be asked to complete a healthy history form and physical activity questionnaire. Completing these forms will provide insight on your health and physical activity levels. Additionally, you will be given a rating of perceived exertion scale, which is used to measure your fatigue level when exercising. All information that is collected will be confidential and will only be used to compare results of the study.

In order to produce results, you will be required to exercise during this study. You will complete three different trials on three different days – one trial on a landbased treadmill and two trials at different temperatures on an underwater treadmill. During all trials your heart rate, rating of perceived exertion, oxygen consumption, and energy expenditure will be recorded every minute. Each trial will last between 20-25 minutes and are described in the tables below.

Land-Based Treadmill Trial

Treadmill speed/ Incline	Duration of each stage
Warm up – treadmill off	5 min
3 mph / 0 incline	2 min
4.5 mph / 0 incline	2 min
6 mph / 0 incline	2 min
6.5 mph / 0 incline	2 min
6.5 mph / 1% incline	2 min
6.5 mph / 2% incline	2 min
6.5 mph / 4% incline	2 min
1.5 mph – cool down	Continue until heart rate is w/in 100 beats/min.

Underwater Treadmill Trials

The two underwater trials are identical except for the water temperature, which will be at 35°C and 40° C.

Warm up – treadmill off	5 min
3 mph / 0 jets resistance	2 min
4.5 mph / 0 jets resistance	2 min
6 mph / 0 jets resistance	2 min
6.5 mph / 0 jets resistance	2 min
6.5 mph / 30% jets resistance	2 min
6.5 mph / 40% jets resistance	2 min
6.5 mph / 50% jets resistance	2 min
1.5 mph – cool down	Continue until heart rate is w/in 100 beats/min.

Treadmill speed/ Jets resistance

Duration of each stage

RISK: The possible risks for this study are muscle soreness and strain, which are both common when performing any physical activity. To reduce the likelihood of any of these risks occurring to you, a proper warm-up and cool-down will be incorporated into each study session.

BENEFITS: The benefits of participating in this study are that you will gain further knowledge about how your body responds to exercising in different water temperature environments and how these results are comparable to exercising on a land-based treadmill. You will be able to incorporate this data into your regular exercise regimen. Additionally, incorporating aquatic exercise increases exercise adherence, which can increase your quality of life and delay the physiological effects of aging.

The investigator will answer any questions or concerns you may have at the phone number listed below. All information that is collected will be confidential and will be stored in a locked room in room 307E. Additionally, your participation in this study is entirely voluntary, and you may decline to enter this study or may withdraw from it at any time without jeopardy. The investigator may also terminate your participation in the study at any time.

Contact information:

Dana Kiger	(513) 519-4481	dlk66@zips.uakron.edu
Kelly Johnson	(541) 490-7025	kej20@zips.uakron.edu
Dr. Ron Otterstetter	(330) 972-7738	ro5@uakron.edu

The Institutional Review Board for the Protection of Human Subjects has reviewed and approved this study. For questions about your rights as a research subject you may contact the IRB at (330) 972-7666.

I understand that I am not receiving any compensation for participating in this study, other than individual data from the testing procedures. I consent to participate in this study:

Signature of Research Subject/Date

Witness/Date

APPENDIX B
PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

Being more active is very safe for most people. However, some people should check with their physician before they start becoming more physically active. Please complete this form as accurately and completely as possible.

PAR-Q FORM Please mark YES or No to the following: YES NO

Has your doctor ever said that you have a heart condition and recommended only medically supervised physical activity? ____ ____

Do you frequently have pains in your chest when you perform physical activity? ____ ____

Have you had chest pain when you were not doing physical activity? ____ ____

Have you had a stroke? ____ ____

Do you lose your balance due to dizziness or do you ever lose consciousness? ____ ____

Do you have a bone, joint or any other health problem that causes you pain or limitations that must be addressed when developing an exercise program (i.e. diabetes, osteoporosis, high blood pressure, high cholesterol, arthritis, etc.)? ____ ____

Are you pregnant now or have given birth within the last 6 months? ____ ____

Do you have asthma or exercise induced asthma? ____ ____

Do you have low blood sugar levels (hypoglycemia)? ____ ____

Do you have diabetes? ____ ____

Have you had a recent surgery? ____ ____

If you have marked YES to any of the above, please elaborate below:

Do you take any medications, either prescription or non-prescription, on a regular basis? Yes/No
What is the medication for?

How does this medication affect your ability to exercise or achieve your fitness goals?

Please note: If your health changes such that you could then answer YES to any of the above questions, tell your trainer/coach. Ask whether you should change your physical activity plan.

I have read, understood, and completed the questionnaire. Any questions I had were answered to my full satisfaction.

Name: _____

Date: _____

APPENDIX C

GODIN LEISURE TIME PHYSICAL ACTIVITY QUESTIONNAIRE

Godin Leisure Time Physical Activity Questionnaire

Considering a 7-Day Period (a week), how many times on the average do you do the following kinds of exercise for more than 15 minutes during your free time? (write on each line the approximate number)

Times Per Week

1. Strenuous Exercise _____
 - a. (Heart beats rapidly
 - b. Examples: running, jogging, hockey, football, soccer, squash, basketball, cross country skiing, judo, roller skating, vigorous swimming, vigorous long distance bicycling

2. Moderate Exercise _____
 - a. (Not Exhausting)
 - b. Examples: fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, alpine skiing, popular and folk dancing

3. Mild Exercise _____
 - a. (Minimal Effort)
 - b. Examples: yoga, archery, fishing from river bank, bowling, horseshoes, golf, snow-mobiling, easy walking

4. Considering a 7-Day period, during your leisure-time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?
 - a. Often
 - b. Sometimes
 - c. Never/Rarely

APPENDIX D
RPE CHART

The Borg Scale is a method to measure perceived exertion that personal trainers and strength coaches can use to determine a client's intensity level. Research has shown that accurately using a Rate of Perceived Exertion (RPE) scale correlates to training heart rate, percentage of VO2 max and breathing rate.

There are a number of RPE scales but the most common are the 15-point scale (6-20), and the 9-point scale (1-10).

15 Point Scale

- 6 - 20% effort
- 7 - 30% effort - Very, very light (Rest)
- 8 - 40% effort
- 9 - 50% effort - Very light - gentle walking
- 10 - 55% effort
- 11 - 60% effort - Fairly light
- 12 - 65% effort
- 13 - 70% effort - Somewhat hard - steady pace
- 14 - 75% effort
- 15 - 80% effort - Hard
- 16 - 85% effort
- 17 - 90% effort - Very hard
- 18 - 95% effort
- 19 - 100% effort - Very, very hard
- 20 - Exhaustion

APPENDIX E
HUMAN SUBJECTS APPROVAL FORM




Office of Research Services and Sponsored Programs

Akron, OH 44325-2102
(330) 972-7666 Office

NOTICE OF APPROVAL

August 3, 2012

Dana Kiger
101 Arms Blvd, Apt. 12
Niles, Ohio 44446

From: Sharon McWhorter, IRB Administrator 

Re: IRB Number 20120705 "Comparison of Physiological Responses between Aquatic and Land-Based Treadmill Jogging in College-Aged Individuals"

Thank you for submitting an IRB Application for Review of Research Involving Human Subjects for the referenced project. Your protocol represents minimal risk to subjects and has been approved under Expedited Categories 4 & 7.

Approval Date: August 3, 2012
Expiration Date: August 3, 2013
Continuation Application Due: July 19, 2013

In addition, the following is/are approved:

- Waiver of documentation of consent
- Waiver or alteration of consent
- Research involving children
- Research involving prisoners

Please adhere to the following IRB policies:

- IRB approval is given for not more than 12 months. If your project will be active for longer than one year, it is your responsibility to submit a continuation application prior to the expiration date. We request submission two weeks prior to expiration to insure sufficient time for review.
- A copy of the approved consent form must be submitted with any continuation application.
- If you plan to make any changes to the approved protocol you must submit a continuation application for change and it must be approved by the IRB before being implemented.
- Any adverse reactions/incidents must be reported immediately to the IRB.
- If this research is being conducted for a master's thesis or doctoral dissertation, you must file a copy of this letter with the thesis or dissertation.
- When your project terminates you must submit a Final Report Form in order to close your IRB file.

Additional information and all IRB forms can be accessed on the IRB web site at:
<http://www.uakron.edu/research/orssp/compliance/IRBHome.php>

Cc: Ronald Otterstetter – Advisor/Kelly Johnson – Co PI
Cc: Stephanie Woods – IRB Chair

Approved consent form/s enclosed