

2012

Comparison of RPE between ATM and SWW at 50%, 60%, and 70% HRR

Natalie J. Hughs

Eastern Washington University

Follow this and additional works at: <http://dc.ewu.edu/theses>



Part of the [Exercise Science Commons](#)

Recommended Citation

Hughs, Natalie J., "Comparison of RPE between ATM and SWW at 50%, 60%, and 70% HRR" (2012). *EWU Masters Thesis Collection*. 26.

<http://dc.ewu.edu/theses/26>

This Thesis is brought to you for free and open access by the Student Research and Creative Works at EWU Digital Commons. It has been accepted for inclusion in EWU Masters Thesis Collection by an authorized administrator of EWU Digital Commons. For more information, please contact jotto@ewu.edu.

COMPARISON OF RPE BETWEEN ATM AND SWW

AT 50%, 60%, AND 70% HRR

A Thesis

Presented To

Eastern Washington University

Cheney, Washington

In Partial Fulfillment of the Requirements

for the Degree

Master of Science in Physical Education

By

Natalie J. Hughs

Spring 2012

THESIS OF NATALIE HUGHS APPROVED BY

WENDY REPOVICH, GRADUATE STUDY COMMITTEE

DATE _____

WAFI ALKURDI, GRADUATE STUDY COMMITTEE

DATE _____

MASTER'S THESIS

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Eastern Washington University, I agree that the JFK Library shall make copies freely available for inspection. I further agree that copying of this project in whole or in part is allowable only for scholarly purposes. It is understood, however, that any copying or publication of this thesis for commercial purposes, or for financial gain, shall not be allowed without my written permission.

Signature _____

Date _____

Abstract

The purpose of this study was to compare RPE between ATM and SWW at 50%, 60%, and 70% HRR in a healthy adult population. Fifteen subjects (7 male, 8 female) performed both ATM and SWW at each pre-determined % HRR for a total of four days. The participants attended two familiarization sessions in which they practiced protocol and were taught the RPE scale. Each participant was scheduled for two testing sessions (one for the ATM and one for SWW) after the familiarization where they conducted the testing protocol of two minutes steady-state HR at each personalized % HRR. Within the final 10 seconds of the two minutes at each % HRR participants reported their RPE for the % HRR. These RPE values were analyzed for normality and for comparison using three paired t-tests. The two aquatic walking modes suggested that at 50%, 60%, and 70% HRR there was no significant difference. Results of this study suggest that RPE can be used to set intensity and workload interchangeably between ATM and SWW when walking at submaximal workloads of 50%, 60%, or 70% HRR.

Acknowledgements

This thesis research was supported by Aquabilt which provided the portable aquatic treadmill for the purposes of this study. I would like to thank Aquabilt, specifically Mr. Robert Adley, for donating the aquatic treadmill to Eastern Washington University after research was completed. With the aquatic treadmill having a home at the university, it will continue to benefit many different programs and people for years to come. Also, I would like to thank my advisor Wendy Repovich for inspiring me to begin a thesis based on a passion of mine, having faith in my self-motivation to complete it, but most importantly being the inspiration for returning to Eastern Washington University for my Master's degree. Without you I would have not accomplished such a monumental accomplishment. Thank you.

TABLE OF CONTENTS

Abstract.....	iv
Acknowledgments.....	v
Chapter 1: Introduction.....	1
Water walking.....	1
Statement of the problem.....	6
Limitations.....	6
Delimitations.....	7
Assumptions.....	8
Operational definitions.....	8
Hypothesis.....	9
Significance of study.....	9
Summary.....	9
Chapter 2: Literature Review.....	11
Introduction.....	11
Aquatic exercise.....	11
Heart rate responses and aquatic exercise.....	12
The rating of perceived exertion in aquatic exercise.....	16
Summary.....	20
Chapter 3: Methods.....	22
Introduction.....	22
Participants.....	22
Procedures.....	23

Equipment and Instrumentation.....	26
Statistical Analysis.....	27
Summary.....	27
Chapter 4: Results.....	29
Introduction.....	29
Data Analysis.....	29
Table 1.....	30
Summary.....	31
Chapter 5: Discussion.....	32
Introduction.....	32
Future Research.....	35
Summary.....	36
References.....	37
Appendices.....	44
Appendix A: Informed Consent.....	44
Appendix B: Borg RPE Scale.....	46
Vita.....	48

Chapter 1

Introduction

Water walking

Shallow, deep, and aquatic treadmill forms of running and walking may be beneficial to those who seek a form of low-impact aerobic exercise (Denning, Bressel, & Dolny, 2010). Aquatic running and walking has gained popularity in part from its ability to reduce strain and stress to the lower extremities, making it a well-accepted form of conditioning for injured athletes or those seeking cross-training (Bushman et al., 1997; Moening, Scheidt, Shepardson, & Davies, 1993). Water running has become a recovery method recommended by physical therapists and physicians for those who suffer from lower extremity musculoskeletal injuries (Melton-Rodgers, Hunter, Walter, & Harrison, 1996; Town & Bradley, 1989). There are many reasons aquatic running is chosen for therapy, mostly due to the buoyancy, resistance and the hydrostatic pressure that water provides the body. These properties of water result in perceived pain relief, swelling reduction, and reduced pressure in the lower extremities (Hinman, Heywood, & Day, 2007).

Aside from rehabilitation, aquatic running may also be used as a means of maintaining or improving aerobic fitness. Track athletes find aquatic running advantageous because it can be used as a form of cross-training to maintain aerobic fitness while reducing chances of injury (Chu & Rhodes, 2001; Nakazawa, Yano, & Miyashita, 1994; Town & Bradley, 1989). Track runners can reduce their repetitive high ground reaction forces while continuing to train the same muscles and motions with aquatic treadmill (ATM) running and shallow water running (SWR) (Nakazawa et al.).

Track runners and those receiving either rehabilitation or training programs are usually prescribed an exercise program that is designed using set workloads. There are two common methods used to measure workload and intensity when exercising. One method used to rate intensity is using heart rate (HR). As HR increases, the energy that is required to deliver oxygen to the muscles also increases because the heart must beat harder and faster to deliver an adequate amount of oxygen to organs and muscles (James, 2011). This method requires either pulse palpation or a HR monitor to monitor intensity. Although HR is a fairly accurate method for setting intensity and workload, HR palpation can be difficult during exercise and HR monitors are not accessible to all. Another method to set workload and intensity would be rating how difficult the work is perceived based on breathlessness and muscular fatigue. The talk test along with various scales to rate exertion levels are easily accessible and do not require equipment or palpation. A common method used in aquatics is using rating of perceived exertion (RPE), specifically the Borg 6-20 scale, where the participant is able to rate their perception of exertion based on the physiological responses that the body has at different workloads (Borg, 1982; Briggs, 2003).

Workload and intensity are the basis for developing any exercise prescription. When RPE is examined in aquatic exercise, it is still unknown if RPE correlates with HR in all forms of aquatic running. Knowing if there are differences in RPE between ATM and shallow water walking (SWW) by using HR will help aid in exercise prescription when transitioning from ATM to SWW. There are many similarities between the two water walking modalities, but it is important to be aware of the slight differences between the two and how differences may impact exercise prescription. An ATM has variable

speeds and is usually submersed in water to perform a type of SWR (Gleim & Nicholas, 1989). SWR is performed in depths from waist to chest level (Dowzer, Reilly, Cable, & Nevill, 1999). Similar muscles may be worked in ATM and SWR, but with the added frontal resistance water provides in SWR, differences in responses may occur at higher running speeds. Due to added frontal resistance, there have been mixed results in cardiorespiratory responses between SWR and ATM, but there are no studies specifically comparing the two exercise modalities (Dowzer et al., 1999; Gleim & Nicholas, 1989; Pohl & McNaughton, 2003; Town & Bradley, 1989).

Aquatic forms of walking and running can benefit those who want to reduce ground reaction forces by exercising in an environment that decreases impact to the lower extremities. As previously mentioned, aquatic exercise can benefit many different populations due to the pain-relief, reduced impact, and added resistance that aquatics provides. Different forms of aquatic walking and running may benefit populations differently. Some exercises may be too difficult on land, which make ATM or SWW a desired alternative compared to dry land exercise choices for obese and those with osteoarthritis (Denning et al., 2010). It has been suggested that ATM and treadmill (TM) training are equal in their ability to improve aerobic fitness and lose weight (Greene et al., 2009). For those beginning a program where lower-extremity pressure needs to be limited, simply moving to different depths can have an impact on the body's responses. While water walking, the amount of pressure placed on lower extremity joints decreases along with energy expenditure and the cardiorespiratory responses as the water level increases (Gleim & Nicholas, 1989). Although cardiorespiratory responses decrease when exercising in water, similar cardiorespiratory benefits can be experienced when

increasing workload while pressure on lower extremity joints remains constant (Denning et al., 2010).

ATM running or SWW/SWR is recommended for maintaining the kinematics of walking and running, which makes it a good choice for lower extremity rehabilitation or maintaining aerobic fitness. As the water level increases on the body, water resistance and metabolic demand increase. Water levels at the xiphoid process have been observed to elicit similar physiological responses between ATM and TM running (Shono et al., 2000). Although chest-depth water walking creates similar responses between ATM and TM running, this study compared SWW and ATM running at the xiphoid process which has not been explored. SWR resembles the kinematics, physiological responses and oxygen consumption response more closely to TM running than deep water running (DWR) (Dowzer et al., 1999). ATM and SWR are similar to TM running; however, physiological responses have been studied in ATM and SWR in few research studies, none of which compare the two responses (Alberton et al, 2011; Dowzer et al, 1999; Whitley & Schoene, 1987).

A common form of aquatic rehabilitation or cross-training is DWR. This form of exercise may be beneficial for those who are in the beginning stages of a lower extremity recovery as DWR has no impact with the pool floor. A buoyancy belt is most commonly worn to aid in floatation which contributes to deviations in kinematics and muscle recruitment from TM running (Moening et al., 1993). DWR may benefit a recovering athlete in maintenance of aerobic capacity (Chu & Rhodes, 2001) however, SWR has more similarities to TM running in kinematics and muscle recruitment (Silvers, Rutledge, & Dolny, 2007).

SWR resembles land running more closely than DWR due to the toe-off phase that SWW provides. This toe-off phase creates a running pattern and muscle activation similar to TM running when comparing to DWR, although ATM running remains the most closely related with TM running (Frangolias & Rhodes, 1995). ATM running and walking tends to mimic TM running more closely than SWW in part due to holding an upright posture as compared to a forward lean that is observed during SWW. This forward lean becomes more apparent as speed increases in SWW. ATM running does not include frontal resistance, and therefore the mechanics of ATM running are more similar to that of TM running than SWR. No studies to date have explored the similarities between ATM and SWW kinematics, physiological responses, or perceived responses. Although ATM running appears more closely related to TM running, the lack of accessibility of ATM's makes SWR a convenient comparable mode of exercise. Often times the two aquatic running methods appear similar, the added resistance with speed elevation in SWR may increase HR and RPE more rapid than ATM running (Denning, 2010). Regardless of the aquatic walking or running choice, HR raises linearly with maximal oxygen uptake (VO_{2max}) and RPE during water walking in both SWR and ATM running (McArdle, Katch, & Katch., 2001; Silvers et al, 2007; Shono et al., 2000). ATM running has been shown to elicit peak cardiorespiratory responses similar to TM running when immersed to xiphoid process (Silvers et al., 2007). When other methods of measurement of intensity vary, such as HR or VO_{2max} between land and water running or walking, RPE remains a common method to track workload in aquatics.

The RPE scale allows subjects to select an intensity number scaled to physiological sensations. Accurately determining RPE takes minimal training, which

makes the Borg RPE scale an easy choice to use as a guideline for monitoring the intensity of a workout (Dishman, 1994). RPE is most often used to track workload and HR during exercise. There are two scales used for the identification of the intensity level. The first scale created was Borg's RPE scale which consisted of numbers 6-20 to reflect the resting and maximum HR (HR_{max}); i.e, six reflecting sixty beats per minute (Borg, 1982; Dishman).

The Borg RPE scale is a well-known tool for assessing workload during exercise. ATM and SWW were researched in this study to compare if RPE can be used as a prescription equally between SWW and ATM at three different heart rate reserves (HRR's). With this knowledge, practitioners and trainers will be able to prescribe intensity for at-home workout programs, aiding further in rehabilitation or cross-training for that person.

Statement of the problem

This study was designed to assess if there is a significant difference between ATM and SWW based on HR responses and RPE.

Limitations

This study only consisted of physiological measurements (HR and RPE) while individuals water walked immersed to the xiphoid process, thus making this study applicable only to individuals exercising at this depth. The xiphoid process typically elicits responses similar to TM running and studies usually submerge subjects into the water at the xiphoid process for consistency (Barela, Stolf, & Duarte, 2006; Denning, 2010; Silvers et al., 2007). The xiphoid was measured at rest and marked with a piece of tape where the participant entered the water to this level while standing flat-footed and

maintained that level while SWW and ATM walking to the best of their ability. It was observed that as the speed of water walking increased, the water level fluctuated, most commonly immediately below the xiphoid process to assist in accurate HR chest to watch transmission.

Participants were limited to a height of about 5'5 due to the depth of the pool used for this study. Participants were limited to a height that allowed them to walk at a depth of the xiphoid process in the shallow end of the pool, which is four feet deep. During the SWW, subjects were asked to speed up after maintaining the assigned HR for two minutes after reaching the thirty second steady state. This enabled participants to maintain their HR at the given percentage of their calculated HRR. This proved to be a limitation due to the HR wrist watch fluctuations when changing directions while SWW across the pool. This was not a limitation for the ATM to a continuous stride and stationary position. The HR was monitored by the participant and researcher while the HR was measured in 5 seconds intervals with a chest strap transmitter to verify that % HRR was maintained during the two minutes.

Participants were not told what form of water walking that they should use, just that their HR should be elevated to the selected % HRR. Future studies should limit the type of water walking performed on both the SWW and ATM to add specificity to the RPE scale as it appeared to be easier for participants to raise and maintain their HR when using the high knees water walking method compared to a longer walking stride

Delimitations

A convenience sample of 15 healthy swimmers and community water walkers was selected to participate in both ATM running and SWW at three different HRR's as

determined by a power analysis. This population was solicited to decrease the learning curve and apprehension towards water for ATM because the participants should already be familiar with aquatic walking. The PAR-Q form was used to limit participants in this study to healthy adults. Any boxes that were marked YES on the PAR-Q form disqualified possible participants from the study. Measurements in this study were delimited to water levels at the xiphoid process based on previous studies (Denning, 2010; Shono et al., 2000; Silvers et al., 2007).

Assumptions

It was assumed that water temperature did not impact the study's results because the temperature was maintained within 27°-29°C difference on testing days. HR in water may be impacted depending on the water temperature, but staying within a 2°C range helped control for HR variability, therefore HR is assumed to have similar reactions on both days (Avellini, Shapiro, & Pandolf, 1983; Gleim & Nicholas, 1989; McArdle et al., 2001). It is also assumed that each participant understood the Borg RPE scale and correctly stated the perception of exertion for each % HRR.

Operational Definitions

HR is defined as beats per minute recorded by a Polar HR monitor RS800CX, recording HR in five seconds intervals for the two minute time periods. This HR monitor was chosen because it has the ability to upload exercise profiles with the recorded HR data to the computer after the tests were conducted (Polarusa.com). The HR monitor was used to assess if participants were maintaining the set workload.

The RPE was the rating given by the subject on the Borg 6-20 scale (Chen, Fan, & Moe, 2002). Subjects were taught how to accurately state their RPE through a

demonstration and practice at the initial informational session held prior to the study. The RPE values were used to assess perceived workload.

Hypothesis

The purpose of this study was to compare RPE in SWW and ATM running at 50%, 60%, and 70% HRR. The null hypotheses created based on the purpose of the study were: There will be no significant difference in RPE measured during ATM walking and SWW at the xiphoid process at any 50%, 60% or 70% HRR.

Significance of the study

ATMs have not been available to the general population except in clinical settings. Most ATM's are permanently placed in a rehabilitation facility and are not mobile. With the development of reasonably priced portable ATMs, it is likely they will become more readily available in a variety of recreational pools and therefore will be easily accessible to the general population. When a person wants to continue a training program using SWW, it would be important to know whether an exercise prescription is appropriate when comparing SWW to ATM walking. The results of this study might be used to assist athletic trainers and physical therapists in exercise prescription for SWW after using the ATM under supervision.

Summary

The RPE scale is commonly used in aquatics as an intensity prescription. Different populations' benefits from aquatic exercise, most of these populations are prescribed a set workload for the aquatic walking. If workload is prescribed on an ATM, it would be helpful to know if RPE can be used to prescribe workload interchangeably between ATM and SWW. When a training program based off an ATM is continued

using SWW, it would be important to know whether an exercise prescription using RPE is appropriate when comparing SWW.

Chapter 2

Literature Review

Introduction

The purpose of this study was to determine if RPE is similar between ATM and SWW. This chapter reviews the previous literature on SWR and SWW, DWR and ATM running physiology to gain insight into training and rehabilitation modalities. TM running physiology was reviewed to give a basis of what physiological effects to expect with ATM and SWW.

Aquatic Exercise

Water exercise provides an ideal environment for rehabilitation, training, and conditioning as it can maintain and increase aerobic fitness (McArdle et al., 2001). Water is approximately 800 times denser than air (Craig & Dvorak, 1966), which adds resistance during locomotion, compared to that of TMR. When submersed in water to the neck, the body weighs about 1/10 of its land weight. The buoyancy provided by the water makes aquatic walking an attractive form of conditioning for the elderly, injured, and obese (Chu & Rhodes, 2001; Melton-Rodgers et al., 1996). Combining the buoyancy with greater resistance may be an ideal combination for exercise prescription.

There are three different ways to mimic running form in an aquatic environment; DWR, SWR, and ATM running. DWR simulates running with no foot contact on the pool floor. This type of running is often aided by a flotation device to assist with keeping the head out of the water. DWR enables people to move lower extremities through a full range of motion with no impact to the skeletal system (Bushman et al., 1997). Deep water running consists of a slightly forward upright position with arms and legs following a

unilateral motion with closed hands from an elbow positioned at a 90° angle (Chu & Rhodes, 2001). Often times it is the first step to therapy for those with lower extremity injuries.

Shallow water walking is a common form of water exercise that limits impact on skeletal system while the feet strike the bottom of pool. Walking or running in water between ankle and neck height is considered SWW. To compare SWR, DWR, and ATM running, cadence is suggested to show the physiological impact of the various running modalities. The resistance of the water affects the leg turnover which differs between DWR and SWR because of the toe-off phase (Town & Bradley, 1989). Most commonly, participants are submerged to chest depth which increases the resistance against the lower extremities (Denning et al., 2010; Fujishima & Shimizu, 2003; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001; Silvers et al., 2007).

The ATM is the most recent innovation in aquatic exercise. Aquatic treadmill running is similar to SWR, however no forward movement is involved. Aquatic treadmills are used by therapists and those looking to cross-train because ATM running possesses all the physiological qualities of exercising in an aquatic environment along with the specificity of muscle movement in locomotion on land.

Heart rate responses and aquatic exercise.

Water provides buoyancy that can give balance to those who may not be able to achieve the same amount of success on land. Body weight is reduced in the water due to Archimedes' principle, which states that an object will experience buoyancy which is equal to the weight of the volume of water displaced. (Okuno, Caladas, & Chow, 1982). Immersion depths in water effect how much unloading of the body is happening.

Physiological responses, such as HR, RPE, and VO_{2max} are all impacted depending on the depth of immersion.

Immersion depths have impacts on the physiological adaptations that must be made during exercise in the water. Water immersion alone causes vast changes in the physiological responses of resting individuals immersed to the neck (Chu, Rhodes, Taunton, & Martin, 2002). Based on Farhi and Linnarsson's study (1977), immersion to the hip had a stroke volume of 78 mL/beat, the xiphoid at 110 mL/beat, and the chin-level at 120 mL/beat. The HR modifications appear to depend on immersion depths; as someone gets more submerged, the atrial stretch receptors cause an increase in SV and HR (Chu et al.). Although there has not been a difference shown in tidal volume between water immersions, the vital capacity has been observed to decrease during neck level immersion (Chu & Rhodes, 2001).

Exercising in an aquatic environment elicits different responses than land exercise. Depending on immersion depth, water temperature, and mode of exercise the physiologic responses can be impacted. Hydrostatic pressure, drag, and buoyancy are all variables that have impact shallow water and deep water exercise (Gleim & Nicholas, 1989). As a result the typical physiological variables used to measure aerobic capacity such as RPE, HR, and VO_{2max} are also impacted (Gleim & Nicholas, 1989).

When running in water of different depths, the hydrostatic pressure creates changes in the heart's activity. Results from past studies suggest that the relationship between the baroreceptor and Bainbridge reflexes are the reasons behind lower HR responses (Denning, 2010; McArdle et al., 2001; Pohl & McNaughton, 2003). Hydrostatic forces aid in the venous blood return which increases stroke volume, thus increasing

cardiac output and decreasing HR. At different water levels, the hydrostatic pressure on the thoracic cavity causes a redistribution of blood, which results in increased stroke volume, thus decreasing HR but keeping cardiac output the same (McArdle, Magel, Lesmes, & Pechar, 1976). This stroke volume increase may account for the lower HR that is observed during water running (Dowzer et al., 1999). Hydrostatic pressure also attributes to displacement of the blood, increasing lactate levels after exercise in the water. Lactate levels are reported to be greater during DWR and SWR than TMR. It is thought to be caused from the displacement of blood out of the muscles due to the external hydrostatic pressure that the water provides (Davidson & McNaughton, 2000).

Immersion depth impacts ground reaction forces for the lower extremities depending on the amount of buoyancy the water provides. According to Harrison, Dawson, Lanrence, & Blanskby (1992), water depth to the umbilicus reduces weight 57%, while being immersed to the 7th cervical vertebra reduces weight by 85%. At the immersion depth of the xiphoid process, the added energy expenditure required due to drag forces of moving in water is similar to the energy expenditure of that on land. When submersed in waist deep level of water, there is no significant difference between land and water when comparing VO_{2max} values at peak and at rest (Gleim & Nicholas, 1989; Whitley & Schoene, 1987). Differences may also be attributed to changes in muscle activation patterns (Silvers et al., 2007). Multiple studies have concluded that as depth increased, HR and VO_2 significantly lowered (Gleim & Nicholas, 1989; Pohl & McNaughton, 2003). In healthy adults, VO_2 is similar between ATM running and TMR when immersed to the xiphoid process (Denning et al., 2010). For rehabilitation, if the

drag forces created when walking or running in shallow water at the xiphoid process will elicit similar responses to ATM running at the same depth remain unexplored.

One of the physiological differences in aquatic exercise compared to land is that a significantly lower HR_{max} is observed when exercising immersed to the xiphoid than on land (Barbosa, Garrido & Bragada, 2007; Hall, Macdonald, Maddison, & O'Hare, 1998; Town & Bradley, 1989). This phenomenon may be related to the hydrostatic pressure and buoyancy which promotes higher stroke volume. Town and Bradley (1989) reported that HR_{max} was significantly different in both shallow and deep water running than on land, HR_{max} being reported lower in water. This HR_{max} was reported to differ from land by 16-26 beats in deep water running (Svedenhag & Segar, 1992; Town & Bradley, 1989) and about 21 beats difference in shallow water running. HR in SWR reached 94.1% according to Dowzer, Reilly, Cable, and Nevill (1999), and 88.6% of maximal values according to Town and Bradley (1989). These values are higher than DWR, which was found to be 90% of HR_{max} on land (Town & Bradley 1989). In all of these cases, HR was lower than TMR during maximal performance. These differences in HR may be attributed to hydrostatic pressure depending on buoyancy and level of immersion. Although different vital capacity is observed during SWW due to hydrostatic pressure on the chest, RPE's remain comparable at maximal effort, as decided by VO_{2max} (Heithold & Glass, 2002).

In submaximal effort intensities the HR appears to be reduced about 8-11 beats compared to land, with higher reductions observed in the lowest intensities. These HR adaptations may be due to increased venous return as a result of hydrostatic pressure, by decreased sympathetic nervous activity, or perhaps by lower muscular recruitment that

happens. HR's response might also be attributed to the decline in VO_{2max} (Chu et al., 2002). The HR changes observed in these studies suggest that HR responses are different in water than they are on land, thus making HR overwork or underwork participants who are prescribed an intensity based off of HR.

Depth of water may decrease HR through pressure distribution and temperature regulation which makes HR a possibly inaccurate measure of exertion levels. Other physiological indicators for intensity include oxygen consumption and lactate thresholds, which use measurement instruments that are not accessible to many. To monitor the intensity levels, the Borg scale seems most practical and appropriate to use (Borg, 1982).

The rating of perceived exertion in aquatic exercise.

The Borg scale of rating of perceived exertion is a common method of regulating exercise intensity while running or walking on a treadmill (Shono et al., 2000). RPE has also been used in aquatic exercise, significant correlations were found between RPE and intensity (Alberton et al., 2011) and HR (Shono et al., 2001). The RPE may be the best method for prescribing aquatic running because RPE rises linearly with VO_{2max} in DWR (Svendsen & Seger, 1992).

Variables in immersion and other changes that influence RPE have implications in prescription of exercise along with types of exercise in the water (water biking, swimming, aqua aerobics, etc.). Observing the changes in RPE from transition from land to water, and between different aquatic running styles has implications for changes in prescription of exercise from one activity to the next. RPE cannot always be translated to HR when exercising, especially in water activities. Land differences as compared to water may elicit different responses in RPE due to the hydrostatic pressure that water

provides, its reduction of impact it provides on the body, temperature, but most importantly depth of immersion.

When comparing RPE in aquatic exercise, immersion depths have an inverse relationship on RPE. As observed by Barbosa et al. (2007), a higher RPE was recorded when immersed to the hip as compared to a lower RPE when immersed to the breast. This difference in RPE can be contributed to increasing ground reaction forces due to less buoyancy.

The Aquatic Exercise Association (AEA) recommends the use of an intensity scale while performing aquatic exercise (Briggs, 2003). Silvers, Rutledge, and Dolny, (2007) examined oxygen consumption and RPE when water walking on a treadmill. Their research revealed HR and RPE as having a strong linear relationship. When exercise prescriptions are created, knowing that the relationship between HR and RPE is still linear will be able to verify that HR and RPE continue to rise and fall together regardless if exercise occurs in an aquatic environment or a land environment.

Perceived exertion levels with HR, oxygen consumption and blood lactate on submaximal swimming have been suggested to be highly correlated (Sherman & Michaud, 1997). High correlations were verified between all the variables, which led the authors to the conclusion that RPE can be used to measure the effort intensity in swimming. HR and RPE have also been compared to aerobic threshold and anaerobic threshold in submaximal intensities by Bellevue, Cisar, Cisar, Bowen, and Wilkinson (2009). The results of the study were similar to the previous findings, that there was no statistical difference in HR and RPE between aerobic threshold and anaerobic threshold. Indexes used for RPE have not been significantly different between land and water

walking in submaximal work, suggesting further that RPE is an acceptable form of measuring intensity in the water. During maximal work in deep water and on land no findings with significant differences between exercises in RPE have been shown either (Nakanishi, Kimura, & Yokoo, 1999). However, at depths other than the xiphoid process, RPE indexes and HR responses are observed to show a decrease when similar protocols are used, suggesting that immersion depths impact RPE significantly (Rutledge et al., 2007). Although these studies suggest that there is no difference in RPE between SWW and ATM walking or running at submaximal or maximal exercise have not been compared.

When comparing aquatic treadmill running and walking, the kinematics are well controlled to mimic the motions of land running. This form of exercise is valuable because it helps to control for many limitations, such as foot contact with the floor and similar mechanics and body positions. Aquatic treadmills provide a condition similar to running, which increases the validity of the research on aquatic environments' impact on the physiological systems. One research study compared RPE responses to different depths. They observed that RPE was greatest at 10 cm below the xiphoid as compared to the xiphoid and 10 cm above the xiphoid. These small changes in water depth demonstrate that depth influences energy expenditure, HR and RPE. Although the changes in water depth were relatively small, they must have attributed to changing the relationship between resistance and buoyancy (Alkurdi, Paul, Sadowski, & Dolny, 2010). This same study also took the idea of RPE overall and RPE of the lower extremity separately. Feelings of fatigue and perceived exertion may change RPE due to an increase or decrease in water depth. The lower extremities may be impacted from intensity

differently in water than the overall body. If overall RPE and RPE of the legs are significantly different from the intensity levels in water than the two should have been measured in all studies for validation. However, Alkurdi et al. (2010) did not find any significant differences between the RPE of the lower extremities or overall rating.

Submaximal intensities performed in chest deep water do not vary in the physiological responses depending on the temperature of the water. Lee, Toner, McArdle, Vrabas, & Pandolf (1997) conducted a comparative study for walking on a treadmill in the water at different water temperatures (20 and 26 degrees Celsius) both in low intensity and high intensities. RPE did not significantly change between the different temperatures and intensities. Adding to this theory, Masumoto Shono, Hotta, & Fujishima (2008) compared the responses between land and water walking at the same RPE. No significant differences were found in HR behavior or oxygen consumption in water temperatures of 31-33 degrees Celsius. The authors did not mention however what velocities the participants were working at, it was limited to a 13 on the Borg's scale. Therefore, it is still unknown if temperatures below 20C or above 33C will impact the RPE scale. There were have been no findings that thermoregulation is related to RPE. RPE instead appears to be related to the cardiopulmonary variables (Masumoto et al., 2007; Masumoto et al., 2008).

Intensity is a large marker of energy output. Through HR, the intensities of 60 and 90% maximal effort in water is significantly different from RPE's given for exercising at that 60 or 90% maximal effort on land. The intensities of 70 and 80% were observed to have lower values of RPE in the water environment as compared to that on land (Frangolias & Rhodes, 1995). This study did not take into consideration the lower HR

that is observed in water exercise, therefore this study's results should be taken cautiously when controlling for exercise prescription. HR_{max} is lower in the water as discussed previously, therefore the percentage of HR_{max} that this study used may be incorrect because the average lowering of HR in water was not deducted from HR_{max} (Killgore, 2003).

Summary

Although not all aspects of RPE have been explored in the aquatic environment, the recommendation and validation of the Borg scale gives a good estimate of total energy expenditure regardless what type of water exercise, depth, or temperature (Borg, 1982). However, the correct usage of this scale is important to gaining valid and reliable data. Many of the studies mentioned did not mention within their procedures about the familiarization that participants had with RPE. Along with this, how one tells their RPE can be based on many different physiological indicators, such as breathing rate, feeling of the heartbeat, or even sweat (Borg, 1982). The proper training on RPE is important to make the measuring instrument correct before performing any exercise activity in the water (Borg, 1982). To control for familiarization, the participants in these research studies should have demonstrated that they could do the same activity two separate days at the same HR and give the same RPE index as before. If participants do not, then it might be an indicator that they have not yet successfully understood the Borg RPE scale.

Other considerations when looking at studies comparing RPE in any environment should be controlling for duration. Duration and intensity are related, but taking into consideration the psychological aspect of reporting RPE, participants in studies may report RPE differently upon the expectation of a given duration. Overall, the responses of

RPE all use Borg's scale indexes which are associated with mechanisms that an aquatic environment changes and seem to be partly influenced by physiological and perhaps psychological mechanisms. Future studies need to be conducted to validate the use of the Borg scale in an aquatic environment due to its major physiological differences from land. The available research does show large suggestion, along with the AEA, that the RPE scales seem reliable and valid to measure perceived exertion levels in individuals (Alkurdi et al., 2010; Dolbow, Farley, Kim, & Caputo, 2008). Importance lies within teaching the RPE scale to participants and verifying the reproducibility of the use of the scale in each water activity. If a participant is well educated on RPE and can reproduce control situations of RPE, then they can be given a prescription of exercise based on the RPE scale.

Chapter 3

Methods

Introduction

The purpose of this study was to compare RPE at 50%, 60%, and 70% HRR between ATM and SWW in a sample of swimmers and community water aerobics members. The comparisons of HR and RPE in aquatic walking added to the limited research on aquatic walking. This chapter covers participant requirements, protocol and procedures on ATM and SWW, statistical analysis of RPE, and equipment / instrumentation.

Participants

A convenience sample of 15 community aqua aerobics members, swimmers and water walkers volunteered for this study. Similar study sample sizes range from 12 (Alberton et al., 2011) to 25 (Silvers et al., 2007). A power analysis from surveysystem.com, based off a similar study conducted by Hall and associates, revealed that 15 participants were needed for the current study with a p-value of .05 (Hall et al., 1998). Participants were above the age of 18 to give consent. Participants consisted of both males and females, but no attempt to have equal numbers of each was required because HR and RPE are not gender specific.

This population was chosen because of the applicability it has to rehabilitation patients and those who may be more inclined to choose aquatic rehab as their first choice of rehabilitation modalities. This choice of participants also reduced the time for familiarity prior to the tests because no participants had apprehension to exercise in the water because water walking was a familiar activity to the participants. Prior to selection,

all participants completed the PAR-Q assessment. Any answer selected other than "No" eliminated them from participation in this study.

Procedures

Prior to beginning the study, the human subjects' approval was obtained through the Eastern Washington University Institutional Review Board. Following IRB approval, participants were recruited from an informational flyer that was distributed to local aquatic centers. Interested volunteers were given a PAR-Q form to complete. Interested volunteers turned in the PAR-Q in a timely manner, and copies were then made, one being filed and the other for the participant. Those who turned in PAR-Q's and qualified for this study based on the acceptance criteria were allowed to participate in the study. Volunteers who have anything other than a "No" on the PAR-Q were not used for this study.

When 15 qualified people volunteered, they were given consent forms (Appendix B). These consent forms described the study and the requirements for participation, including location and times. The participants were informed that a total of four days were required for full participation (two days familiarization, one day ATM, and one day SWW). At the first scheduled session, consent forms were returned from the volunteer that met the acceptance criteria based on the PAR-Q. Participants were scheduled for the required four days for the study at 45 minute intervals, with the first day also consisting of a resting HR reading and receiving a completed consent form. The first 15 individuals were able and willing to participate; therefore advertising ceased after the sample size of 15 participants was achieved.

Participants were comfortable in an aquatic environment due to recruitment techniques (Alberton et al., 2011). Participants were instructed as part of the preparatory period to refrain from ingesting stimulants, to stay well hydrated, and to avoid intense exercise 24 hours prior to beginning the study (Alberton et al.). Participants were instructed to wear a bathing suit that does not create excessive drag and to wear that swimsuit for all four sessions. Aquatic shoes are not only a popular trend in SWW, but they are also needed to produce friction on the aquatic treadmill. Appropriately sized aquatic shoes were worn by all subjects during practice sessions and data collection.

When participants began the study, it was necessary to get a resting HR value. Participants were instructed to lie flat on their back for five minutes before resting HR was measured for the last minute of that five minute resting period. This value was considered the ambient HR, therefore 10 was subtracted from the recorded rate for a resting HR value. Rating of perceived exertion was taught and practiced on the first and second days of familiarization (Day, McGuigan, Brice, & Foster, 2004). The RPE was taught to participants from the instructions supplied for the Borg-RPE-Scale on the scale of 6-20 (See Appendix A) (Borg, 1998). The instructions were told to the participant before every session and a poster of the 6-20 scale was held in sight during all testings (See Appendix A). Participants were read the Borg RPE instructions and practiced reporting RPE when using the aquatic walking protocol. Both ATM and SWW were conducted on the first two familiarization sessions to practice RPE and protocols. The third day either SWW or ATM was randomly selected for the first day of data collection. The sessions consisted of the data collection from the aquatic walking protocol described below.

The day of testing, a Polar HR monitor (Vantage XL, Polar, Lake Success, New York) with chest strap was applied before entering the water. Prior to the warm-up, the HR monitor was turned on and began recording HR. Pool availability determined what form of exercise will occur on the first day of exercise (ATM or SWW). The RPE scale was placed in viewing distance of the participant throughout the entire study. The xiphoid process was located and marked with a piece of tape to give a visual indicator that the water level is at the xiphoid process. The participant was reminded of the RPE scale and how to use it before they entered the water.

Participants entered the water to the level of their xiphoid process for SWW, while the ATM (Model A-2000 from Aquabilt) was moved to a depth that matched the xiphoid process. An ample warm-up of four minutes followed the entry into the water, walking at a speed lower than their calculated 50% HRR (Hall et al., 1998). The warm up consisted of water walking in the same modality (ATM or SWW) that was being tested that day (Matthews & Airey, 2001; Town & Bradley, 1989).

After the four minute water walking warm-up, the aquatic walking protocol began. The participant was told what HR goal to obtain for the first two minutes at 50%, the next two minutes at 60%, and the final two minutes at 70% HRR. The participant slowly gained speed until the HR monitor matched the % HRR assigned for that participant's first two minutes. Once % HRR was achieved, it was held thirty seconds to achieve steady-state HR before recording HR for a two minute time period. The last ten seconds of each two minutes participants verbally reported their RPE. RPE was then recorded by the researcher. The HR was monitored through the HR watch during each testing session. Participants were told to either speed up or slow down to keep their HR at

% HRR \pm 5 bpm. They were also verbally reminded to keep the water level at the xiphoid when SWW (Matthews & Airey, 2001). Once the third % HRR was completed, the participants slowed their walking rate down until they felt cooled down, then they exited the pool and confirmed the scheduled time for the second day of testing. Participants knew the modality for the second test day but the walking speeds and protocol remained the same between test days.

Following the completion of the test, the HR monitor values along with given RPE was recorded in an excel spreadsheet. The four days for this study was within a two week time period to avoid HR response changes, conducted the same time of day both days, with a minimum of 24 hours between tests for complete HR recovery.

Equipment and Instrumentation

A water resistant chest strap HR monitors was used for this study. The HR monitor that was used in this study was a Polar HR monitor model: RS800CX (Lake Success, NY). This HR monitor is water resistant to 20 meters and stores the HR data for later download to a computer. The watch was worn by the participant during the test sessions so they can monitor their own HR so they are able to speed up or slow down to maintain the within five beats of their % HRR designated for that two minute session.

The Borg 6-20 RPE scale was used to determine participants' personal estimations of exertion levels. This scale was posted in viewing distance at all times during SWW and ATM walking (Alberton et al., 2011). This scale has been suggested to estimate exertion levels, whereas the HR monitor will estimate cardiopulmonary output (Matthews & Airey, 2001).

HRR was used as the dependent variable because it is the preferred method to more accurately prescribe exercise intensity (James, 2011). The more accurate formula of Gellish et al. (2007) ($206.9 - (0.67 \times \text{age})$) was used to determine age-predicted HR_{max} .

The aquatic treadmill that was used for this study was an Aquabilt pool treadmill (Model A-2000, Canton, CT). This treadmill is self-propelled, so participants had their hands on the provided handlebar when performing the submaximal ATM walking and were wearing aquatic shoes to provide the traction necessary to propel the treadmill belt.

Statistical Analysis

The information gathered from both RPE and HR was placed into SPSS Statistical Package 17.0 (Chicago, IL). The dependent variable that was measured was RPE, this variable was measured three times after two minutes of walking at each HRR % of 50%, 60%, and 70% on both the ATM and while SWW. Descriptive statistics of all variables were performed and reported as mean, standard deviation, and range. The dependent variable was assessed for a normal distribution. The three RPE values given in ATM walking and the three RPE values in SWW required an analysis of RPE using paired t-tests for each % HRR. The alpha level was set at $p < 0.05$ for all statistical assessment based on previous studies (Anderson, 2003; Matthews & Airey, 2001; Silvers, 2007).

Null Hypothesis: There will be no significant difference in RPE between ATM and SWW in a healthy population at 50%, 60%, or 70% HRR.

Summary

The purpose of this study was to compare RPE between ATM walking and SWW at 50%, 60%, and 70% HRR in a sample of active swimmers, water walkers, and water

aerobics members submersed to a water level at the xiphoid process. This chapter identified procedures for participant selection, equipment used, data collection and analysis. Looking for a significant difference in RPE between SWW and ATM walking will help aid in exercise prescription using water walking modalities.

Chapter 4

Results

Introduction

The purpose of this study is to explore the relationship between ATM and SWW at 50%, 60%, and 70% HRR when assessing RPE. This chapter reviews the statistical analysis on the comparison of RPE between ATM and SWW at the three different HRR's. This chapter also consists of data analysis on descriptive statistics and paired t-tests for all data input.

Data Analysis

Descriptive statistics were run on all variables and reported throughout this chapter. Three different paired-samples t-test were used to analyze the RPE values reported from participants between ATM and SWW at each % HRR. The participants of this study ranged from 18 years old to 73 years old, the mean age was 21. Of the 15 participants selected for the study, seven were male and eight were female.

Descriptive statistics of the data revealed that five of the six independent variables (ATM and SWW) were normally distributed measured on an interval scale. Measurements of RPE on a 6-20 scale were measured at 50%, 60%, and 70% HRR on both ATM and SWW from 15 participants. Standard deviation was greatest for the SWW at 50% HRR (1.870) and lowest for ATM walking at 60% HRR (1.163) as noted in Table 1. Standard deviations also reflect the ranges observed. Ranges were greatest for the 50% HRR in SWW (7), and lowest for SWW at 70% HRR and ATM walking at 60% HRR (4) (Table 1).

Table 1

Descriptive Statistics

<i>RPE (n = 15*)</i>	SWW		ATM	
	Mean	S. D.	Mean	S. D.
50% HRR	10.73	1.870	11.07	1.483
60% HRR	13.20	1.521	13.07	1.163
70% HRR	15.27	1.624	14.87	1.552

* $n = 15$; males = 7 females = 8.

To evaluate data for normal distribution, the Shapiro-Wilk test was conducted along with evaluation of skewness and kurtosis of the data. All data were evaluated and determined to be normally distributed ($p < 0.05$) for skewness and kurtosis. The SWW at 70% HRR was the only variable that resulted in a significantly different distribution from normal ($p < 0.05$) according to the Shapiro-Wilk test results. The Shapiro-Wilk reported all significance values exceeding 0.05, excluding SWW at 70% which resulted in a significance value less than 0.05 ($p = 0.013$). Evaluation that all data appears normally distributed began with box plots, skewness, and kurtosis analysis. To measure the probability that the scores displayed significant kurtosis or skewness, the values of each attribute were divided by their standard error. Analysis of skewness and kurtosis suggested that there was no significant difference ($p > 0.05$) from a normal distribution as none of the values exceeded ± 1.97 . Skewness and kurtosis appeared to be normally distributed for all variables, including the SWW at 70% HRR, although values were slightly more platykurtic (-1.49) than other % HRRs.

The Mann-Whitney test was used to verify the null hypothesis that there will be no significant difference between ATM and SWW at 70% HRR. This test was chosen for

the 70% HRR because SWW at 70% HRR was significantly different from a normal distribution according to the Shapiro-Wilk test for normality. The Mann-Whitney test was used for the SWW 70% non-parametric data. The null hypothesis was accepted ($p > 0.05$) according to the Mann-Whitney test ($U = 98.500$; $p = .553$). The paired samples t-test results suggest that there were no significant differences between SWW and ATM walking when comparing RPE at three different % HRRs.

A paired samples t-test was calculated on each HRR comparing the 50%, 60%, and 70% HRR RPE values for participants between ATM and SWW. The paired samples t-test revealed that the null hypothesis was accepted ($p > 0.05$) at all three % HRR. Thus, it appears that neither the SWW nor ATM walking have any significant difference between 50%, 60%, and 70% HRR RPE values. The results of this study suggest that one can use RPE as a prescription for exercise interchangeably between ATM and SWW.

Summary

The RPE data collected during this study was analyzed and assessed for a normal distribution and analyzed to reveal that the null hypothesis was accepted with $p > 0.05$. The results mentioned in this chapter suggest that the null hypothesis was accepted at all three % HRRs. To confirm the results that there was no significant difference SWW at 70% HRR, a follow up on the possible non-parametric data reported in the Shapiro-Wilk test was conducted. The Mann-Whitney test was run and supported the initial findings that there was no significant difference between the two water walking modalities.

Chapter 5

Discussion

Introduction

The purpose of this study was to determine if RPE was similar between ATM and SWW at 50%, 60%, and 70% HRR. This chapter provides a discussion of the results of the ATM and SWW at the three different % HRRs with respect to previous research in aquatic running. This chapter consists of a discussion on the results of this study in comparison to ATM and TM running studies, SWW and TM walking studies, and directions for further research.

Discussion

The null hypothesis that there would be no significant difference between ATM and SWW at 50%, 60%, or 70% HRR was supported by the results of this study. Results showed no significant difference between the three % HRRs ($p < 0.05$). The supports research to accept the use of RPE as a way to measure workload in an aquatic environment in a relatively healthy population of participants familiar with aquatic exercise.

The present study assessed the RPE responses between SWW and ATM walking. To draw similarities between all aquatic modalities, examining the similarities and differences between ATM and TM running along with SWW and DWR may help practitioners to prescribe intensity using RPE accurately. Studies that have compared TM to ATM use have used motorized treadmills, most with Flowmill, when comparing the physiological differences between the two (Masumoto et al., 2008; Shono et al., 2000; Shono et al., 2001; Silvers et al., 2007). One possible explanation given for the

similarities was that using the Flowmill allows both the walking and running action of the treadmill but also drag created by adjusting water flow with the jets (Masumoto et al.; Silvers et al.). Multiple studies have shown that the ATM is comparable to TM running during peak cardiorespiratory responses when submerged to the xiphoid process (Masumoto et al.; Shono et al., 2000; Silvers et al.). This study attributed the similar responses between land and water running to the drag forces imposed by the adjustable fluid resistance from the water jets. The added resistance opposed the effects of buoyancy, therefore creating the same cardiorespiratory responses as observed on land. The ATM used in the present study did not have any way to increase frontal water flow, which may impact cardiorespiratory responses differently than observed using ATMs with fluid resistance.

Since there was no manipulation of resistance with the ATM in the present study it is possible that the natural resistance created with the different intensities during SWW may be reflected in the RPE values. SWW appeared to be more challenging at the 70% HRR than ATM walking at the same % HRR. Interestingly, the SWW also appeared to be less challenging than the ATM at the 50% HRR. The added resistance of moving through water that opposes the effects of buoyancy observed in Silvers, Rutledge, and Dolny (2007) may be a cause of why SWW appeared to have a trend of increasing difficulty than self-propelled ATM.

Often times DWR is a precursor to the ATM when beginning an aquatic rehabilitation program for lower extremities. The progression from DWR to ATM or SWW involves foot contact with the pool floor or tread of the ATM. To examine the differences between the three water walking modalities, comparing submaximal

responses may provide insight for creating a prescription for workload using RPE in water walking modalities. Matthews and Airey (2001) reported greater RPE scores for DWR at a 60%, 70%, and 80% HRR than TM running. From this information, one may deduce that exercise prescription using RPE would not be appropriate when transferring from a TM exercise program to a DWR program. To date, no studies have compared SWW and DWR RPE submaximal responses. Results produced from the present study infer that RPE may be transferable from ATM to SWW, but not for DWR. Therefore, knowing that SWW holds more submaximal cardiorespiratory similarities to TM running, submaximal exercise prescription should begin with ATM or SWW, not DWR.

There is no physical reason other than no foot contact with the pool floor between DWR and SWW or ATM to choose DWR as the first mode of exercise for a rehabilitation program. For this reason, it may be more advantageous to begin a rehabilitation or exercise program using the ATM or SWW than using DWR. The results presented in this study demonstrated that RPE was not different between SWW and ATM walking at 50%, 60%, or 70% HRRs which suggests that one may prescribe workload from ATM to SWW interchangeably. For this reason, if exercise is at 50%, 60%, or 70% HRR then RPE may be used to identify workload based on the workload prescribed. Results of this study may be different when using a % HRR lower than 50%, suspecting that ATM walking would be perceived as easier than SWW. With this information, self-propelled ATM prescription might prove to be an advantageous first step for a rehabilitation program over both DWR and SWW.

When comparing HR_{max} between DWR, SWR, and TM running, it appears that SWW has a HR_{max} that closely relates to TM running when compared to DWR (Dowzer,

Reilly, Cable, and Neville, 1999). This difference between maximal cardiorespiratory responses may be a result of decreased buoyancy and increased resistance. One can infer from this information that using SWW rather than DWR would be a better choice when choosing a running mode that relates to land running. Knowing that SWW is more similar to TM running in terms of HR_{max} , provides support for the speedy progression from DWR into SWR for those who are cross training or water walking for lower extremity rehabilitation.

Implications of understanding aquatic rehabilitation, progression, and proper use and prescription of the RPE scale may help increase awareness of aquatic rehabilitation. Providing proper exercise prescription whether the prescription is for a track athlete looking to cross-train, persons looking for lower-extremity rehabilitation or anybody seeking ways to alleviate pressure on lower extremities will benefit from understanding the body's cardiorespiratory responses in an aquatic environment.

Recommendations for future research

While this study did not find any significant differences in RPE at 50%, 60%, or 70% HRR, many questions arose after results of the comparisons were analyzed. There were no significant differences between 50%, 60%, 70% different % HRRs, although it did appear that SWW was perceived to be more challenging than the ATM walking as speed increased when comparing mean RPE values. This presents several interesting questions. Although no significant differences were found, if a % HRR over 70% HRR was chosen for the mode of exercise it appears that there may be a significant difference between the two aquatic walking modalities when using a % HRR or RPE as workload. The data might also present significant differences between ATM and SWW at HRRs

that are lower than 50% HRR, where ATM might be at a significantly higher RPE at the same % HRR than SWW at slower speeds when comparing the trend of the mean values.

Summary

Water exercise provides an ideal environment for rehabilitation, training, and conditioning as it can maintain and increase aerobic fitness (McArdle et al., 2001). The purpose of this study was to examine if RPE is significantly different between ATM and SWW at submaximal HRRs. The results of the present study reflected the findings in previous literature with respect to RPE and workload. ATM and TM running studies were compared to this study along with SWW and DW walking studies, and recommendations for future research.

References

- Alkurdi, W., Paul, D. R., Sadowski, K., & Dolny, D. G. (2010). The effect of water depth on energy expenditure and perception of effort in female subjects while walking. *International Journal of Aquatic Research & Education, 4*(1), 49-60.
- Alberton, C. L., Antunes, A. H., Pinto, S. S., Tartaruga M. P., Silva, E. M., Cadore, E. L., and Krueel, L. F. M. (2011). Correlation between rating of perceived exertion and physiological variables during the execution of stationary running in water at different cadences. *Journal of Strength & Conditioning Research, 25*(1), 155-162.
- Anderson, E. W. (2003). *Selected physiologic responses in deep water running with endurance athletes* (master's thesis). Retrieved from: Eastern Washington University.
- Avellini, B. A., Shapiro, Y., & Pandolf, K. B. (1983). Cardio-respiratory physical training in water and on land. *European Journal of Applied Physiology & Occupational Physiology, 50*(2), 255-263.
- Barbosa, T. M., Garrido, M. F., & Bragada, J. (2007). Physiological adaptations to head-out aquatic exercises with different levels body immersion. *Journal of Strength & Conditioning Research, 21*(4), 1255-1259.
- Barela, A. M. F., Stolf, S. F., & Duarte, M. (2006). Biomechanical characteristics of adults walking in shallow water and on land. *Journal of Electromyography & Kinesiology, 16*(3), 250-256.
- Bellevue, O., Cisar, R., Cisar, C., Bowen, J., & Wilkinson, S. (2009). Evaluation and comparison of 300-yd and 500-yd shallow water run tests as predictors of aerobic power. *International Journal of Aquatic Research & Education, 3*(4), 378-397.

- Borg, G. G. (1982). Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in a new cycling strength test. *International Journal of Sports Medicine*, 3(3), 153-158.
- Briggs, P. (2003). The physically challenged. *Aquatic Exercise Association Aquatic Fitness Professional Manual. 1*, 320
- Bushman, B. A., Flynn, M. G., Andres, F. F., Lambert, C. P., Taylor, M. S., & Braun, W. A. (1997). Effect of a four week deep water run training on running performance. *Medicine & Science in Sports & Exercise*, 29, 694-699.
- Chen, M. J., Fan, X., & Moe, S. T. (2002). Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. *Journal of Sports Sciences*, 20(11), 873.
- Chu, K. S., Rhodes, E. C., Taunton, J. E., & Martin, A. D. (2002). Maximal physiological responses to deep-water and treadmill running in young and older women. *Journal of Aging & Physical Activity*, 10(3), 306-313.
- Chu, K. S. & Rhodes, E. C. (2001). Physiological and cardiovascular changes associated with deep water running in the young. *Sports Medicine*, 31(1), 33-46.
- Craig & Dvorak (1966). Thermal regulation during water immersion. *Journal of Applied Physiology*, 21, 1577-1585.
- Day, M. L., McGuigan, M. R., Brice, G. G., & Foster, C. C. (2004). Monitoring exercise intensity during resistance training using the session RPE scale. *Journal of Strength & Conditioning Research*, 18(2), 353-358.

- Davidson, K. K., & McNaughton, L. L. (2000). Deep water running training and road running training improve $\text{VO}_{2\text{max}}$ in untrained women. *Journal of Strength and Conditioning Research*, *14*(2), 191-195.
- Denning, M. M. (2010). *The Effects of Aquatic Exercise on Physiological and Biomechanical Responses* (master's thesis). Retrieved from: Ebscohost
- Denning, W. M., Bressel, E., & Dolny, D. (2010). Underwater treadmill exercise as a potential treatment for adults with osteoarthritis. *International Journal of Aquatic Research and Education*, *4*, 70-80.
- Dishman, R. K. (1994). Prescribing exercise intensity for healthy adults using perceived exertion. *Medicine & Science in Sports & Exercise*, *26*(9), 1087-1094.
- Dolbow, D. R., Farley, R. S., Kim, J. K., & Caputo, J. L. (2008). Oxygen consumption, heart rate, rating of perceived exertion, and systolic blood pressure with water treadmill walking. *Journal of Aging & Physical Activity*, *16*(1), 14-23.
- Dowzer, C. N., Reilly, T., Cable, N. T., & Nevill, A. (1999). Maximal physiological responses to deep and shallow water running. *Ergonomics*, *42*(2), 275-281.
doi:10.1080/001401399185649
- Farhi & Linnarsson. (1997). Cardiopulmonary readjustments during graded immersion in water at 35 degrees C. *Respiratory Physiology*, *30*(1-2), 35-50.
- Frangolias, D. D., and Rhodes, E. C. (1995). Maximal and ventilatory threshold responses to treadmill and water immersion running. *Medicine & Science in Sports & Exercise*, *27*, 1007-1013.
- Gellish, R. L., Goslin, B. R., Olson, R. E., McDonald, A., Russi, G. D., & Moudgil, V. K. (2007). *Medicine & Science in Sports & Exercise*. *39*(5), 822-9.

- Gleim, G. W., & Nicholas, J. A. (1989). Metabolic costs and heart rate responses to treadmill walking in water at different depths and temperatures. *American Journal of Sports Medicine*, *17*, 248–252.
- Greene, N. P., Lambert, B. S., Greene, E. S., Carbuhn, A. F., Green, J. S. & Crouse, S. F. (2009). Comparative efficacy of water and land treadmill training for overweight or obese adults. *Medicine & Science in Sports & Exercise*, *41*, 1808-1815.
- Hall, J., Macdonald, I. A., Maddison, P. J., & O'Hare, J. P. (1998). Cardiorespiratory responses to underwater treadmill walking in healthy females. *European Journal of Applied Physiology and Occupational Physiology*, *77*, 278-284.
- Harrison, J., Dawson, B., Lanrence, S., & Blanskby, B. (1992). Non-invasive and invasive determinations of the individual anaerobic threshold in competitive swimmers. *Journal of Swimming Research*, *8*, 11-17.
- Hinman, R. S., Heywood, S. E., & Day, A. R. (2007). Aquatic physical therapy for hip and knee osteoarthritis: Results of a single-blind randomized controlled trial. *Physical Therapy*, *87*, 32-43.
- Heithold, K. & Glass, S. (2002). Variations in heart rate and perception of effort during land and water aerobics in older women. *Journal of Exercise Physiology*, *5*(4), 22-28.
- James, G. (2011). ACSM's Guidelines for Exercise Testing and Prescription (8th edition). *Sport & Exercise Scientist*, *2*(8), 24.
- Killgore, G. L. (2003). *A biomechanical and physiological comparison of deep-water running styles*. Eugene, OR; United States: Kinesiology Publications, University of Oregon.

- Lee, D. T., Toner, M. M., McArdle, W. D., Vrabas, I. S., & Pandolf, K. B. (1997). Thermal and metabolic responses to cold-water immersion at knee, hip, and shoulder levels. *Journal of Applied Physiology*, *82*(5), 1523-1530.
- Matthews, M. & Airey, M. (2001). Comparison of ratings of perceived exertion during deep water running and treadmill running: Considerations in the prescription of exercise intensity. *Sports Medicine, Training and Rehabilitation*. *10*, 247-256.
- Masumoto, K., Shono, T., Hotta, N., & Fujishima, K. (2008). Muscle activation, cardiorespiratory response, and rating of perceived exertion in older subjects while walking in water and on dry land. *Journal of Electromyography & Kinesiology*, *18*(4), 581-590.
- Masumoto, K., Shono, T., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2007). Age-related differences in muscle activity, stride frequency and heart rate response during walking in water. *Journal of Electromyography & Kinesiology*, *17*(5), 596-604.
- McArdle, W. D., Katch, F. I., & Katch, V. L. (2001). *Exercise physiology: energy, nutrition, and human performance*. 5th ed. Philadelphia; United States: Lippincott Williams & Wilkins.
- McArdle, W. D., Magel, J. R., Lesmes, G. R., & Pechar, G. S. (1976). Metabolic and cardiovascular adjustment to work in air and water at 18.25, and 33°C. *Journal of Applied Human Sciences*. *40*, 85-90.
- Melton-Rogers, S., Hunter, G., Walter, J., & Harrison, P. (1996). Cardiorespiratory responses of patients with rheumatoid arthritis during bicycle riding and running in water. *Physical Therapy*, *76*(10), 1058-1065.

- Moening, D, Scheidt, A, Shepardson, L, & Davies, G. J. (1993). Biomechanical comparison of water running and treadmill running. *Isokinetics and Exercise Science*, 3(4), 1-9.
- Nakanishi, Y., Kimura, T., & Yokoo, Y. (1999). Physiological responses to maximal treadmill and deep water running in the young and the middle aged males. *Applied Human Science*, 18, 81-86.
- Nakazawa, K., Yano, H., & Miyashita, M. (1994). Ground reaction forces during walking in water. In M. Miyashita, Y. Mutoh, & A.B. Richardson (Eds.), *Medicine and Science in Aquatic Sports* (pp. 28–34). Basel: Karger.
- Okuno, E., Caldas, I. L., & Chow, C. (1982). *Física para Ciências Biológicas e Médicas* [Physics for biological and medical sciences]. São Paulo: Editora Harbra.
- Pohl, M. B. & McNaughton, L. R. (2003). The physiological responses to running and walking in water at different depths. *Research in Sports Medicine*, 11(2), 63.
- Sherman, N. W., & Michaud, T. J. (1997). VO_{2max} estimation in healthy adults using submaximal deep-water running. *Journal of Strength and Conditioning Research*, 11(2), 73-76
- Shono, T., Fujishima, K., Hotta, N., Ogaki, T., & Masumoto, K. (2001). Cardiorespiratory response to low-intensity walking in water and on land in elderly women. *Journal of Physiological Anthropology and Applied Human Science*, 20, 269-274.
- Shono, T., Fujishima, K., Hotta, N., Ogaki, T., Ueda, T., Otoki, K. et al. (2000). Physiological responses and RPE during underwater treadmill walking in women of

- middle and advanced age. *Journal of Physiological Anthropology and Applied Human Science*, 19, 195–200.
- Silvers, W. M., Rutledge, E. R., & Dolny, D. G. (2007). Peak cardiorespiratory responses during aquatic and land treadmill exercise. *Medicine & Science in Sports & Exercise*, 39, 969-975.
- Svedenhag & Segar. (1992). Running on land and in water: comparative exercise physiology. *Medicine & Science in Exercise & Sport*, 24(10), 1155-1160.
- Town, G. P., & Bradley, S. S. (1989). Maximal metabolic responses of deep and shallow water running in trained runners. *Medicine & Science in Exercise & Sport*. 23, 8-241.
- Whitley, J., & Schoene, L. (1987). Comparison of heart rate responses water walking versus treadmill walking. *Journal of Physical Therapy*, 67(10), 1501-1504.

Appendix A: Informed Consent

Consent Form

Comparison of RPE between SWW and ATM walking at 50%, 60%, and 70% HRR.

Principal Investigator: Natalie Hughs, Graduate Candidate for the MS in Exercise Science, EWU PEHR – njhughs@eagles.ewu.edu, (253) 332-2532. Responsible Project Investigator: Wendy Repovich, PEHR Department – wrepovich@ewu.edu, (509) 359-7960

Purpose Benefits

The purpose of this research is to compare rating of perceived exertion (RPE) responses to shallow water walking (SWW) and aquatic treadmill (ATM) walking exercising at 50%, 60%, and 70% of heart rate reserve (HRR), which will be determined prior to your tests. This study will add to the limited research on ATM and SWW along with drawing comparisons between RPE and heart rate (HR) between the two exercises. Your participation in this study is voluntary. This research may help to give more accurate exercise prescriptions when moving from ATM walking to SWW. In addition, this research will assist the Principal Investigator in satisfying requirements for a Masters Degree in Exercise Science.

Procedures

To participate in this study you must be relatively healthy. To determine that status you will complete a PAR-Q health assessment form and must have a score of 0. You will be required to attend two days of familiarization for both ATM and SWW along with two days of research, one for ATM and one for SWW. These sessions will be approximately 30 minutes each, must be within a two-week period, and must have at least 24 hours separating each session. You must wear a form fitting swimsuit, along with the provided water shoes and a heart rate monitor during all sessions. Blood pressure will be taken prior to exercise every test day. RPE will be taught during the first two familiarization sessions. The first day you will get your resting heart rate taken and practice the both the ATM and SWW protocol after learning RPE. The second day you will practice RPE and the both protocols. We will determine your speed for the tests based on HR values from your 50%, 60%, or 70% of HRR during these sessions. The last two days will consist of either the ATM or SWW test. We want the two sessions to be at the same depth in the water so we will mark your breastbone with tape before entering the pool. Once in the water we will adjust either where the treadmill is located or where you are doing the SWW based on that mark. You will warm up for four-minutes after entering the pool. Following the warm-up, you will begin walking at the speed we have determined will raise your HR to the 50% HRR. You will continue to walk at that speed for three minutes when you will verbally report your RPE. You will repeat three minutes at each HRR (50%, 60%, and 70%) reporting the RPE until all three HRRs are completed. An optional cool-down is allowed after completion of the submaximal testing. Your participation is voluntary and you may drop from the study at any time.

Appendix A: Informed Consent

Consent Form**A comparison of RPE between SWW and ATM walking at 50%, 60% and 70% HRR.****Risk, Stress or Discomfort**

This study consists of submaximal aquatic walking. Because you are experienced in water exercise, there should be no stress or discomfort during any session. A heart rate chest strap transmitter will be worn during the exercise sessions underneath appropriate swim attire, which you may not have worn before so you may experience some discomfort since it must be worn tight enough to transmit the HR.

Other Information

The information gathered from the research, such as age, all heart rate, and all RPE values will be given to anyone whose name is not identified above. You are expected to give truthful information on the PAR-Q form. You are able to withdraw from this study at any time without penalty. You may receive extra credit, if applicable, if you complete all four sessions of this study as a thank you for participation.

 Signature of Principal Investigator

 Date
Subjects Statement

The study described above has been explained to me, and I voluntarily consent to participate in this, research activity. I have had many opportunities to ask questions. I understand that by signing this form I am not waiving my legal rights. I understand that I will receive a signed copy of this form.

 Signature of Participant

 Date

If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protections Administrator (rgalm@ewu.edu; 509-359-6567).

Appendix B: Instructions to the Borg-RPE-Scale

During the work we want you to rate your perception of exertion, i.e. how heavy and strenuous the exercise feels to you and how tired you are. The perception of exertion is mainly felt as strain and fatigue in your muscles and as breathlessness or aches in chest.

Use this scale from 6 to 20, where 6 means “No exertion at all” and 20 means “Maximal exertion.”

- 9 Very light. As for a healthy person taking a short walk at his or her own pace.
- 13 Somewhat hard. It still feels OK to continue
- 15 It is hard and tiring, but continuing is not terribly difficult.
- 17 Very hard. It is very strenuous. You can still go on, but you really have to push yourself and you are very tired.
- 19 An extremely strenuous level. For most people this is the most strenuous exercise they have ever experienced.

Try to appraise your feeling of exertion and fatigue as spontaneously and as honestly as possible, without thinking about what the actual physical load is. Try not to underestimate, nor to overestimate. It is your own feeling of effort and exertion that is important, not how it compares to other people's. Look at the scale and the expressions and then give a number. You can equally well use even and odd numbers.

Any questions?

Appendix B: Borg 6-20 RPE Scale

<u>Rating of perceived exertion</u>	
6	No exertion at all
7	
8	Extremely light
9	
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

VITA

Author: Natalie J. Hughs

Place of Birth: Renton, Washington

Undergraduate Schools Attended: Green River Community College,
Eastern Washington University

Degrees Awarded: Bachelor of Science, 2010, Eastern Washington University

Honors and Awards: Graduate Assistantship, Physical Education Department, 2011-
2012, Eastern Washington University

Professional
Experience: Internship, Bellevue PRO Sports Club, Bellevue, Washington,
2010