CARDIOVASCULAR SYSTEM RESPONSE TO THERAPEUTIC WATER TREADMILL WALKING IN OLDER ADULTS

by

David Roger Dolbow

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Date of Final Defense

Jennifer L. Caputo

Dr. Jennifer L. Caputo, Committee Chair

Richard S. Farley

Dr. Richard S. Farley, Committee Member

Dr. Jwa K. Kim, Committee Member

Dianne Bartley

Dr. Dianne A. R. Bartley, HPERS Department Chair

Dr. Abdul S. Rao, Dean of Graduate Studies

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Because older adults have a greater propensity toward musculoskeletal problems, aquatic exercise is a valuable modality for rehabilitation and physical training. However, little research has been completed concerning the effects of therapeutic water walking on the cardiovascular system of older persons. Therefore, the purpose of this study was to examine the cardiovascular responses to slow, medium, and fast water treadmill walking on older adults. Healthy adults (n=20) between 55 and 64 years of age were tested in a therapeutic pool. Comparisons of cardiovascular responses to water treadmill walking in 92°F (33°C) water with land treadmill walking at 70°F (21°C) ambient temperature were completed. Water depth was at the superior aspect of the iliac crest (waist level) and treadmill speeds were at 2.0 mph, 2.5 mph, and 3.0 mph for both water and land treadmills. Following land and water treadmill acclimation, all participants performed five-minute bouts of exercise at each speed. Oxygen consumption (VO_2), heart rate (HR), systolic blood pressure (SBP), and rating of perceived exertion (RPE) were measured during each exercise bout. The conclusions of this study indicate that VO_2, HR, and RPE measures statistically increased with each speed increase during both land and water treadmill walking. BP statistically increased with each speed increase during water treadmill walking but not land treadmill walking. Likewise, VO_2, HR, SBP, and RPE measures were statistically higher during therapeutic water treadmill walking compared to land treadmill walking at 2.5 mph and 3.0 mph.

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CHAPTER I

INTRODUCTION

Aquatic exercise is a popular mode of physical conditioning. This popularity may be attributed to the effects of water buoyancy, resistance, and water temperature (Napoletan, 1993). The buoyancy characteristic reduces stress on joints while water resistance provides a means of muscular strengthening in a supported environment. Also, when water temperature is above 90°F (32°C), an analgesic effect results (Craig, 1996). These characteristics provide an excellent medium for rehabilitation and physical training programs (Craig, 1996; DeMaere, Ruby, & Swann, 1997; Mayo, 2000; Napoletan, 1993; Town & Bradley, 1990; Wilder, Brennan, & Scholte, 1993). This is especially useful for older adults because of the disproportionate number of musculoskeletal problems in this subgroup compared to the general population (Takeshima, Masatoshi, Kobayashi, Tanaka, & Pollock, 1997). The potential importance of aquatic exercise is magnified when considering older adults are the fastest growing segment of the United States population and the median age continues to increase within the United States and the world (Longley, 2003).

Because the number of individuals over 55 years of age in the United States will double by 2030, chronic disease and physical limitations that generally accompany aging will become an increasing concern for healthcare professionals (Powers & Howley, 2004).

With an increased susceptibility to injuries and musculoskeletal problems, older adults may benefit from water exercise which is less stressful to joints. The unique properties of water exercise have been credited with improving muscular and cardiovascular fitness, reducing musculoskeletal stress, reducing pain, increasing flexibility, improving ambulation stability, and enhancing psychological wellness (Alexander, Butcher, & MacDonald, 2001; Byrne, Craig, & Wilmore, 1996; Lord, Mitchell, & Williams, 1993; Whitlach & Adema, 1996). However, water exercise also introduces hydrostatic pressure, which can alter the cardiovascular responses to exercise (Arborelius, Dalldin, & Lundgren, 1972). During water immersion, hydrostatic pressure causes movement of blood volume from the periphery to the thorax creating increases in stroke volume (SV) and cardiac output (Q). Heart rate (HR) remains the same or decreases and systolic blood pressure (SBP) remains the same or increases depending on the ratio of Q to vascular resistance. These effects may have an even greater impact on older adults when combined with the natural decline in cardiovascular efficiency associated with aging (Brooks, Fahey, & White, 1996). Thus, it is important to explore the cardiovascular response to walking in warm water with older adults.

The cardiovascular components of SV, Q, oxygen consumption (VO_2), SBP, and HR during water walking/jogging at neck level without floor contact is impacted by the redistribution of blood from the periphery to the thorax and the non-use of anti-gravity musculature (Arborelias et al., 1972; Derion et al., 1992; Farhi & Linnarsson, 1977). A consensus of research indicates that VO_2 and HR measures are lower during water treadmill walking/running at neck level than land treadmill walking/running at similar speeds and at peak intensities. A major reason for the decreased VO_2 is the non-use of antigravity musculature due to the non-weight bearing status of the exercise. The primary reason for low HR measures is the redistribution of blood from the periphery to the thorax area resulting in increased SV and Q. RPE is higher during water walking/running at neck level than running on a land treadmill at sub-maximal levels of VO_2. Nevertheless, at maximal levels of VO_2, there is no difference in RPE.

When contact with the pool floor is introduced by walking at lesser depths, water level becomes a key factor in determining the cardiovascular response. The level of physical effort is affected by water resistance and water buoyancy and how these factors impact the cardiovascular system during walking at different levels of immersion (Takeshima et al., 1997). Results from studies concerning the cardiovascular response to walking on the pool floor indicate that when the depth of water immersion is lower and weight bearing is introduced, VO_2 and HR measures increase and become similar to those during walking out of water with the most similar being at waist level for young adults and axilla level for older adults (Takeshima et al.). Also, RPE scores are similar for water and land walking at these water depths (Takeshima et al.).

Water treadmill walking introduces the impact of a moving floor surface in the water. Walking on a water treadmill alters the cardiovascular response by eliminating the frontal resistance of the water because the body is no longer moving through the water in a forward direction, but rather walking in a stationary manner as the treadmill floor moves (Gleim & Nicholas, 1989).

At lower levels of water walking, ankle to waist, VO_2 and HR are higher during water treadmill walking than land treadmill walking (Gleim & Nicholas, 1989). This is because the buoyancy of the water at these levels is not great enough to compensate for the added energy needed to overcome the resistance that the water produces against the legs as they are moved through the water. There is also agreement that HR increases as water temperature increases and RPE is higher while walking on a treadmill in water than on land. Research also indicates that once treadmill speed is increased to the point where walking gives way to running, the body floats more between foot strikes which alters the activity to the point that VO_2 and HR relationships between water and land exercise are altered (Gleim & Nicholas; Napoletan & Hicks, 1995).

While information does exist concerning the impact of water immersion at rest, during water walking/running at neck level without bearing weight, walking on the pool floor at different depths, and walking on a water treadmill, the great majority of these studies were on young, healthy adults. There is a lack of information concerning the effect of walking in warm water at different walking speeds on the cardiovascular system of older adults. If older adults are to optimally and safely utilize the modality of therapeutic pool exercise for rehabilitation or physical fitness, it is important to understand the impact of this activity mode on the cardiovascular system of older adults.

Purpose

To examine the effects of treadmill walking in water at 92°F (33°C) at slow (2.0 mph), medium (2.5 mph), and fast (3.0 mph) walking speeds on the cardiovascular response of adults between the ages of 55 years and 64 years. The independent variables are 1) walking condition with two levels (therapeutic water treadmill and land treadmill), and 2) walking speed with three levels (2.0 mph, 2.5 mph, and 3.0 mph).

There are four dependent variables including VO_2, HR, SBP, and RPE. Even though RPE is not in reality a cardiovascular effect, but rather a perceived exertion by the participant consisting of ordinal as opposed to ratio data, it was included as a dependent variable.

Hypotheses

1. The water walking condition will have a statistically higher VO_2 than the land walking condition.
2. The VO_2 will statistically increase with each increase in speed.
3. There will be a statistically significant interaction between walking condition and speed on VO_2.
4. The water walking condition will have a statistically higher HR than the land walking condition.
5. The HR will statistically increase with each increase in speed.
6. There will be a statistically significant interaction between walking condition and speed on HR.
7. The water walking condition will have a statistically higher RPE than the land walking condition.
8. The RPE will statistically increase with each increase in speed.
9. There will be a statistically significant interaction between walking condition and speed on RPE.
10. The water walking condition will have a statistically higher SBP than the land walking condition.
11. The SBP will statistically increase with each increase in speed.

12. There will be a statistically significant interaction between walking condition and speed on SBP.

Assumptions

1. Participants did not have any cardiovascular or musculoskeletal conditions that affected the results of the study.

Delimitations

1. Participants were volunteers employed at the Tennessee Valley Healthcare System.
2. All participants were between 55 years and 64 years of age.
3. Participants were free from cardiovascular problems that would interfere with the testing procedures.
4. Participants were free from musculoskeletal problems that would interfere with testing procedures.

Definition of Terms

1. Buoyancy – the upward force exerted on objects in liquid (American Red Cross, 1996).
2. Hydrostatic pressure – compression that water exerts on an immersed body (Sova, 1992).
3. Weight bearing – the downward force that gravity exerts on an object (DeMaere et al. 1997). Weight bearing is also defined as the weight placed on the feet/legs while standing (Wikipedia, 2004).
4. Neck level water walking/running – walking/running while immersed in deep water with a floatation device that allows an individual to remain at neck level. The downward force of gravity is negated by water buoyancy (Davidson &

McNaughton, 2000).

5. Water treadmill – a specialized treadmill with the ability to be operational while submerged in water (Gleim & Nicholas, 1989).

Significance of Study

Warm water exercise is a valuable tool for the rehabilitation and physical training of older adults. However, in order for exercise in this medium to be prescribed safely and successfully, the effects of exercise in warm water on the cardiovascular system of older adults must be understood. Few studies have been completed on this topic. Therefore, this study provided information that may benefit healthcare professionals concerning prescription of warm water exercise for older adults.

CHAPTER II

REVIEW OF LITERATURE

This chapter contains a review of the literature on older adults, injuries and health problems associated with older adults, and the benefits of water exercise for this population. The effect of water exercise on the cardiovascular system of younger adults will also be reviewed. The impact of water immersion on the cardiovascular system at rest, during water walking and running at neck level, walking on the pool floor at various depths of immersion, and walking and running on a water treadmill at different levels of immersion will all be summarized. The cardiovascular review will begin with a focus of the effect of water immersion on SV and Q, followed by emphasis on the effects of water immersion on VO_2, HR, and RPE. SBP will also be discussed when data are available. This chapter ends with an overall summary including a statement of the purpose and the significance of the study.

Older Adults

The median age of the worlds' population is increasing due to a decline in fertility and a 20 year increase in the average life span during the latter half of the twentieth century (Longley, 2003). Because fertility was greatly elevated during the two decades after World War II (the baby boom), there is a high number and percentage of older adults in the current population (Longley). In 2000, the worldwide population of persons 65 years of age or older was estimated to be 420 million, an increase of 9.5 million from

1999. Between 2000 and 2030, it is projected that the population of persons 65 years of age or older will increase to between 550 and 973 million (Longley).

The estimated average age of the United States population increased from 28 years in 1970 to 35.3 years in 2000. The most rapid increase in size of any age group over the past decade occurred in the 45 to 54 year age group. This age group increased by 49% or by 37.7 million persons between 1990 and 2000, largely due to the baby boom group entering into this age level (Longley, 2003). If this trend continues, in 2010, the group with the largest growth will be the 55 and 64 year old group. In 2000, there were 24,274,684 persons in the United States between the ages of 55 years and 64 years. This constitutes 8.6% of the United States population. The percentage of persons in the United States that are over 55 years of age was 21% in 2000. Both the number of persons 55 years or older and the percentage of persons 55 years of age or older are expected to have the highest rate of change over the next two decades (United States Census Bureau, 2000).

The number of individuals over 55 years of age in the United States will double by 2030 and the number of adults specifically between the ages of 55 years to 64 years is expected to have the greatest increase over the next two decades. As a result, the special challenges of chronic disease and physical limitations that accompany aging will become an increasing concern for healthcare professionals (Powers & Howley, 2004).

Injuries and Reduced Health

As a person ages, most systems of the body become less efficient, resulting in an increased risk of disease and injury. Aging characteristics include decreased reserve capacity of organ systems, which is most apparent during periods of maximal exertion or stress, decreased internal homeostatic control such as blunting of the thermoregulatory system, decline in baroreceptor sensitivity, decreased ability to adapt in response to different environments causing vulnerability to hypothermia and hyperthermia with changing temperatures, and orthostatic hypotension with change of position and decreased capacity to respond to stressors such as exertion, fever, and anemia (American College of Sports Medicine [ACSM], 1998; Powers & Howley, 2004; Shepard, 1997).

The aging process is associated with many cardiovascular specific changes. There is a progressive decrease in maximal exercise HR, a decrease in maximal cardiac output of 20%-30% by age 65, an approximate 1% per year decline in VO_2 maximum from the ages of 25 years to 75 years, and a progressive increase in diastolic and systolic BP (ACSM, 1998). Aging also produces a gradual decrease in early diastolic filling of the heart chambers with a greater reliance on late filling, a reduction of cardiac myocytes with hypertrophy of the remaining heart tissue, and decreased baroreceptive sensitivity (ACSM). These changes may contribute to the increase in SBP observed with aging and, in turn, create a greater susceptibility to tachycardia, fibrillation, congestive heart failure, hypertension, and orthostatic hypotension (ACSM).

Along with reduced efficiency of the major systems of the body, older individuals are more susceptible to a wide range of injuries (especially related to falls) and chronic conditions. In 2001, approximately 2.7 million older adults were treated for nonfatal injuries in hospital emergency departments (Centers for Disease Control and Prevention, 2003). Musculoskeletal problems have a nearly linear relationship with advancing years of adulthood with osteoarthritis being most common. Osteoarthritis is considered to be universal among males and females by the age of 65 years (Trombly, 1995).

With the decreased efficiency of the cardiovascular system and increased susceptibility to injuries and musculoskeletal problems with advancing age, older individuals may benefit from an exercise medium that is safer and less taxing on joints. Water exercise is one mode of exercise that is beneficial in helping to deal with these issues.

Benefits of Water Exercise

Although older people are fully able to reap physical and psychological benefits from physical activity programs, many are limited in participation in traditional land-based exercise due to the physical problems that accompany older age. Heyneman and Premo (1992) outlined a water-based exercise program that provides the benefits of land-based exercise without stress or strain to arthritic joints. The buoyancy and supportive effects of the water allows individuals to have increased freedom of movement with reduced discomfort. Kendrick, Binkley, McGettigan, and Ruoti (2002) demonstrated an increase in the muscular strength of males and females over 65 years of age through water exercise while Park et al. (2003) demonstrated the ability of obese women to increase both muscular strength and aerobic fitness through a water exercise program. Suomi and Collier (2003) found that older adults that participated in water exercise had an increased ability to perform activities of daily living while Douris et al. (2003) and Maginnis, Privett, Raskas, and Newton (1999) provided support for the idea that the balance of older adults can be improved through water exercise. Watanabe, Takeshima, Okada, and Inomata (2000) found elderly persons who participated in water activities had a reduced state of anxiety.

Water exercise has been shown to increase muscular strength, aerobic fitness, mobility, and the ability of older adults to perform ADL's while providing a less stressful environment for exercise. However, the unique properties of the water environment may alter the response of the cardiovascular system. The impact of water immersion on the cardiovascular system is presented in the following section.

Cardiovascular Impact of Water Immersion at Rest

The buoyancy and hydrostatic forces on a person immersed in water alter the functioning of the cardiovascular system. The following is a review of the available information on how SV, Q, HR, and SBP are affected by water immersion during rest.

Stroke volume.

Stroke volume is the amount of blood pumped out of the left ventricle per heart beat (Powers & Howley, 2004). Arborelias et al. (1972) studied 10 men, 20 years to 31 years of age, immersed to chin level in 95°F (35°C) water. The hydrostatic pressure exerted on the body by the water caused a shift in blood volume from the periphery to the thorax. This shift produces an increased diastolic filling of the heart, which, in turn, produces a greater SV. Farhi and Linnarsson (1977) studied the effects of being immersed in water at different levels on the cardiopulmonary system. It was observed that SV increased with the level of immersion. Mean stroke volume was measured at 78 ml/beat while submerged to hip level, 110 ml/beat at xiphoid level, and 120 ml/beat at chin level. Weston, O'Hare, Evans, and Corrall (1987) found similar results at chin level in 9 men and 7 women (mean age = 34 years) with a 50% increase in stroke volume during water immersion in temperatures between 93°F (34°C) and 96°F (35.5°C). From the literature, it is apparent that stroke volume increases with water immersion. While the increase in central blood volume with water immersion increases SV, it has either no impact or the opposite impact on HR.

Heart rate.

Resting HR measures of young men immersed to chin level in 95°F (35°C) water were found to be similar to those on land (Arborelias et al., 1972). However, Farhi and Linnarsson (1977) found that HR decreased with hip and xiphoid levels of immersion, but then increased when immersion was to chin level. Farhi and Linnarsson noted the increased Q and SBP during immersion caused a reflexive action initiated by the baroreceptors that caused HR to decrease at lower levels of submersion. However, at the highest level of immersion (chin), the atrial stretch receptors became dominant over the baroreceptors and caused an increase in HR.

Other researchers using xiphoid level of immersion in water found no change in HR measures in young adults (Craig & Dvorak, 1968) or a decrease in HR in older adults (Derion et al., 1992). Even though there are some discrepancies concerning HR responses to water immersion, it is generally accepted that HR responses remain the same or decrease slightly with water immersion in young adults (Derion et al., 1992; Hall, Bisson, & O'Hare, 1990). Unlike the small changes that occur with HR during water immersion, Q undergoes a significant change.

Cardiac output.

Q is the product of SV and HR over a defined period of time. Thus, when SV is increased and HR is constant or near constant during water immersion, cardiac output will increase (Farhi & Linnarsson, 1977; McArdle, Katch, & Katch, 1996). The increased SV during water immersion results from the central distribution of blood volume and resulting increased diastolic filling of the ventricles. The increased Q has been shown to be as great as 34% (Hall et al., 1990). Arborelius et al. (1972) found a 32% increase in cardiac output during water immersion. While Q, HR, VO_2, and SV have been well researched, fewer researchers that have measured the effects of water immersion on SBP. Following is a review of the available information.

Systolic blood pressure.

There is a paucity of research literature on the effects of water immersion on SBP. Weston et al. (1987) studied the hemodynamic changes in young men during immersion in water at temperatures between 93°F (34°C) and 96°F (35.5°C) and found no significant differences in SBP from those on land. The researchers speculated that because a 50% increase in SV was observed, there must also be a reduction in peripheral resistance. This was concluded because peripheral resistance directly affects SV by making it either harder for blood to pass through the vessel (greater resistance) or allowing blood to pass through with less restriction (less resistance). In a study of 10 young men it was observed that intra-arterial systolic blood pressure was 10 mmHg higher during chin level immersion in water than on land (Arborelias et al., 1972). Although SBP was increased, it was lower than the hydrostatic pressure increase of 15 mmHg induced by the water (Arborelias et al.). From these studies it can be surmised that there is no significant effect of water immersion at rest on systolic blood pressure.

During water immersion, SV and Q increase due to hydrostatic pressure and movement of blood volume from the periphery to the thorax. HR remains the same or decreases and SBP remains the same or increases depending on the ratio of Q to vascular resistance. However, SBP remains below the hydrostatic pressure level. The cardiovascular response while water walking/running at neck level is reviewed in the following section.

Cardiovascular Impact of Water Walking/Running at Neck Level

Water walking/running at neck level (usually requiring a floatation device), eliminates the stress of gravity by removing ground contact. For this reason, aquatic exercise has been widely used in athletic and rehabilitation centers over the last decade (Quinn, Sedory, & Fisher, 1994). The decrease in weight bearing removes impact stress and creates changes in the cardiovascular responses and perceived exertion during exercise. The following section presents a review of the literature concerning changes in VO_2, HR, and RPE during water walking/running at neck level.

Volume of oxygen consumption.

Butts, Tucker, and Smith (1991) observed lower oxygen cost during neck level water running at 84°F (29°C) than during land treadmill running in 12 female high school cross country runners. The researchers speculated that due to the buoyancy of the body in water, less work is required by antigravity muscles to maintain body posture. Butts, Tucker, and Smith also suggested that the cooling effects of the water resulting in less thermoregulatory demand, may have helped reduce the amount of energy needed during the activity.

Butts, Tucker, and Greening (1991), as well as Brown, Chiwood, Beason, and McLemore (1997) found similar responses in HR and VO_2 in males and females, 20 years to 23 years of age during neck level water running and land treadmill running. The water temperatures in these studies were 84°F (29°C) and 86°F (30°C), respectively. Both males and females had lower $VO_{2\ max}$ values during water running. The reasons cited by Butts, Tucker, and Greening (1991) and Brown et al. for the lower $VO_{2\ max}$ values included a lower metabolic response due to the non-activity of antigravity muscles and a lower HR due to the central shift in blood volume, which resulted in an increased SV and Q. Bishop, Frazier, Smith, and Jacobs (1989) studied 7 trained runners running in 82°F (28°C) water at neck level and on a land treadmill at self-selected paces. The VO_2 measures were statistically higher during land treadmill running, again supporting a decreased metabolic response to the water exercise.

Quinn et al. (1994) studied the effectiveness of using water running to improve or maintain VO_2 levels. Novice water exercisers ran in neck level water at 77°F (25°C) and on a land treadmill during a 4-6 week training program. In the end, the average $VO_{2\ max}$ value of water exercise group participants decreased by 7%. The researchers concluded that neck level water running was not a sufficient training method to improve or maintain VO_2 levels. In contrast, Davidson and McNaughton (2000) found increases in $VO_{2\ max}$ when comparing VO_2 measures of initially low fitness level untrained women during neck level water running and road running. In the study, the VO_2 measures in both groups significantly increased over 4 weeks of training. Water temperatures ranged from 71.5° F (22° C) to 77° F (25° C). Davidson and McNaughton concluded that both forms of exercise were adequate to significantly improve the cardiovascular fitness level of untrained women. The reason for the different outcomes of the two studies is unexplained.

Town and Bradley (1990) tested collegiate cross country runners during neck level water running. Unlike in other studies, these runners did not use water floatation devices to assist buoyancy. Although the difference was not as great as when floatation devices were used, there was still a statistically lower VO_2 for neck level water running as compared to running on a land treadmill. The reason for the higher VO_2 levels during water running without a floatation device as compared to using a floatation device is that it requires greater physical effort to maintain a body at surface level without a floatation device.

Although there are some conflicting results, the majority of researchers provide evidence that water running at neck level results in a lower VO_2 than running on a land treadmill. The decreased use of antigravity musculature and the decreased thermoregulatory demand, contributed to the lower metabolic cost of neck level water running. The following section explores reduced HR during water running at neck level immersion.

Heart rate.

With reduced VO_2 measures during neck level water running, it is logical to also expect lower HR measures due to the redistribution of blood from the periphery to the thorax and the reduced load on the muscular system. Brown et al. (1997) tested 24 volunteer college students who walked/jogged in 86°F (30°C) water at neck level and on a land treadmill. None of the participants were trained athletes. Using a matched cadence method for determining intensity, HR measures were found to be 12 bpm lower during water treadmill walking/jogging for males and 20 bpm lower during water walking/jogging for females. Butts, Tucker, and Greening (1991) also found that healthy adult women (mean age 21.9 years) had HR averages 11 bpm lower while walking/running in water at neck level than they did while walking/running at similar speeds on a land treadmill. The men participating in the study (mean age 20.6 years) had a 10 bpm lower HR walking/running on a water treadmill as compared to similar speeds on a land treadmill. The water temperature was 84°F (29°C) and 86°F (30°C) for men and women, respectively. These findings are in agreement with observations of Brown et al. (1997) in that water walking/running had lower HR measures than land treadmill walking/running, but differ in the fact that there was no significant difference between males and females. This may be due to the fact that Brown et al. went to greater lengths to match the treadmill speed with the water running cadence, throughout the testing procedures.

HR measures were also found to be lower during neck level water running in 84°F (29°C) water as compared to land treadmill running in male and female high school and college cross country runners at similar speeds (Butts, Tucker, & Smith, 1991; Town, & Bradley, 1990). However, at self-selected paces, HR measures were not significantly different between water and land treadmill running even though VO_2 measures were found to be lower in water running at neck level (Bishop et al., 1989). Svedenhag and Seger (1992) tested 10 young men (mean age 26 years), who were trained runners at four different sub-maximal levels and found that HR measures during water running at neck level were lower than those of land treadmill runners at each level of VO_2.

Mercer and Jensen (1998) tested 15 men (mean age 24.3 years) and 13 women (mean age 21 years) at various levels of sub-maximal VO_2 in water, submerged at neck level, and on a land treadmill. At the same VO_2 level, there was no statistical difference in HR between water and land. This finding differs from the results of Svedenhag and Seger (1992) who found lower HRs at the same VO_2 levels in water running at neck level. A possible explanation for the difference in the two studies is that there was a

3.5°F water temperature difference with Svedenhag and Seger using 77°F (25°C) water while Mercer and Jensen used 80.5°F (27°C) water. Because HR generally increases with temperature, the variation in temperature between the studies could explain the varying HR findings.

As is the case with VO_2, it is apparent that water running at neck level elicits lower HR values than running on a land treadmill. This is due to redistribution of blood from the periphery to the thorax area with resulting increased SV and Q and the non-use of antigravity musculature. The HR measures at selected VO_2 sub-maximal levels and self-selected paces are not as clear with researchers finding different results. Water temperature may also have played a role in the different results in these studies. While VO_2 and HR measures during walking/running at neck level differ similarly relative to land treadmill walking/running, RPE values indicate a different trend.

Rating of perceived exertion.

Research on trained and untrained adults, as well as high school cross country runners indicates that at peak exercise there is no difference between RPE of running in water at neck level and running on a land treadmill (Bishop et al. 1989; Butts, Tucker, & Smith, 1991; Mercer & Jensen, 1998).

However, at submaximal intensities, Michaud, Rodriguez-Zagas, Andres, Flynn, and Lambert (1995) found that at equivalent VO_2 levels, RPE in water treadmill running was higher. Svedenhag and Seger (1992) tested RPE of 10 men that were trained runners in neck level water at 77°F (25°C) at four different sub-maximal HR intensities. Svedenhag and Seger reported that even though HR measures of water exercisers were lower than the land treadmill runners at each level of VO_2, RPE was higher in water runners.

RPE is generally higher during water running at neck level than running on a land treadmill at sub-maximal levels of VO_2. However, at maximal levels of VO_2 there is no difference in RPE.

Summary of cardiovascular impact of water walking/jogging at neck level.

The majority of researchers indicate that VO_2 and HR measures are lower during water treadmill walking/running at neck level than land treadmill walking/running at similar speeds and at peak measures. The primary reason for the decreased VO_2 is the decreased use of antigravity musculature due to the non-weight bearing status of the exercise. The primary reason for low HR measures is the distribution of blood from the periphery to the thorax area resulting in increased SV and Q. RPE is higher during water walking/running at neck level than running on a land treadmill at sub-maximal levels of VO_2. However, at maximal levels of VO_2 there is no difference in RPE.

Walking on the pool floor provides the effects of partial weight bearing, water buoyancy, and water resistance. The degree to which each of these properties is experienced depends on the water level. Accordingly, cardiovascular demands are also altered.

Cardiovascular Response to Walking on the Pool Floor at Various Depths

Walking on the pool floor requires participants to move forward through the water as opposed to stationary walking/running in neck level water without touching the floor. This action introduces frontal resistance to the body. This causes distortion of posture and walking mechanics, which may, in turn, affect the cardiovascular response to the activity.

Volume of oxygen consumption.

Town and Bradley (1990) compared the metabolic responses to water running at neck level without wearing a floatation device to assist buoyancy in shallow water running at 1.3 meters using the pool floor and running on a land treadmill. The runners were college cross country athletes who were also trained water runners. Running on a land treadmill produced a greater VO_2 than running in water. Running at a depth of 1.3 meters with partial weight bearing produced greater VO_2 measures than neck level running, but less than running on a land treadmill. Town and Bradley suggested that the greater results for lower depth running were due to the addition of partial weight bearing during testing. Runners at 1.3 meters depth recorded VO_2 values equal to 90.3% of the land treadmill runners while deep water runners averaged 88.6% of land treadmill VO_2 values.

Takeshima et al. (1997) used RPE as a self-selected intensity guide while testing 15 elderly adults (age 61 years to 80 years) walking on the floor at axilla level in 86°F (30°C) water and on land (indoor track). They categorized the intensities as <13 RPE (easy), 13 RPE (moderate) and >13 RPE (hard). Using RPE as a guide for intensity for each individual, the researchers found that VO_2 measures were statistically higher for land walking at the hard intensity only and that at a given intensity, the VO_2-HR relationship was similar to walking on land. The researchers also calculated VO_2 values at HRs of 90 bpm, 120 bpm, and 150 bpm and found no significant difference during walking in water or on land. The researchers presented the idea that older adults may differ from younger adults with respect to the central distribution of blood volume during water immersion. This could explain why the older participants in the study had the same VO_2-HR relationship responses at all levels of exertion (easy, moderate, and hard), both on land and in water. According to the research literature, as the amount of weight supported increases, VO_2 measures increase. However, when comparing VO_2 and HR levels, it appears that the VO_2-HR relationship in water is similar to the relationship on land.

Heart rate.

HR measures were compared during neck level water walking/jogging (not using the pool floor) and xiphoid level water walking/running (using the pool floor) by Robertson, Brewster, and Factora (2001). These researchers tested 42 young, healthy adults with the intensity level being maintained at an RPE of 15. Xiphoid depth walking/jogging had an average HR of 10 bpm higher than walking/jogging at neck level water. Average HR measures were 155 bpm for xiphoid level and 145 bpm for the neck level. These results lend support to the idea that as weight bearing increases so does HR. Whitley and Schoene (1987) compared water walking at waist depth in water temperatures between 77°F (25°C) and 80.5°F (27°C) with land treadmill walking in 12 female college students. There were statistically higher HR measures in water walking at waist depth than walking on a land treadmill.

Takeshima et al. (1997) using RPE to determine intensity (<13 RPE [easy], 13 RPE [moderate] and >13 RPE [hard]) found similar HR measures in 15 elderly adults during walking on the pool floor at axilla level in 86°F (30°C) water and land walking (indoor track), at easy, moderate, and hard intensities. This was true even though peak

HR measures were statistically higher for land walking at the hard intensity than walking in a pool at axilla level.

As weight bearing increases, so does HR. Also, at waist level immersion for young adults and axilla level immersion for older adults, HR measures are similar during walking in water and on land. The similarity in HR at different water levels indicates that the cardiovascular system in older adults reacts differently than the cardiovascular system in younger people and that water depth needs to be greater for older people to achieve the same HR as during land walking. The limited data on RPE during walking with partial weight bearing is reviewed in the following section.

Rating of perceived exertion.

Takeshima et al. (1997) tested elderly participants walking on the pool floor at axilla level and walking on land (indoor track) at three similar paces as monitored by elapsed time, HR, and RPE of each lap. The mean RPE scores were 9, 13, and 15 in water and on land. There were no statistical differences in the mean RPE scores found among the three speeds tested between the land and water conditions. Robertson et al. (2001) found that when 42 young adults were tested at the same RPE (15), while walking on a pool floor at xiphoid water level and in water at neck level (not touching the pool floor), the HR measures were 10 bpm higher at xiphoid level. Overall, walking on the pool floor at various levels of water depth produces similar RPE scores as walking on a land treadmill.

Summary of cardiovascular responses to walking on the pool floor at various depths.

Data from studies concerning the cardiovascular response to walking on the pool floor indicate that when the depth of water immersion is lower and weight bearing is introduced, VO_2 and HR measures increase and become similar to those during walking out of water with the most similar being at waist level for young adults and axilla level for older adults. Also, RPE scores are similar for water and land treadmill walking. Following is a review of the body of research available concerning the comparison of walking on a water treadmill and walking on a land treadmill. Water treadmill walking introduces the impact of a moving floor surface in the water.

Comparing Water Treadmill Walking and Land Treadmill Walking

While walking in water using the floor to propel forward, frontal resistance is created as the body moves through the water. However, when walking on a water treadmill, the floor moves and the participant walks on the moving floor without traveling forward in the water. Walking on a moving floor reduces the frontal resistance of the activity and allows the participant to walk in a more natural upright posture as compared to the frontal leaning posture of walking on the pool floor and alters the cardiovascular responses to the activity.

Volume of oxygen consumption.

Gleim and Nicholas (1989) measured the metabolic responses of 6 men and 5 women (mean age 27.5 years), to walking on a treadmill in water at different depths and temperatures. VO_2 was lowest during land treadmill walking, was greater with water walking at ankle depth, and greater still at knee depth. There was no change in VO_2 between knee and mid-thigh depth and VO_2 actually dropped from mid-thigh to waist depth, but was still higher than walking on a land treadmill. Water treadmill walking at waist level produced higher VO_2 values than walking on a land treadmill at speeds between 2 mph and 5 mph. The researchers concluded that increasing water depth from ankle to waist level increases the work of walking on a water treadmill beginning with speeds of 2.0 mph. Gleim and Nicholas further suggested that for depths of waist level and below, water buoyancy is limited and cannot sufficiently counter the increased work of moving the legs against water resistance. Thus, VO_2 is higher compared to land treadmill walking. At waist level and at speeds greater than 5 mph, VO_2 was similar between walking on a water treadmill and land treadmill. Gleim and Nicholas theorized that this might be because of the advent of jogging and the associated floating phenomenon. However, the sides of the underwater treadmill in this study did not allow visualization of the participants feet thus it was not possible to determine the speed at which participants began to jog.

Hall, MacDonald, Maddison, and O'Hare (1998) studied the cardiovascular responses of 8 women (mean age 30.3 years), during walking on a treadmill immersed in water at chest depth and walking on a land treadmill. The researchers also tested the effects of two separate water temperatures 82°F (28°C) and 97°F (36°C). The researchers found that VO_2 and HR increased linearly with increasing speed both in water and on land. At 2.0 mph, VO_2 was similar in and out of water. At 2.8 mph and 3.4 mph, VO_2 was significantly higher in water treadmill exercise as opposed to exercise on the land treadmill. Water temperature did not affect VO_2 measures. The researchers concluded that walking in chest deep water at 2.5 mph or above requires greater energy expenditure than walking at the same speeds on a land treadmill. The fast walking speed during this test was determined by a pilot test conducted by Hall et al. (1998). Results from the pilot study provided evidence that the fastest walking speed possible in water was 3.4 mph. Beyond this speed, participants ran.

Byrne et al. (1996) compared the effects of walking on a water treadmill in 90-92°F (32-33°C) temperatures on 20 adults (age 21 to 30 years). Water depth in this study ranged from mid-abdominal to mid-sternum because of variations in height of the participants and the constant water level. Tests were conducted at speeds of 2.0 mph and 3.0 mph. Water treadmill walking elicited greater Q, SV, and VO_2 at both speeds.

Napoletan and Hicks (1995) examined the cardiovascular responses to water treadmill walking at 2.0 mph and treadmill running at 3.5 mph at depths of mid-thigh and chest of 9 adults between the ages of 22 years to 31 years (5 females and 4 males). Walking on a water treadmill at 2.0 mph, VO_2 was statistically higher at both depths than on a land treadmill and water walking at mid-thigh produced a statistically higher VO_2 than at chest level. The researchers suggested that at mid-thigh level, buoyancy effects were not able to match the effects of water resistance on VO_2. However, when the speed increased to 3.5 mph and the participants were running and not walking, VO_2 was only higher in water at mid-thigh level while at chest level, the VO_2 was similar to that of land treadmill running.

Shono et al. (2000) studied the cardiovascular responses of 20 females between 52 years and 64 years of age while walking on a treadmill in 86.5°F (30.3°C) water at xiphoid level. Each participant walked for 4 minutes at four progressively increasing speeds with a one minute rest between bouts. The speeds were .75 mph, 1.1 mph, 1.5 mph, and 1.88 mph, respectively. VO_2 increased exponentially as walking speed increased. There was also a statistical significant linear relationship between VO_2 and HR.

Generally at lower levels of water walking, ankle to waist, VO_2 is higher during water treadmill walking than land treadmill walking. This is because the buoyancy of the water at these levels is not great enough to compensate for the added energy needed to overcome the resistance that the water produces against the legs as they move through the water. Water treadmill walking at waist level produces higher VO_2 values than land treadmill walking between speeds of 2 mph and 5 mph in young adults. These comparisons in VO_2 between water and land treadmill walking are consistent until the activity switches from walking to jogging or running. When walking turns into running, VO_2 on a water treadmill decreases due to the floating phenomenon. The floating phenomenon occurs when more time is spent floating between foot strikes due to the combination of water resistance and buoyancy. Water resistance does not allow leg movements to keep up with treadmill speed while the buoyancy allows the person to float between foot strikes reducing workload. VO_2 increases exponentially as speed increases while walking on a water treadmill at xiphoid level. There is also a linear relationship between VO_2 and HR in adults between 52 years and 64 years of age as speed increases during water walking at xiphoid level. Following is a review of literature comparing the impact of water treadmill walking and land treadmill walking on HR, with a focus on the effects of water depth and temperature.

Heart rate.

Gleim and Nicholas (1989) measured the HR response to walking on a water treadmill at different depths and temperatures. At 87°F (30.5°C) water at waist level, the

HR response was greater for any VO_2 compared to land treadmill walking. This difference is even greater when the water temperature increased to 97°F (36.1°C). The temperature of water affects the HR versus VO_2 relationship in water at waist depth, but not at shallower depths. The researchers suggested that treadmill exercise at waist depth or higher should be done in the coolest water tolerable, i.e. 71.5°F (22°C).

Hall et al. (1998) studied the cardiovascular response of 8 women (mean age 30.3 years), while walking on a treadmill immersed in water at chest depth and walking on a land treadmill. The researchers also used two water temperatures during the testing. The researchers found that VO_2 and HR increased linearly with increasing speed, both in water and on land. HR measures during water treadmill walking were higher at 97°F (36°C) across all speeds when compared to 82°F (28°C) and on land. The researchers concluded that HR measures were higher in warmer water at all speeds and that caution should be used when prescribing warm water walking to older adults at risk of cardiovascular disease. Heart rate values during walking at 2.0 mph, were similar between water and land treadmill walking. At higher speeds, water treadmill walking resulted in greater HR values than land treadmill walking.

Byrne et al. (1996) measured the responses of 20 adults, 21 years to 30 years of age, walking on a water treadmill in 90°F-92°F (32°C-33°C) temperatures at a water depth between mid-abdominal and mid-sternum level. The researchers found similar HR measures between water and land treadmill walking at 2.0 mph. However, the HR measures during water treadmill walking at 3.0 mph were statistically higher than the HR measures during walking on a land treadmill at 3.0 mph. Analysis of data matching values of VO_2 and HR revealed that HR levels were statistically lower and SV levels statistically higher during water exercise. Thus, it appears that exercise HR is not a good indicator of intensity during water walking.

While studying young male and female adults in 90°F (32°C) water, Napoletan and Hicks (1995) found that mean HR was 12.5 bpm higher during water treadmill walking at mid-thigh depth at 2.0 mph than walking at the same speed on a land treadmill. At chest depth, when running occurred, there was no statistical difference in HR as compared with land treadmill running. Shono et al. (2000) found that the HR of older individuals increased as speed increased during walking on a water treadmill at xiphoid level. Also, there was a linear relationship among HR, VO_2 and RPE as speed increased.

Overall, walking on a water treadmill in warm water results in greater HR values than walking on a land treadmill. However, there are conflicting findings. Gleim and Nicholas (1989) found that water treadmill walking at temperatures of at least 87°F (30.5°C) at waist level and above produced a greater HR response at all VO_2 levels than walking on a land treadmill. Whereas, Byrne et al. (1996) found that at 2.0 mph in 90-92°F (32-33°C) at mid-abdominal to mid-sternum depth, there was no difference in HR. However, Byrne et al. did report that at 3.0 mph there was a significant increase in HR during water treadmill walking over land treadmill walking. Most researchers agree that as temperature increases, so does HR. HR also increases as speed increases during water treadmill walking. A linear relationship between HR and VO_2 and HR and RPE has been shown as speed increases during water treadmill walking. Hall et al. (1998) contradicted these findings by reporting that there was no difference in HR between water and land treadmill walking at 2.0 mph. However, at 2.8 mph and 3.4 mph, Hall et al. did report greater HR values during water treadmill walking and land treadmill walking. Following is a review of literature comparing the effects of water treadmill walking with land treadmill walking, with a focus on differences in ratings of perceived exertion.

Rating of perceived exertion.

There is a lack of research comparing RPE of water treadmill walking/running and land treadmill walking/running. Byrne et al. (1996) measured the differences in RPE during water walking at mid-abdominal and mid-sternum levels on a water treadmill and land treadmill walking at speeds of 2.0 mph and 3.0 mph. RPE was greater at 3.0 mph than at 2.0 mph in both conditions, and greater during water treadmill walking than land treadmill walking. Napoletan and Hicks (1995) found that RPE was statistically higher for adult males and females, 22 years -31 years of age, during walking in water at mid-thigh level than walking on a land treadmill at 2.0 mph. Running on a water treadmill at 3.5 mph at mid-thigh depth also had a statistically greater RPE than running in water at chest depth or running on a land treadmill at the same speed. Shono et al. (2000) reported that older adults experienced an exponential increase in RPE with increasing speeds during water walking at xiphoid level and that there was a linear relationship between RPE and HR as speeds increased.

Summary of water treadmill walking and land treadmill walking.

Generally, water treadmill walking at depths from ankle to chest level, have resulted in higher VO_2, HR, and RPE than during land treadmill walking. This is because the buoyancy of the water at these levels is not great enough to compensate for the added energy needed to overcome the resistance that the water produces against the legs as they are moved through the water. There is also agreement that HR increases as water temperature increases.

Researchers also indicate that there is a large difference in the cardiovascular response to water walking and water jogging or slow running because of the floating phenomenon. Once treadmill speed is increased to the point where walking gives way to running, the body floats more between foot strikes which alters the activity to the point that VO_2 and HR relationships between water and land exercise are altered. VO_2, HR, and RPE all increase exponentially in older people as speed increases during walking on a treadmill in 86.5°F (30.3°C) temperature water at xiphoid level.

Overall Summary

The median age of the worlds population continues to increase with the number of those between the ages of 55 years and 64 years expected to have the greatest increase in the United States over the next two decades (Longley, 2003; United States Census Bureau, 2000). Along with the increasing number of older adults comes an increase in age-related injuries due to falls and diseases such as osteoarthritis (Centers for Disease Control and Prevention, 2003; Trombly, 1995).

Water exercise has been shown to be an ideal mode of exercise for older adults. The properties of water buoyancy and resistance and water temperature reduces stress on joints while aiding muscular and cardiovascular fitness, flexibility, improved ambulation stability, and enhanced psychological wellness (Alexander et al., 2001; Byrne et al., 1996; Craig, 1996; Demaere et al., 1997; Lord et al., 1993; Mayo, 2000; Napoletan, 1993; Town & Bradley, 1990; Whitlach & Adema, 1996; Wilder et al., 1993). However, the water buoyancy and hydrostatic forces that act on a body immersed in water alter the response of the cardiovascular system (Arborelius et al., 1972). These effects may become magnified when combined with the natural decline in cardiovascular efficiency with age (Brooks et al., 1996).

The majority of research on water exercise has been conducted on young adults running in deep water under non-weight bearing conditions. These studies show lower VO_2 and HR measures when compared to those produced while running on land or on a land treadmill while full weight bearing (Bishop et al., 1989; Butts, Tucker & Greening, 1991; Quinn et al., 1994; Svedenhag & Seger, 1992).

Researchers using partial weight bearing during walking in water at various levels up to the waist, and at various temperatures, showed higher VO_2 and HR measures than those at neck level, eliminating weight bearing. In addition, HR measures increased further as the water temperature increased (Gleim & Nicholas, 1989; Hall et al., 1998). RPE has been reported to be higher during water walking/running at neck level, however at peak values of VO_2 there is no difference in RPE between running in water at neck level and walking/running on a land treadmill. When walking on the pool floor or on a water treadmill, RPE has been reported to be similar for both water walking and land walking or land treadmill walking. However, when walking on a water treadmill, VO_2, HR, and RPE have been reported to be higher than when walking on a land treadmill at similar speeds (Bishop et al., 1989; Butts, Tucker, & Smith, 1991; Byrne et al., 1996; Mercer & Jensen, 1998; Michaud et al., 1995; Takeshima et al., 1997). Shono et al. (2000) found that VO_2, HR, and RPE increase exponentially as speed increased during walking on a treadmill in 86.5°F (30.3°C) water at xiphoid level. Shono et al. also reported a linear relationship among VO_2, HR, and RPE as speeds increased.

Few studies have been conducted concerning the cardiovascular responses of older adults to water walking. HR measures of older adults have been shown to be higher than that of younger adults during walking at higher intensities at axilla level immersion in water (Takeshima et al., 1997). This led Takeshima et al. to suggest that the cardiovascular response to hydrostatic pressure of water walking may be different for older adults. To date, no studies have been completed concerning older adults walking on a water treadmill at 92°F (33°C). If water treadmill walking is going to be safe and effective for rehabilitation of older adults, it is imperative that the cardiovascular responses to this activity be understood. This is especially true for the therapeutic pool setting. Thus, the purpose of this study was to examine the effects of slow, medium, and fast treadmill walking in water at 92°F (33°C) on the cardiovascular response of older adults. These responses were compared to walking on a land treadmill at similar speeds at an ambient temperature of 70°F (21°C).

CHAPTER III

METHODOLOGY

Participants

A total of 20 participants were recruited for this study (males = 13, females = 7). The age range of all participants was 55 years to 64 years with a combined mean age of 58.0 years (males = 57.4 years, females = 59.0 years). A power analysis performed for walking condition and walking speed indicated that 20 participants were enough to achieve a high power (≥ 0.82) for results in this study.

All participants completed a standard VA Medical Center Informed Consent form (see Appendix A), an Authorization to Use/Disclose Protected Health Information form (see Appendix B), and underwent a pretest screening that included HR and BP measures (supine, sitting, and standing), as well as a musculoskeletal examination by a registered kinesiotherapist (see Appendix C). All participants completed the Physical Activity Readiness Questionnaire (PAR-Q: ACSM, 1998) (see Appendix D) prior to the start of the study. The PAR-Q has a sensitivity of nearly 100% and specificity of approximately 80% for detecting medical contraindications to exercise (ACSM). In addition, information concerning height, weight, and participation in physical activities, was reported on the PAR-Q. The participants were free of known cardiovascular, respiratory, and musculoskeletal disorders. All participants were independent in ambulation.

Instrumentation

Musculoskeletal screening.

Participants were measured for limitations in joint range of motion using a goniometer (M. A. Rallis Co., Monmouth Jct., NJ) and the American Academy of Orthopaedic Surgeons standards (Norkin & White, 2003). The goniometer has been shown to have face, content, criterion-related, and construct validity as well as good to excellent reliability (Norkin & White). Also, the hip flexors and extensors, knee flexors and extensors, and the ankle dorsiflexors and plantarflexors of the lower extremities were tested for limitations in muscular strength using manual muscle testing techniques and scores recommended by Hislop and Montgomery (2002). Participants were also tested for weight bearing discomfort during standing with full weight on each extremity alone and while walking. All participants displayed joint range of motion and muscular strength within normal limits as described by the American Academy of Orthopaedic Surgeons standards and Hislop and Montgomery respectively, and were free of weight bearing discomfort.

VO_2 measurements.

VO_2 was measured by calculation of expired gas via the Moxus Modular VO_2 System (AEI Technologies, Naperville, IL). This device has been shown to be valid and to demonstrate a high degree of accuracy when compared to the traditional, well established method using Douglas bags for analyzing VO_2 and VCO_2 (Phillips, 2000). The VO_2 testing equipment was manually calibrated (environmental settings and gas analyzer calibration) at the start of every testing day. This process consisted of allowing the system to warm-up and stabilize, then testing both ambient and tank gas values (oxygen and carbon dioxide). The gases were calibrated to both high and low settings using the tank gas values. Tank gas values for retested prior to each treadmill test. VO_2 measures were recorded during the last 30 seconds of minute 4 and minute 5 of each 5 minute walking bout.

Heart rate measurement.

HR values were measured with an "Edge" Polar heart rate monitor (Polar USA, Lake Success, N.Y.). This device has a transmitter that straps around the chest and a watch receiver that attaches around the wrist. This device has been shown to correlate highly with palpated heart rates during land and water activities (Ebbeling, Ebbeling, Ward, &, Rippe, 1991; Rippe, 1992). Measurements were recorded during the last 30 seconds of minute 4 and minute 5 of each 5 minute walking bout.

Measurement of rating of perceived exertion.

The Borg scale for RPE was used as an exercise intensity indicator. This scale is a simple 6-20 numerical RPE used by many exercise physiologists and coaches to assess levels of intensity during training or physical testing (Borg, 1982). It allows the participant to rate the intensity of exercise using numbers. The Borg RPE scale has been shown to correlate well with HR and blood lactate levels during arm and leg exercise (Borg, Hassmen, & Lagerstrom, 1987). RPE measures were recorded during the last 30 seconds of minute 4 and minute 5 of each 5 minute walking bout.

Blood pressure measurement.

SBP was used as the blood pressure dependent variable because SBP rises with exercise while diastolic blood pressure remains relatively unchanged (McArdle et al. 1996). A standard medical stethoscope and sphygmomanometer (Tycos, Welch Allyn

Co., Arden, N.C.) were used to measure SBP prior to and during the testing. SBP was recorded at the first sound of blood rush (1^{st} Korotkoff sound). Because of difficulty accurately measuring the SBP during walking due to the sound of the treadmill and water, SBP measures were taken immediately upon cessation of each exercise bout at minute five. The BP cuff was inflated during the last 10 seconds of walking so that the SBP measures could be taken quickly upon cessation of walking. This method was used to enable the testing procedure to be as close to true walking blood pressure as possible while promoting accurate measurements.

Land and water treadmills.

A Pacer treadmill (Accumill C956, Dallas, TX) was used for the land treadmill test while an AquaGaiter (Ferno, Wilmington, OH) was used for the water treadmill tests.

Measurement of speed and distance.

A pilot study was conducted by the author to determine the accuracy and reliability of the AquaGaiter treadmill. Comparing the distance traveled as per the treadmill readout panel and number of treadmill belt rotations multiplied by the length of the belt, resulted in a consistent 15% difference at 2.0 mph, 2.5 mph, and 3.0 mph. Because of this discrepancy, the AquaGaiter water treadmill was adjusted up 15% at each speed utilized during the research process. The rate of speed and distance traveled was verified prior to each day of testing by counting the number of revolutions that the 10 ft belt traveled per minute and per five minutes. This was completed to help ensure the reliability and validity of the water treadmill protocol.

Height and weight.

The height and weight of participants without shoes was measured one time using a Healthometer scale (Continental Scale Corp. Bridgewater, IL.).

Procedures

This study was approved by the Institutional Review Board at Middle Tennessee State University (see Appendix E), the Institutional Review Board at Vanderbilt University (see Appendix F) and the Research and Development Committee at the Tennessee Valley V.A. Healthcare System (see Appendix G). Testing on the land treadmill took place in a kinesiotherapy clinic while the water treadmill testing took place in the kinesiotherapy therapeutic pool. Both are located at the Tennessee Valley V.A. Healthcare System, Murfreesboro, Tennessee.

Each participant completed an informed consent form and a PAR-Q questionnaire. Height, weight, HR, and BP measures, as well as the musculoskeletal screening, were performed by a registered kinesiotherapist. As part of the screening process participants were asked the number of days that they exercise for 30 minutes or more per week.

Participants received standardized instructions so that each participant had identical information concerning his or her participation. Participants were informed that their participation was important, but that they were free to end their participation at any time with freedom from ridicule or any other negative response. No participants were permitted to observe other participants during testing and all participants were asked not to discuss the experimental procedures or their experiences during the testing with other participants. There were no incentives or information provided to the participants other than the knowledge that they were assisting in a research study.

In order to familiarize the participants with both land and water treadmill ambulation, each participant completed one 5 minute session at 2.0 mph, 2.5 mph, and 3.0 mph consecutively on each apparatus the week prior to testing. Hall et al. (1998) reported that 10 minutes of walking on land and water treadmills is adequate to familiarize participants with the activity and 5 minutes of treadmill walking is adequate to reach a steady state of exercise.

After familiarization, all participants completed both treadmill tests in random order. One test was on a land treadmill at a room temperature of 70°F (21°C) and the other was on a water treadmill with the water temperature at 92°F (33°C). The water depth was at the level of the superior aspect of the iliac crest. Sova (1992) suggested that the ideal water depth for most healthy aquatic exercisers is within the waist to armpit level. In the rehabilitation setting, the progression for ambulators is from 0% weight bearing (neck level) to 100% weight bearing (out of water). The hypothetical midway point in the rehabilitation process is 50% weight bearing which is approximately the level of the superior aspect of the iliac crest (Harrison, Hillman, & Bulstrode, 1992). Thus, the superior aspect of the iliac crest level was selected as the water depth in this study.

Both land and water sessions and the speeds of walking were completed in a random counter balanced order. Each participant completed three bouts of 5 minutes duration at speeds of 2.0 mph, 2.5 mph, and 3.0 mph. There was a cessation of walking between each bout of treadmill walking until the participant's HR had returned to within 10 beats of the starting HR. These speeds were selected to be similar to the speeds used in a similar study using younger adults (Hall et al., 1998). Participants were asked to walk in a normal fashion with reciprocal arm swing. Water and land treadmill tests were separated by 24 hours. Each participant's VO_2, HR, and RPE were measured during the last 2 minutes of each exercise bout and the mean scores used for comparison. The SBP was measured immediately upon cessation of walking at the end of each exercise bout and was also used for comparison. Measured values were analyzed for differences between the main effects of land and water conditions and the main effects of the 3 different speeds (2.0 mph, 2.5 mph, and 3.0 mph). Interactions between main effects were also analyzed. All participants were asked to refrain from smoking two hours prior to each test and to refrain from drinking tea, coffee, or other caffeine containing drinks. Participants were asked to arrive two hours post-absorptive.

Statistical Analyses

A power analysis was completed to ensure that the number of participants was sufficient to detect differences in cardiovascular response if in fact there were differences. Descriptive statistics were calculated in order to describe the sample being tested and a 2 x 3 repeated measures ANOVA design with a MANOVA (Multivariate Analysis of Variance) approach was utilized to test the main effects of condition (water/land) and speed (2.0 mph, 2.5 mph, and 3.0 mph) and interactions between condition and speed for each dependent variable (VO_2, HR, RPE, and SBP). Paired *t* tests were used as post hoc tests for analyzing the simple effects (where specifically the differences occur). These analyses were calculated via the SAS computerized system. The level of statistical significance was set at .05 familywise (for each of several comparisons). For the paired *t* tests, Bonferroni corrections were used resulting in a level of statistical significance set at .0056 for the simple effects.

CHAPTER IV

RESULTS

Employees from the Veteran Affairs Tennessee Valley Healthcare System were included in this study. A total of 21 employees volunteered to participate. However, one volunteer was unable to wear a nose clip during testing procedures and did not complete the testing resulting in a final *N* of 20.

Power Analysis

A power analysis was conducted for the walking condition (land and water) and the walking speeds (2.0 mph, 2.5 mph, and 3.0 mph) for each of the dependent variables (VO_2, HR, RPE, and SBP). Although 20 participants were included in the study, $N = 40$ was used to calculate the power for the two walking conditions and $N = 60$ was used to calculate the power of the three speed conditions because of the repeated measures design. All 20 participants completed each of the testing conditions. The larger numbers were used to produce a more accurate assessment of the power. The two factors involved in this analysis that were expected to alter the accuracy of the estimated power were the repeated measures design, which caused an underestimation of the power, and the numbers used in the power analysis ($N = 40$ for walking condition and $N = 60$ for walking speeds), which overestimated the power of the study. It was expected that these two factors would balance each other and result in the most accurate power assessment. The power of the walking condition for VO_2 was calculated to be .95 while the power of the speed condition for VO_2 was calculated to be .99. The power of the walking condition for HR was .99 and the power of the speed condition for HR was also .99. The power of the walking condition for RPE was .95 while the power of the speed condition for RPE was calculated to be .99. The power for the walking condition for SBP was .82 and the power of the speed condition for SBP was .98. The results of these analyses indicates there was an adequate number of participants to detect a difference in effect of the conditions (land treadmill walking/water treadmill walking and 2.0 mph, 2.5 mph, 3.0 mph speeds) on the dependent variables (VO_2, HR, RPE, SBP).

Demographic/Descriptive Data

Demographic data appear in Table 1. The age range of the participants was predetermined to be 55 years to 64 years old. The overall mean age was 58.0 years. The predominant sex in the study was male ($n = 13$). The number of days of exercise per week that represented the greatest number of participants was 0 ($n = 7$). The mean number of days that the participants exercised per week was 2.8 (males = 2.6, females = 3.0). A summary of physical descriptives appears in Table 2. The mean height of the participants was 68.2 inches and the mean weight was 82.1 kg. BMI was divided into three categories, < 25.0 kg/m^2 (normal body mass), 25.0 to 29.9 kg/m^2 (overweight), and > 29.9 kg/m^2 (obese). The majority of participants had a BMI between 25.0 kg/m^2 and 29.9 kg/m^2 ($n = 10$). The mean BMI of all the participants was 27.4 kg/m^2 (overweight).

Analysis of VO_2

A 2(w) X 3(w) [two walking conditions by three speed conditions] repeated analysis of variance (ANOVA) was performed for VO_2 through the Multivariate ANOVA (MANOVA) approach (see Table 3). There was a statistically significant main effect of the walking condition on VO_2 (F (2,18) = 35.58, $p < .0001$, Wilks' Lambda

Table 1

Demographic Data of the Participants (N = 20)

Variable	$M \pm SD$	% of Sample
Age (yrs)		
Males	57.4 ± 1.9	
Females	59.0 ± 2.2	
Sex		
Males		65%
Females		35%
Number of Exercise Days per Week		
0		35%
1		15%
2		10%
3		20%
5 or more		20%

Table 2

Physical Descriptives of the Participants (N = 20)

Variable	$M \pm SD$	% of Sample
Height (in)		
Males	69.5 ± 2.3	
Females	65.7 ± 1.6	
Weight (kg)		
Males	86.3 ± 13.6	
Females	74.2 ± 16.9	
BMI (kg/m^2)		
Males	27.9 ± 4.1	
Females	26.5 ± 6.3	
< 25.0		25.0%
25.0 to 29.9		50.0%
> 29.9		25.0%

Table 3

Walking Condition and Speed Main Effects and Interactions on VO_2 (N = 20)

Variable	*df*	*F*	$M \pm SD^b$
Main Effect of Walking Condition	(1, 19)	35.6*	
Land			11.1 ± 1.2
Water			13.8 ± 4.3
Main Effect of Walking Speed[a]	(2, 18)	366.6*	
2.0			9.6 ± 2.0
2.5			12.3 ± 2.4
3.0			15.5 ± 3.4
Interaction of Walking Condition & Speed[a]	(2, 18)	32.4*	
Land and 2.0			9.4 ± 1.3
Water and 2.0			9.8 ± 2.5
Land and 2.5			11.1 ± 1.3
Water and 2.5			13.5 ± 2.7
Land and 3.0			12.9 ± 1.6
Water and 3.0			18.1 ± 2.6

Note. [a] = mph, [b] = ml/kg/min., * = $p < .001$.

0.348) and a statistically significant main effect of speed on VO_2 (F (2,18) = 366.58, $p <$ .0001, Wilks' Lambda = 0.024). There was also a statistically significant interaction between the main effects of walking and speed on VO_2 (F (2,18) = 32.36, $p < .0001$, Wilks' Lamda = 0.218). To determine where the specific differences occurred, paired t tests were run with a Bonferroni correction resulting in *alpha pc* < .0112 used to indicate statistical significance. All factor comparisons were found to be statistically significant at the .0001 level except 2.0 mph speed on land with 2.0 mph speed in water which was not statistically significant (.3558) (see Table 4). Thus, hypotheses 1, 2, and 3 were supported by the results. Hypothesis 1 stated, "the water walking condition will have a statistically higher VO_2 than the land walking condition" hypothesis 2 stated, "the VO_2 will statistically increase with each increase in speed" and hypothesis 3 stated, "there will be a statistically significant interaction between walking condition and speed on VO_2." In each case, there was a greater VO_2 value for the water condition and for higher speeds. The combination of the water walking condition and the highest speed produced the highest VO_2 value.

Analysis Heart Rate

A 2(w) X 3(w) [two walking conditions by three speed conditions] repeated ANOVA was performed for HR through the MANOVA approach (see Table 5). The MANOVA results showed a statistically significant main effect of walking on HR (F (2,18) = 42.38, $p < .0001$, Wilks' Lambda = 0.309) and a statistically significant main effect of speed on HR (F (2,18) = 121.67, $p < .0001$, Wilks' Lambda = 0.069). The interaction between the main effects was also statistically significant (F (2,18) = 55.21, p < .0001, Wilks' Lamda = 0.140). Paired t tests with Bonferroni corrections were

Table 4

Simple Interactions Between Groupings of Main Effects on VO_2 (N = 20)

Group 1	Group 2	*T* – Value(*df*)	Significance Value
Land and 2.0[a]	Water and 2.0[a]	0.95(19)	.3558
Land and 2.5[a]	Water and 2.5[a]	5.12(19)	.0001**
Land and 3.0[a]	Water and 3.0[a]	8.61(19)	.0001**
Land and 2.0[a]	Land and 2.5[a]	7.43(19)	.0001**
Land and 2.5[a]	Land and 3.0[a]	8.33(19)	.0001**
Land and 2.0[a]	Land and 3.0[a]	10.70(19)	.0001**
Water and 2.0[a]	Water and 2.5[a]	13.42(19)	.0001**
Water and 2.5[a]	Water and 3.0[a]	12.12(19)	.0001**
Water and 2.0[a]	Water and 3.0[a]	21.85(19)	.0001**

Note. [a] = mph, ** = *alpha pc* < .0112 in one tailed paired *t* test with Bonferroni Correction.

Table 5

Walking Condition and Speed Main Effects and Interactions on HR (N = 20)

Variable	*df*	*F*	$M \pm SD^b$
Main Effect Walking Condition	(1, 19)	42.4*	
Land			97.8 ± 11.2
Water			112.6 ± 18.0
Main Effect of Walking Speed[a]	(2, 18)	121.7*	
2.0			95.6 ± 10.0
2.5			103.6 ± 12.7
3.0			116.4 ± 19.0
Interaction of Walking Condition & Speed[a]	(2, 18)	55.2*	
Land and 2.0			93.3 ± 9.9
Water and 2.0			98.0 ± 9.8
Land and 2.5			96.9 ± 10.2
Water and 2.5			110.4 ± 11.4
Land and 3.0			103.3 ± 11.6
Water and 3.0			129.5 ± 15.7

Note. [a] = mph, [b] = bpm, * = $p < .001$.

completed to reveal statistically significant simple effects at *alpha pc* $< .0112$ (see Table 6). All simple effects were statistically significant except between land walking at 2.0 mph and water walking at 2.0 mph. Hypotheses 4, 5, and 6 were supported by the results. Hypothesis 4 stated, "the water walking condition will have a statistically higher HR than the land walking condition" hypothesis 5 stated, "the HR will statistically increase with each increase in speed," and hypothesis 6 stated, "there will be a statistically significant interaction between walking condition and speed on HR." In each case, there was a greater HR value for the water condition and faster speeds. The combination of the water walking condition and highest speed of 3.0 mph produced the highest HR value.

Analysis of Rating of Perceived Exertion

A 2(w) X 3(w) [two walking conditions by three speed conditions] repeated ANOVA was performed for the RPE variable using a MANOVA approach (see Table 7). There was a statistically significant main effect of walking on RPE (F (2,18) = 17.12, $p <$ .0006, Wilks' Lambda = 0.526) and a statistically significant main effect of speed on RPE (F (2,18) = 58.96, $p < .0001$, Wilks' Lambda = 0.132). Again, the interaction between the main effects was statistically significant for RPE (F (2,18) = 17.07, $p <$ .0001, Wilks' Lamda = 0.345). Paired t tests indicated all simple effects were statistically significant except comparison of 2.0 mph on land and 2.0 mph in water (see Table 8). Hypotheses 7, 8, and 9 were supported by the results. Hypothesis 7 stated, "the water walking condition will have a statistically higher RPE than the land walking condition," Hypothesis 8 stated, "the RPE will statistically increase with each increase in speed," and hypothesis 9 stated, "there will be a statistically significant interaction between walking

Table 6

Simple Interactions Between Groupings of Main Effects on HR (N = 20)

Group 1	Group 2	T – Value(*df*)	Significance Value
Land and 2.0[a]	Water and 2.0[a]	2.03(19)	.0571
Land and 2.5[a]	Water and 2.5[a]	6.51(19)	.0001**
Land and 3.0[a]	Water and 3.0[a]	8.90(19)	.0001**
Land and 2.0[a]	Land and 2.5[a]	7.91(19)	.0001**
Land and 2.5[a]	Land and 3.0[a]	10.03(19)	.0001**
Land and 2.0[a]	Land and 3.0[a]	11.91(19)	.0001**
Water and 2.0[a]	Water and 2.5[a]	9.61(19)	.0001**
Water and 2.5[a]	Water and 3.0[a]	10.44(19)	.0001**
Water and 2.0[a]	Water and 3.0[a]	14.46(19)	.0001**

Note. [a] = mph, ** = *alpha pc* < .0112 in one tailed paired *t* test with Bonferroni Correction.

Table 7

Walking Condition and Speed Main Effects and Interactions on RPE (N = 20)

Variable	*df*	*F*	$M \pm SD$[b]
Main Effect Walking Condition	(1, 19)	17.1*	
Land			9.2 ± 2.2
Water			10.9 ± 2.7
Main Effect of Walking Speed[a]	(2, 18)	59.0*	
2.0			8.2 ± 1.7
2.5			10.1 ± 2.3
3.0			11.7 ± 2.4
Interaction of Walking Condition & Speed[a]	(2, 18)	17.1*	
Land and 2.0			7.9 ± 1.8
Water and 2.0			8.6 ± 1.6
Land and 2.5			9.2 ± 2.2
Water and 2.5			11.1 ± 2.1
Land and 3.0			10.4 ± 1.9
Water and 3.0			13.0 ± 2.1

Note. [a] = mph, [b] = RPE (Borg scale), * = $p < .001$.

Table 8

Simple Interactions Between Groupings of Main Effects on RPE (N = 20)

Group 1	Group 2	T – Value(*df*)	Significance Value
Land and 2.0[a]	Water and 2.0[a]	1.82(19)	.0845
Land and 2.5[a]	Water and 2.5[a]	3.97(19)	.0008**
Land and 3.0[a]	Water and 3.0[a]	5.38(19)	.0001**
Land and 2.0[a]	Land and 2.5[a]	4.61(19)	.0002**
Land and 2.5[a]	Land and 3.0[a]	5.64(19)	.0001**
Land and 2.0[a]	Land and 3.0[a]	7.96(19)	.0001**
Water and 2.0[a]	Water and 2.5[a]	7.11(19)	.0001**
Water and 2.5[a]	Water and 3.0[a]	9.23(19)	.0001**
Water and 2.0[a]	Water and 3.0[a]	10.76(19)	.0001**

Note. [a] = mph, ** = *alpha pc* < .0112 in one tailed paired *t* test with Bonferroni Correction.

condition and speed on RPE." There was a greater RPE value for the water condition and faster speeds. The combination of the water walking condition and the fastest speed (3.0 mph) produced the highest RPE value.

Analysis of Systolic Blood Pressure

A 2(w) X 3(w) [two walking conditions by three speed conditions] repeated ANOVA was performed for SBP through the MANOVA approach (see Table 9). There was a statistically significant main effect of walking on SBP (F (2,18) = 20.46, p < .0002, Wilks' Lambda = 0.482) and a statistically significant main effect for speed on SBP (F (2,18) = 36.68, p < .0001, Wilks' Lambda = 0.197). There was also a statistically significant interaction (F (2,18) = 10.65, p < .0009, Wilks' Lambda = 0.458). Paired t tests were used with Bonferroni corrections to determine simple effects (see Table 10). All simple effects were statistically significant except for comparison of 2.0 mph on land and 2.0 mph in water, 2.0 mph on land and 2.5 mph speed on land, and 2.0 mph on land and 3.0 mph on land. Results supported Hypotheses 10, "the water walking condition will have a statistically higher SBP than the land walking condition," Hypotheses 11, "the SBP will statistically increase with each increase in speed," and Hypothesis 12, "there will be a statistically significant interaction between walking condition and speed on SBP." There was a greater SBP for the water condition and faster speeds. The combination of the water walking condition and highest speed produced the highest SBP value.

Table 9

Walking Condition and Speed Main Effects and Interactions on SBP (N = 20)

Variable	*df*	*F*	$M \pm SD$[b]
Main Effect Walking Environment	(1, 19)	20.5*	
Land			133.6 ± 22.8
Water			149.8 ± 26.4
Main Effect of Walking Speed[a]	(2, 18)	36.7*	
2.0			132.9 ± 21.4
2.5			140.1 ± 23.8
3.0			152.2 ± 28.7
Interaction of Walking Condition & Speed[a]	(2, 18)	10.7*	
Land and 2.0			129.8 ± 20.8
Water and 2.0			136.0 ± 22.2
Land and 2.5			131.7 ± 20.1
Water and 2.5			148.5 ± 24.7
Land and 3.0			139.3 ± 26.9
Water and 3.0			165.0 ± 24.8

Note. [a] = mph, [b] = mmhg, * = $p < .001$.

Table 10

Simple Interactions Between Groupings of Main Effects on SBP (N = 20)

Group 1	Group 2	T – Value(*df*)	Significance Value
Land and 2.0[a]	Water and 2.0[a]	1.68(19)	.1085
Land and 2.5[a]	Water and 2.5[a]	4.51(19)	.0002**
Land and 3.0[a]	Water and 3.0[a]	4.92(19)	.0001**
Land and 2.0[a]	Land and 2.5[a]	1.13(19)	.2730
Land and 2.5[a]	Land and 3.0[a]	2.32(19)	.0314
Land and 2.0[a]	Land and 3.0[a]	3.02(19)	.0071
Water and 2.0[a]	Water and 2.5[a]	4.16(19)	.0005**
Water and 2.5[a]	Water and 3.0[a]	7.10(19)	.0001**
Water and 2.0[a]	Water and 3.0[a]	8.39(19)	.0001**

Note. [a] = mph, ** = *alpha pc* < .0112 in one tailed paired *t* test with Bonferroni Correction.

Summary of Results

Performing ANOVA's using the MANOVA approach, all 12 hypotheses were supported. For each dependent variable (VO_2, HR, RPE, and SBP), the water condition at 2.5 mph and water condition at 3.0 mph resulted in statistically significant higher values than the land condition at the same speeds. Likewise, VO_2, HR, and RPE during water and land walking, were statistically higher with each successive increase in speed. The combination of the water condition and the highest speed (3.0 mph) produced the highest values. SBP values rose enough to be statistically significant with each successive increase in walking speed on the water treadmill, but did not change in value with increased speeds during walking on the land treadmill.

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effects of treadmill walking in water at 92°F (33°C) at slow (2.0 mph), medium (2.5 mph), and fast (3.0 mph) walking speeds on the cardiovascular response of adults between the ages of 55 years and 64 years. The independent variables were 1) walking condition with two levels (therapeutic water treadmill and land treadmill) and 2) walking speed with three levels (2.0 mph, 2.5 mph, and 3.0 mph). There were four dependent variables including VO_2, HR, RPE, and SBP. All participants were employees of the Tennessee Valley Healthcare System. The 20 volunteers (males = 13, females = 7) had a combined mean age of 58.0 years (*M* males = 57.4 years, *M* females = 59.0 years).

Comparison of Sample to the Population

The ACSM (1998) indicated that 33% of older adults regularly participate in physical activities, which is similar to the 40% of participants in this study that participate in 30 minutes of exercise three times per week or more. These figures partially explain why obesity has been called an epidemic in the United States with nearly 1 in 4 people over the age of 51 years being categorized as obese and approximately 40% categorized as overweight (Center On An Aging Society, 2003). Flegal and Troiano (2000) reported that the median BMI for adults 50 years to 59 years of age is 27.2 kg/m^2 (overweight) and the median BMI for adults between the ages of 60 years and

69 years of age is 27.4 kg/m^2 (overweight). This is consistent with the participants in this study with 25% of the participants being categorized as obese and 50% of the participants categorized as overweight. The average BMI of the participants in this study was 27.4 kg/m^2 (overweight) while the median BMI score was 26.8 kg/m^2 (overweight). Overall, based on BMI and regularity of exercise statistics, the sample utilized in this study is similar to the general population of older people in the United States.

Background Information

Aquatic exercise is a popular mode of physical conditioning and rehabilitation due to the effects of water buoyancy, resistance, and water temperature (Napoletan, 1993). Water buoyancy reduces stress on joints while water resistance provides a means of muscular strengthening in a supported environment. Also, when water temperature is above 90°F (32°C), an analgesic effect results (Craig, 1996). This is especially useful for older adults because of the disproportionate number of musculoskeletal problems compared to the general population (Takeshima et al., 1997). The potential importance of aquatic exercise becomes evident when considering that older adults are the fastest growing segment of the population in the United States and the world (Longley, 2003).

With an increased susceptibility to injuries and musculoskeletal problems, older adults may benefit from water exercise which is less stressful to joints. Water exercise has been credited with improving muscular and cardiovascular fitness, reducing musculoskeletal stress, reducing pain, increasing flexibility, improving ambulation stability, and enhancing psychological wellness (Alexander et al., 2001; Byrne et al., 1996; Lord et al., 1993; Whitlach & Adema, 1996). However, the hydrostatic pressure of water can alter the cardiovascular responses to exercise (Arborelius et al., 1972). During water immersion, hydrostatic pressure causes blood to move from the periphery to the thorax creating increases in SV and Q. HR remains the same or decreases and SBP remains the same or increases depending on the ratio of Q to vascular resistance. These effects may have an even greater impact on older adults when combined with the natural decline in cardiovascular efficiency associated with aging (Brooks et al., 1996). Thus, it is important to explore the cardiovascular response to walking in warm water with older adults.

The cardiovascular components of SV, Q, VO_2, SBP, and HR during water walking/jogging at neck level without floor contact is impacted by the redistribution of blood from the periphery to the thorax and the non-use of anti-gravity musculature (Arborelias et al., 1972; Derion et al., 1992; Farhi & Linnarsson, 1977). A consensus of research indicates that VO_2 and HR measures are lower during water treadmill walking/running at neck level than land treadmill walking/running at similar speeds and at peak measures. RPE is higher during water walking/running at neck level than running on a land treadmill at sub-maximal levels of VO_2. Nevertheless, at maximal levels of VO_2, there is no difference in RPE.

When contact with the pool floor is introduced by walking at lesser depths, water level becomes a key factor in determining the cardiovascular response. The level of physical effort is affected by the water resistance and the water buoyancy and how these factors impact the cardiovascular system during walking at different levels of immersion (Takeshima et al., 1997).

Water treadmill walking introduces the impact of a moving floor surface in the water. Walking on a water treadmill alters the cardiovascular response by eliminating the frontal resistance of the water because the body is no longer moving through the water in a forward direction, but rather walking in a stationary manner as the treadmill floor moves (Gleim & Nicholas, 1989).

At lower levels of water walking, (ankle to waist), VO_2 and HR are higher during water treadmill walking than land treadmill walking (Gleim & Nicholas, 1989). This is because the buoyancy of the water at these levels is not great enough to compensate for the added energy needed to overcome the resistance that the water produces against the legs as they are moved through the water. There is also agreement that HR increases as water temperature increases and RPE is higher while walking on a treadmill in water than on land (Gleim & Nicholas).

While information does exist concerning the impact of water immersion at rest, during water walking/running at neck level without bearing weight, walking on the pool floor at different depths, and walking on a water treadmill, the great majority of these studies were on young, healthy adults. There is a lack of information concerning the effect of walking in warm water at different walking speeds on the cardiovascular system of older adults. If older adults are to optimally and safely utilize the modality of therapeutic pool exercise for rehabilitation or physical fitness, it is important to understand the impact of this activity mode on the cardiovascular system of older adults.

Discussion of VO_2 Findings

In the current sample, VO_2 levels statistically increased as speed increased during water and land treadmill walking and water treadmill walking produced higher VO_2 levels than land treadmill walking at speeds of 2.5 mph and 3.0 mph. At 2.0 mph, there was no difference in VO_2 between land and water treadmill walking. An explanation for the reason VO_2 is statistically higher when walking on a water treadmill at 2.5 mph and 3.0 mph than while walking on a land treadmill is because water resistance increases the cardiovascular demand. A reason why this difference is not observed at 2.0 mph, is that as speed of movement decreases in water, the water resistance also decreases. Thus the physical effort needed to walk against water resistance at 2.5 mph and 3.0 mph creates greater cardiac demand than walking without water resistance on a land treadmill. At 2.0 mph in water, there is not enough water resistance to create sufficient demand on the cardiovascular system to produce a statistically different value than walking on a land treadmill. These data support conclusions made by Hall et al. (1998). However, these researchers, utilized young adults as participants, had a different water depth, and different water temperatures than the current study. Hall et al. used water temperatures at 82^0F and 97^0F and a water depth of chest level. The results of the current study are also similar to those of Napoletan and Hicks (1995) in that VO_2 values at 2.0 mph and at chest depth were not higher during water treadmill walking than during land treadmill walking. However, the current study differs from the results of Napoletan and Hicks at mid-thigh depth and Byrne et al. (1996) at mid-abdominal to mid sternum level who all found that VO_2 was higher during water treadmill walking than land treadmill walking at 2.0 mph. Byrne et al. and Napoletan and Hicks used young adults as participants as opposed to older adults. A possible reason why Napoletan and Hicks found statistically higher VO_2 measures during water treadmill walking than during land treadmill walking at 2.0 mph at mid-thigh depth is that at this level, water resistance is still near that of waist level water walking, however, water buoyancy has decreased so that more effort is required by anti-gravity musculature. A possible reason why Byrne et al discovered a statistical difference in VO_2 between water and land treadmill walking at 2.0 mph is that at sternum water level, water resistance to arm swing during walking may have been added to increase the overall water resistance relative the waist depth when the arms are above the water. Napoletan and Hicks found no difference in VO_2 between water and land treadmill walking at 3.5 mph. However, the researchers theorized that at 3.5 mph, the activity changed from walking to running which produced a floating phenomenon resulting in lower O_2 consumption. Shono et al. (2000) documented that VO_2 values increased as speed increased during water treadmill walking. The current results support Shono et al.. Also, Shono et al. utilized older females (52 years to 64 years of age). However, Shono et al. used cooler water (86.5^0F), xiphoid water depth, and slower speeds (.75 mph, 1.1 mph, 1.5 mph, and 1.8 mph) which all differ from the current study.

The current study supports the preponderance of prior studies finding that VO_2 levels increase as speed increases during land and water treadmill walking and that water treadmill walking produces higher VO_2 values than walking on a land treadmill at speeds of 2.5 mph and 3.0 mph. Because the two activities (water and land treadmill walking) have been shown to produce significantly different cardiovascular effects at similar speeds, walking distance and walking speed should not be used to compare the two activities. As such, an individual that walks 2.0 miles per session on a land treadmill at 2.5 mph, cannot perform this same activity on a water treadmill in 92^0 water at waist level and consume the same amount of oxygen. Water treadmill walking at speeds of 2.5 mph and 3.0 mph has shown to be more strenuous than walking on a land treadmill at the same speeds. Therefore, the two activities should not be substituted without compensating for the additional workload during water treadmill walking.

Maximal VO_2 decreases with age and increases with prolonged sub-maximal exercise in a hot humid environment (ACSM, 1998). However, comparing the current study with prior studies, a general conclusion can be made that the VO_2 values are similar despite differences in the age of participants and water temperatures. Water depth at mid-thigh was shown by Napoletan and Hicks (1995) to produce higher VO_2 values than waist and higher levels of water depth at similar speeds.

Discussion of HR Findings

As was the case with VO_2 in the current study, HR increased as walking speed increased on both water and land treadmills and walking on a water treadmill resulted in higher HR values than walking on a land treadmill at speeds of 2.5 mph and 3.0 mph. Also similar to VO_2 results, there was no difference in HR between land and water treadmill walking at 2.0 mph. An explanation for the significant statistical differences between walking on a water treadmill in warm water at waist depth and walking on a land treadmill is that the resistance of the water during walking increases the walking intensity and energy expenditure of the activity. Although water buoyancy at waist level reduces weight bearing and the associated intensity level, it is not enough to overcome the increased intensity and associated energy expenditure produced by the water resistance. Again, similar to VO_2, a possible explanation for the lack of a statistically significant difference in HR between land and water treadmill walking at 2.0 mph is that as the movement of body parts through water slows, the water resistance to the movements decrease. Thus, the level of physical effort was not great enough to demonstrate a difference in HR.

As before, these results support the findings of Hall et al. (1998). The results of the current study also support HR measures of Byrne et al. (1996) at the walking speeds of 2.0 mph and 3.0 mph. Byrne et al. demonstrated no difference in HR between water treadmill walking and land treadmill walking at 2.0 mph (95 bpm), but demonstrated a large statistical difference in mean HR between water and land treadmill walking at 3.0 mph (125 bpm and 104 bpm, respectively). Byrne et al. did utilize warm water (90^0F to 92^0F) which is similar to the current study, but also utilized young adults as participants with the depth of walking between mid-abdominal and mid-sternum which is higher than the current protocol.

Napoletan and Hicks (1995) had no difference in HR between water treadmill walking at chest depth and land treadmill walking at 2.0 mph. These results are supported by the current study. However, Napoletan and Hicks did report a difference in HR between water at mid-thigh depth and land treadmill walking at 2.0 mph which does not support the current study. The statistically significant increases in HR between land and mid-thigh depth water treadmill walking at 2.0 mph may be because the water depth was not high enough to create enough buoyancy effect to offset the water resistance against leg movements during walking. However, water buoyancy may have been present enough to reduce exercise intensity at waist and chest levels resulting in no difference between land and water walking at 2.0 mph for the current study and others with similar results. Shono et al. (2000) found that HR values increased as speed increased during water treadmill walking. These results are supported by the current study. However, Shono et al. used cooler water (86.5^0F), xiphoid water depth, and slower speeds (.75 mph, 1.1 mph, 1.5 mph, and 1.8 mph).

The results of this current study support some past studies, but not others as the results are mixed concerning HR values during walking on a water treadmill and land treadmill. The area of conflict is at the slower speed of 2.0 mph. The implication of the findings that walking on a water treadmill results in higher HR values than when walking on a land treadmill except for 2.0 mph is that the intensity level during water treadmill walking is greater and must be compensated for by either slowing speeds or shortening exercise duration. Maximal HR declines with age and HR elevates as water temperature increases (ACSM, 1998). However, as was the case with VO_2, HR results of the current study are similar to many studies regardless of the age of participants and water temperature. Water treadmill walking at adequate speed will produce a statistically greater HR than walking on a land treadmill. Water temperature affects the degree to which HR is statistically higher during water treadmill walking as opposed to land treadmill walking. Depth of water at mid-thigh has been shown to impact HR values by producing higher measures at 2.0 mph while waist level and deeper levels have not.

Discussion of RPE Findings

RPE results of the current study were consistent with VO_2 and HR. RPE increased as speed increased and RPE values were higher during water treadmill walking than during land treadmill walking at 2.5 mph and 3.0 mph. No statistically significant difference was found between land and water treadmill walking at 2.0 mph. Similar to VO_2 and HR, a possible reason for this is that the slow speed of 2.0 mph and resulting low resistance of water against leg movements may have been too small to create an exercise intensity great enough to increase the cardiovascular workload so that it would illicit a statistically significant difference.

These results partially support the findings of Byrne et al. (1996) and Napoletan and Hicks (1995). Byrne et al. also reported greater RPE scores as speed increased and greater RPE scores during water treadmill walking at mid-abdominal to chest depth than land treadmill walking at 3.0 mph. However, Byrne et al. also reported a greater RPE score during water treadmill walking at mid-abdominal to sternum depth than during land treadmill walking at 2.0 mph which conflicts with the current study. As with the current findings, Napoletan and Hicks did not show a difference in RPE between water and land treadmill walking at chest depth at a speed of 2.0 mph, but did at mid-thigh depth which is in contrast to the current study. As was the case with VO_2 and HR, RPE may be higher at mid-thigh level during water treadmill walking relative to land treadmill walking because the water resistance to leg movements remained high while water buoyancy decreased relative to waist level water walking. Also, similar to VO_2, findings, walking at sternum depth at 2 mph may have introduced arm movement in the water and additional water resistance relative to waist depth in the study by Byrne et al. Shono et al. (2000) also reported that older adults experience an increase in RPE with increasing speeds during walking on a water treadmill at xiphoid level. Shono et al. utilized a cooler water temperature (86.5^{0}F), a water depth at the xiphoid process, and slower speeds (.75 mph, 1.1 mph, 1.5 mph, and 1.8 mph) than the current study.

Results concerning RPE are mixed. Byrne et al. have suggested that RPE is a more prudent means of monitoring water treadmill exercise intensity than HR methods developed from land exercise. The results of the current study support that suggestion at speeds of 2.5 mph and 3.0 mph. The findings from prior studies and the current study indicate that RPE may be valid for monitoring exercise intensity during water walking on a treadmill in cool and warm water temperatures and for older adults as well as younger adults.

Discussion of SBP Findings

In this study, SBP increased as the speed of water treadmill walking increased and was also shown to be higher during water treadmill walking than land treadmill walking at 2.5 mph and 3.0 mph. However, there was no statistically significant difference in SBP when walking at 2.0 mph on land and walking at 2.0 mph in water. Also, there was no statistically significant difference in SBP while walking on a land treadmill at 2.0 mph and 2.5 mph. Likewise, the comparison of walking on a land treadmill at 2.5 mph and walking on a land treadmill at 3.0 mph also resulted in no statistical difference. Lastly, the comparison of land treadmill walking at 2.0 mph and walking on a land treadmill at 3.0 mph did not result in a statistically significant difference in SBP.

As in the cases of VO_2, HR, and RPE, a possible reason why SBP did not show a statistically significant difference between 2.0 mph walking on a land treadmill and 2.0 mph walking on a water treadmill was because at the speed of 2.0 mph water resistance is less than at faster speeds because resistance decreases with slower motion in water. Thus the activity was not intense enough to increase the cardiac workload and in turn increase SBP. A possible explanation why SBP increased as speeds increased from 2.0 mph, 2.5 mph, and 3.0 mph during water treadmill walking and not during land treadmill walking is the effect of hydrostatic pressure increasing blood volume in the thorax resulting in greater end-diastolic blood volume and a greater SV and Q may have resulted in higher systolic blood pressures during water exercise. Also, the added resistance of walking against water may produce sufficient strain to mechanically compress the peripheral arterial system. This is the mechanism by which blood pressure increases during resistive exercise such as weight training (McKardle et al., 1996). Still another possible explanation is that the addition of hydrostatic pressure to the peripheral muscles may reduce the amount of vascular dilation resulting in increased peripheral resistance and increased SBP in water relative to on land. Because of the increase in SBP during water treadmill walking, it may be prudent to monitor the blood pressure of water exercise participants, especially those with history of hypertension. Results of the current study indicate that water treadmill walking at 2.5 mph or more may not be a safe activity for persons with uncontrolled hypertension.

There are no known studies available comparing SBP results of water and land treadmill walking. A possible explanation for this is that many water walking studies are conducted in deeper water which makes SBP measurement difficult. Also, during the current study, SBP monitors found it difficult to accurately read the SBP of participants while walking on the treadmill in the water. Thus, for this study the process had to be modified so that the SBP measures were read immediately upon cessation of walking. Thus, the factors of increased SBP during the activity and difficulty monitoring SBP during the activity decreases the appropriateness of prescribing water exercise for people with hypertension.

Study Limitations and Future Research Needs

Because all participants in this study were employees of the V.A. Tennessee Valley Healthcare System and were free from musculoskeletal and cardiovascular problems the findings are of limited application to the general older population that does have a higher propensity of musculoskeletal and cardiovascular problems. Future research should include those with musculoskeletal and cardiovascular problems because they are the population most likely to utilize a therapeutic pool exercise program. Further, because individuals age 65 years and older were not included in the study, results should not be generalized to older individuals. This population also has a need for therapeutic pool activities due to higher than normal musculoskeletal problems and should also be included in future studies. It is important to determine how people with musculoskeletal and cardiovascular problems and people over 65 years of age will react to therapeutic pool exercise. A limitation of the study was the inability to measure BP values during the water treadmill walking. In this study, BP was measured immediately upon cessation of walking. However, because SBP values were recorded as increasing with speed during water treadmill walking and were greater than land treadmill walking at 2.5 mph and 3.0 mph, it is particularly important to record the SBP values during the walking process in future studies to record the truest impact of water exercise on SBP.

Overall Summary and Conclusions

There are no known studies that are identical to the current study. However, there have been a number of studies that have utilized one or more similar independent variables in one or more similar environmental factors. Most of the previous researchers have focused on the cardiovascular effects of water walking on young adults (Byrne et al., 1996; Gleim & Nicholas, 1989; Hall et al., 1998). The results of this study provide support for the hypotheses that VO_2, HR, and RPE, undergo statistically significant increases as speed increases during both water and land treadmill walking. SBP undergoes a statistically significant increase as speed increases during water treadmill walking, but not land treadmill walking. This study also provides support for the hypotheses that VO_2, HR, RPE, and SBP values during water treadmill walking are statistically higher than during land treadmill walking at speeds of 2.5 mph and 3.0 mph. The hypotheses that the combination of greater speed and water treadmill walking produced the greatest statistically significant values for VO_2, HR, RPE, and SBP were also supported. Important conclusions concerning practical use of the results of this study are as follows:

1. For older adults, walking on a water treadmill at waist depth in warm water creates a greater demand on the cardiovascular system than walking on a land treadmill at speeds of 2.5 mph and 3.0 mph.
2. For older adults, SBP increases with increased speed during water treadmill walking at waist depth in 92^0F water.
3. Caution should be used when prescribing water treadmill exercise to older individuals with hypertension.
4. BP should be monitored during water treadmill walking, especially for those with a history of hypertension.
5. Walking duration and rate of walking speeds are inaccurate methods of monitoring exercise intensity if transitioned from a land treadmill program to a water treadmill program.

It is essential to monitor the cardiovascular intensity of physical activity in water, especially when cross training between land and water activities. HR and RPE are effective methods of monitoring exercise intensity during therapeutic water treadmill walking at waist depth. It is also important to monitor BP during water exercise, especially for those with a history hypertension. Because of the difficulty measuring BP during water exercise, BP should be measured prior to water exercise and during scheduled stoppages in water activity.

Water temperature and age of the participants have been reported to affect VO_2, HR, and SBP (ACSM, 1998; Gleim & Nicholas, 1989). Although not independent or dependent variables in this study, these characteristics were present in the study. Comparing the results of this study with the results of prior studies, VO_2, HR, and SBP findings were similar regardless of water temperature and age. Water temperature may increase the degree to which HR is higher during water treadmill walking than land treadmill walking. Therefore, understanding the cardiovascular effects of water treadmill walking will allow the safe and efficient participation in this mode of exercise.

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Appendix A

VA Medical Center Informed Consent Form

Appendix A

VA Medical Center Informed Consent Form

VA Department of Veterans Affairs

VA RESEARCH CONSENT FORM

(Version Date: October 19, 2004)

Subject Name: ______________________ **Date:** ______

Title of Study: Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults

Principal Investigator: David Dolbow **VAMC: Murfreesboro**

The following information is provided to inform you about the research study and your participation in it. Please read the form and feel free to ask any questions you may have about the information provided below. You will be given the opportunity to ask questions and have your questions answered before making a decision to participate in this study. You will be given a copy of this consent form.

PURPOSE OF THE STUDY

You are being asked to take part in a research study to assist in learning more about how the heart in a person 55 to 64 years of age reacts to walking on a treadmill in warm water. This will help healthcare professionals design safer and more effective exercise programs for patients in this age group.

DESCRIPTION OF THE PROCEDURES AND APPROXIMATE DURATION OF THE STUDY

If you agree to take part in this study, you will be asked to complete three visits taking about 2½ hours of your time. At the first visit, you will be asked to complete a short form that will show if you are ready to take part in physical activity. Your height, weight, heart rate and blood pressure will be measured and your joint range of motion and muscle strength will be tested by an exercise specialist. You will be able to take part in the study if these tests show you are in good health. In order for you to become used to walking on both land and water treadmills, you will practice walking on both kinds of treadmills for 10 minutes. The entire visit will take about 60 minutes.

A week later, you will be tested on one type of treadmill, followed by testing on the other treadmill the next day. One test will be on a land treadmill at 70°F and the other will be on a water treadmill in 92° F water that is about waist deep. You will complete the two tests in random order based on flipping a coin. The tests will be done at least 24 hours apart and at least 2 hours after you have eaten. On the testing days, you will be asked not to smoke or have tea, coffee or other products with caffeine before your study visit.

Both treadmill sessions will begin with 2 minutes of warm-up walking at 1.8 miles per hour, followed by three 5-minute walks at speeds of 2.2 miles per hour, 2.8 miles per hour and 3.4 miles per hour. There will be a rest period after each walking bout until your heart rate has returned to within 10 beats of your resting heart rate. You will be asked to walk in a normal fashion with normal arm swing. Your oxygen uptake, heart rate, rate of perceived effort and blood pressure will be measured during the last two minutes of each exercise bout.

The exercise specialist may stop the testing and take you out of the study if it does not seem to be in your best interest to continue.

Subject's Initials: ____________

VA FORM
JAN 1990 10-1086

IRB Approval Date: OCT 26 2004 IRB Expiration Date: OCT 26 2005 R&D Committee Chair Initials: [signature]

Appendix A

VA Medical Center Informed Consent Form

VA Department of Veterans Affairs

RESEARCH CONSENT FORM

(Version Date: October 19, 2004/Continuation Page 2)

Subject Name: ______________________ **Date:** ______

Title of Study: Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults

Principal Investigator: David Dolbow **VAMC: Murfreesboro**

DESCRIPTION OF THE DISCOMFORTS, INCONVENIENCES, AND/OR RISKS

Completing the three study visits may be inconvenient. Not smoking before visits may be bothersome, and if you are used to having caffeine every morning, not having it may cause you to develop a severe headache.

During the treadmill sessions, you may experience feelings of physical exertion comparable to slow, medium and fast walking. These could include increased heart and breathing rate, stronger heartbeat, sweating and muscle tiredness. Walking in warm water may cause you to feel overheated. If at any time you feel too tired or uncomfortable to continue, you should stop walking and tell the exercise specialist.

For study participants who are veterans:

As a veteran subject, you will not be required to pay for any treatment received as a research subject which is being done solely for the purpose of this research study. However, your insurance carrier will be billed for all routine care and clinical procedures, if applicable. If you are in a "priority group # 7 veteran category" you are subject to making a co-payment as indicated by a means test. Your doctor should be able to provide you with this information or refer you to the appropriate individual for any questions you may have. As a veteran, you will receive medical care and treatment for injuries suffered as a result of participating in a VA research program in accordance with Federal Law. You will incur no additional charges for additional medical care that may result from injury or complications that are a direct result of your participation in this study.

For study participants who are not veterans and participating in a VA funded study:

Immediate necessary care will be provided by the Veterans Affairs Medical Center for injuries suffered as a result of participating in this research study. You or your insurance provider will be financially responsible for the costs of this immediate, necessary treatment. The VA will not provide additional medical care or be responsible for the costs of additional medical care beyond immediate necessary care. Further, VA will not be responsible for monetary compensation for such injury.

ANTICIPATED BENEFITS RESULTING FROM STUDY PARTICIPATION

The study tests may provide helpful information about your level of physical fitness. You will not receive any other benefit.

This study may benefit science and humankind by increasing knowledge of the physical responses of older people to water treadmill walking, which would in turn help healthcare experts develop safer, more effective water rehabilitation and physical training programs.

Subject's Initials ______

VA FORM
JAN 1990 10-1086

IRB Approval Date: OCT 28 2004 IRB Expiration Date: OCT 28 2005 R&D Committee Chair Initials: RBW

Appendix A

VA Medical Center Informed Consent Form

VA Department of Veterans Affairs

RESEARCH CONSENT FORM

(Version Date: October 19, 2004/Continuation Page 3)

Subject Name: ______________________ **Date:** ______

Title of Study: Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults

Principal Investigator: David Dolbow **VAMC: Murfreesboro**

ALTERNATIVE PROCEDURES/OTHER TREATMENT AVAILABLE

Since this study does not involve treatment, you have the option of not taking part.

CONTACT INFORMATION

If you have questions about this study or you need to report a research-related injury, please contact David Dolbow, at 615-893-1360, extension 3915 or my Faculty Advisor, Dr. Charles Huddleston, at 615-893-1360, extension 6117.

If you have general questions about giving consent or your rights as a participant in this study, you can call the Vanderbilt University Institutional Review Board Office at (615) 322-2918 or the Research and Development Service Office at (615) 327-4751, ext. 5287.

RESEARCH RESULTS

In the event new information becomes known that may affect the risks and/or benefits associated with this study or your willingness to participate, you will be informed so you can decide whether to continue in the study.

Forms and other data from the study will be kept in locked files in the kinesiotherapy office at the Murfreesboro VA Medical Center. After six years, they will be destroyed.

If the results of this study are reported in medical journals or at meetings, you will not be identified by name, by recognizable photograph or by any other means without your specific consent.

CONFIDENTIALITY AND PRIVACY

To protect your privacy, your research record will be labeled with a study number instead of your name. Your research records will be maintained according to this medical center's requirements. All information obtained about you during the research study will be kept as confidential as legally possible and will be accessible only to the investigators and any appropriate government agency. Research records, like any other hospital records, may be inspected by federal regulatory authorities, including the Office for Human Research Protections (OHRP), state regulatory authorities and legally authorized parties.

Subject's Initials ______

VA FORM
JAN 1990 10-1086

IRB Approval Date: ______ IRB Expiration Date: ______ R&D Committee Chair Initials: ______

Appendix A

VA Medical Center Informed Consent Form

VA Department of Veterans Affairs

RESEARCH CONSENT FORM
(Version Date: October 19, 2004/Continuation Page 4)

Subject Name: ______________________ **Date:** ______

Title of Study: ***Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults***

Principal Investigator: David Dolbow **VAMC: Murfreesboro**

STATEMENT OF PERSON AGREEING TO PARTICIPATE IN THIS RESEARCH STUDY

I have read ( ) this consent form or have had it read to me ( ).

_________has explained the study to me and all of my questions have been answered. I have been told of the risks or discomforts and possible benefits of the study. I have been told of other choices of treatment available to me.

If I do not take part in this study, my refusal to participate will involve no penalty or loss of rights to which I am entitled. I may withdraw from this study at any time without penalty or loss of VA or other benefits to which I am entitled.

I have been told my rights as a research subject, and I voluntarily consent to participate in this study. I have been told what the study is about and how and why it is being done. All my questions have been answered.

I will receive a signed copy of this consent form.

Subject's Signature Date

______________________ ________

Signature of Subject's Representative*/Relationship Date

______________________ ________

Signature of Witness Date

______________________ ________

Signature of Investigator Date

*Only required if subject is not competent.

Subject's Initials ______

VA FORM
JAN 1990 10-1086

IRB Approval Date: OCT 25 2004 IRB Expiration Date: OCT 25 2005 R&D Committee Chair Initials: RHL

Appendix B

Authorization to Use/Disclose protected Health Information Form

Appendix B

Authorization to Use/Disclose Protected Health Information Form

Veterans Affairs Tennessee Valley Healthcare System (VATVHS)
Informed Consent Document for Research

Principal Investigator: David Dolbow **Version Date: October 19, 2004**
Study Title: Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults
Institution/Hospital: VATVHS – Murfreesboro VAMC

Authorization to Use/Disclose Protected Health Information

(This Authorization applies only to Participants enrolled at VATVHS)

Protected health information (PHI) is individually identifiable health information that is or has been collected or maintained by VA Tennessee Valley Healthcare System (VATVHS), including information that is collected for research purposes only, and can be linked back to the individual participant. Once this has occurred, use or disclosure of such information must follow federal privacy guidelines. A decision to participate in this research means that you agree to let the research team use and share your PHI as described below.

As part of the study, David Dolbow and his study team may report the results of your study tests to those groups named below. If your research record is reviewed by any of these groups, they may also need to review your entire VATVHS medical record. Your records may also be reviewed in order to meet federal or state regulations. Reviewers may include representatives from the Food and Drug Administration, Office of Human Research Protections, Department of Veterans Affairs, the VATVHS Research and Development Committee, the Vanderbilt University Institutional Review Board and the Middle Tennessee State University Institutional Review Board. The persons or groups listed above may not be legally required to follow the procedures and limitations in this Informed Consent and Authorization Form and may release your health information to others. All reasonable efforts will be made to keep your personal health information private and confidential.

The study results will be retained in your research record for at least six years after the study is completed. At that time the research information not already in your medical record will be destroyed. Any research information in your medical record will be kept indefinitely.

If you decide to withdraw your authorization to use or disclose your PHI, we ask that you contact David Dolbow and/or the VATVHS Director of Health Information Management in writing and let them know that you are withdrawing your authorization.

David Dolbow
PM&RS/KT (117)
VATVHS
3400 Lebanon Pike
Murfreesboro, TN 37130

Director of Health Information Management
VATVHS
1310 24th Avenue South
Nashville, TN 37212-2637
615-327-5358

At that time we will discontinue further collection of any information about you. However, the health information collected prior to this withdrawal may continue to be used for the purposes of reporting and research integrity.

Signature: ______________________________ Date: ________________

Date of IRB Approval: OCT 28 2004 IRB

Date of IRB expiration: OCT 26 2005 IRB

Appendix C

Musculoseletal/Cardiovascular Screen

Musculoskeletal/Cardiovascular Screen

Musculoskeletal/Cardiovascular Screen

Participant ID Number______________

Date____________

Height ___ Weight ___

Blood Pressure: Heart Rate:

Supine ____ Standing ____

Sitting ____

Standing ____

Discomfort During Standing or Walking: Yes ___ No ___

Range of Motion:	Strength:
Hip Fexion ____	Hip Flexion____
Hip Extension____	Hip Extension ____
Knee Flexion ____	Knee Flexion ____
Knee Extension ____	Knee Extension ____
Ankle Dorsiflexion ____	Ankle Dorsiflexion ___
Ankle Plantar Fexion ____	Ankle Plantarflexion ___

INSTITUTIONAL REVIEW BOARD
REVIEWED / APPROVED BY THE
CHAIRMAN

Appendix D

Physical Activity Readiness Questionnaire (PAR-Q)

Appendix D

Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire (PAR-Q)

Participant ID Number____________

Date__________

1. Has your doctor ever said you have heart trouble?

   Yes ____ No____

2. Do you frequently have pains in your heart and chest?

   Yes____ No____

3. Do you often feel faint or have spells of severe dizziness?

   Yes____ No____

4. Has a doctor ever said your blood pressure was too high?

   Yes____ No____

5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise or might be made worse with exercise?

   Yes____ No____

6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

   Yes____ No____

7. Are you over 64 and not accustomed to vigorous exercise?

   Yes____ No____

8. Are you afraid of water?

   Yes____ No____

INSTITUTIONAL REVIEW BOARD
REVIEWED / APPROVED BY THE
CHAIRMAN
DATE

Appendix E

Middle Tennessee State University IRB Approval

Appendix E

Middle Tennessee State University IRB Approval

Institutional Review Board
P.O. Box 124
Middle Tennessee State University
Murfreesboro, Tennessee 37132
Office: (615) 898-5005

MIDDLE TENNESSEE STATE UNIVERSITY

05-090 IRB expedited review approval

11/10/04
Protocol Title: Therapeutic Water Treadmill Walking in Older Adults
Protocol Number: 05-090
Mr. David R. Dolbow
113 Countrywood Dr.
Lebanon, TN 37087

Dear Mr. Dolbow:

The MTSU Institutional Review Board, or representative of the IRB, has reviewed your research proposal identified above. It has determined that the study poses minimal risk to subjects and qualifies for expedited review under 45 CFR 46.110 and 21 CFR 56.110.

Please note that any unanticipated harms to subjects or adverse events must be reported to the Office of Sponsored Programs at (615) 898-5005.

Approval is granted for one (1) year from the date of this letter for 50 subjects.

You will need to submit an end-of-project report to the Office of Research and Sponsored Programs upon completion of your research.

Please note that any change to the protocol must be submitted to the IRB before implementing this change.

Sincerely,

Robert Hood by: Kim Collins

Robert Hood, Ph.D.
Chair, Institutional Review Board
Associate Professor
Department of Philosophy
Middle Tennessee State University

Appendix F

Vanderbilt University IRB Approval

Appendix F

Vanderbilt University IRB Approval

Vanderbilt University
Institutional Review Board
D-3232 Medical Center North Nashville, Tennessee 37232-2598
(615) 322-2918 Fax: (615) 343-2648
www.mc.vanderbilt.edu/irb

October 26, 2004

David R. Dolbow, M.Ed.
VATVHS Physical Medicine & Rehabilitation Service - MTSU
113 Countrywood Drive
Lebanon, TN 37087

Charles Huddleston, M.D.
Physical Medicine & Rehabilitation Service - Murfreesboro VAMC
3400 Lebanon Pike
Murfreesboro, TN 37129

RE: IRB# 040925 "Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults"

REVISED NOVEMBER 2, 2004

Dear Dr. Dolbow:

A sub-committee of the Institutional Review Board reviewed the research application identified above. The sub-committee determined the study poses minimal risk to participants, and the application is approved under 45 CFR 46.110 (f)(4). Approval is extended for the Application for Human Research and VATVHS Consent Document dated October 19, 2004, the Physical Activity Readiness Questionnaire, the Musculoskeletal/Cardiovascular Screen and the Investigator's Protocol.

Please be reminded to forward a copy of the MTSU IRB approval documentation as soon as it becomes available.

The Consent Form(s) have been stamped with the approval and expiration date and this copy should be used when obtaining the participant's signature. Federal regulations require that the original copy of the participant's consent be maintained in the principal investigator's files and that a copy be given to the subject at the time of consent. An additional record (i.e., case report form, medical record, database, etc.) of the consent process should also be maintained in a separate location for documentation purposes.

As the Principal Investigator, you are responsible for the accurate documentation, investigation and follow-up of all possible study-related adverse events and unanticipated problems involving risks to participants or others. The IRB Adverse Event reporting policy III.G is located on the IRB website at http://www.mc.vanderbilt.edu/irb/. For your convenience, a flowchart is attached.

If an approval is required from an additional source other than the Vanderbilt IRB, this must be obtained prior to study initiation. These approvals may include, but are not limited to CRC, SRC, VA, IND, IDE.

Please note that approval is for a 12-month period. Any changes to the research study must be presented to the IRB for approval prior to implementation.

DATE OF IRB APPROVAL: October 26, 2004 **DATE OF IRB EXPIRATION: October 26, 2005**

Sincerely,

Grant R. Wilkinson, Ph.D., D.Sc., Vice-Chair
Institutional Review Board
Health Sciences Committee #3

Appendix G

VA Research and Development Approval

Appendix G

VA Research and Development Approval

ORIGINAL

Department of Veterans Affairs

Memorandum

Date: November 24, 2004

From: Chair, Research and Development Committee (151)

Subj: IRB # 040925, "Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults" (Doctoral Dissertation)

To: David Dolbow, MS/Physical Medicine and Rehabilitation Services (VATVHS)

1. At its meeting on 11/12/04, the Research and Development (R&D) reviewed the following documents related to the study indicated above:

- Doctoral Dissertation Proposal
- VU IRB application with study instruments (version date 10/19/04)
- VU IRB approval (dated 10/26/04)
- VA Form 10-1086 (version date 10/19/04)
- TVHS HIPAA rider (version date 10/19/04)
- VA Form 10-1436 (Project Data Sheet with abstract)
- VA form 10-5368 (Investigator Data Sheet)
- VA Form 10-1223 (signed 11/03/04)
- VA Form – Request to Conduct Research

2. Please note that the original copies of the signed consent forms must be maintained by the principal investigator. Signed copies of the consent form are to be given to the study participants and copies sent to the Research and Development Service for scanning into the participant's electronic medical record. Secondary documentation of the consent process should also be maintained in the computerized Patient Record System (CPRS) and/or other record system (i.e. office/clinic file, medical record, case report form, etc.).

3. Please be reminded any serious and unexpected adverse events involving study participants enrolled at the VATVHS and other must be promptly reported to the Research Office.
If the adverse event is alarming, you are required to report the event immediately.

4. Please note that this approval is for a 12-month period only, as determined by the Vanderbilt University IRB approval date. Any further changes to the protocol and/or consent form must be presented to the Institutional Review Board (IRB) and the R&D Committee for approval before implementation of the changes.

5. The Veterans Health Administration requires the contributions of the Department of Veterans Affairs to research are appropriately acknowledged. Please find attached a copy of the VA Handbook 1200.19, Presentation of Research Results, for your reference.

Appendix G

VA Research and Development Approval

Dolbow, David
November 24, 2004
Page 2

VATVHS R&D Committee Approval: 11/12/2004

for Roy Zent, M.D./Ph.D.

Cc: VU IRB
Teresa Holtman, D. Pharm.

Appendix G

VA Research and Development Approval

Department of Veterans Affairs | **REPORT OF SUBCOMMITTEE ON HUMAN STUDIES**

Study Title: Cardiovascular System Response to Therapeutic Water Treadmill Walking in Older Adults
Principal Investigator: David R. Dolbow, M.Ed.

VAMC: VA Tennessee Valley Healthcare System, Murfreesboro Campus **Review Date:** November 3, 2004

COMMITTEE FINDINGS:

1. The information given in the Informed Consent under the <u>Description of Research by Investigator</u> is complete, accurate, and understandable to a research subject or a surrogate who possesses standard reading and comprehension skills.	☑ YES ☐ NO
2. The informed consent is obtained by the principal investigator or a trained and supervised designate under suitable circumstances.	☑ YES ☐ NO
3. Every effort has been made to decrease risk to subject(s)?	☑ YES ☐ NO
4. The potential research benefits justify the risk to subject(s)?	☑ YES ☐ NO
5. If the subject is <u>incompetent</u> and surrogate consent is obtained, have all the following conditions been met; a.) the research can't be done on competent subjects; b.) there is a no risk to the subject, or if risk exists the direct benefit to the subject is substantially greater; c.) if an incompetent subject resists, he/she will not have to participate; d.) if there exists any question about the subject's competency, the basis for decision on competency has been fully described.	☐ YES ☐ NO N/A
6. If the subject is paid the payment reasonable and commensurate with the subject's contribution.	☐ YES ☐ NO ☑ NA
7. Members of minority groups and men have been included in the study population whenever possible and scientifically desirable.	☑ YES ☐ NO

8. Comments: (Indicate if Expedited Review) Expedited pursuant to 45 CFR 46.110(F)(4)

RECOMMENDATION: ☑ **APPROVE** ☐ **DISAPPROVE/REVISE**

SIGNATURE OF CHAIRMAN	DATE
[signature]	11/3/04

VA FORM
OCT 1995 (R) 10-1223