

Advantages and Concerns of  
Aquatic Exercise for  
Cardiovascular Rehabilitation Patients

By

Joy Murry

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Adviser's Name

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## CHAPTER I

### INTRODUCTION

Cardiovascular diseases (CVD) lead the world in causes of death (46,54). After a cardiovascular health event, individuals are encouraged to attend *cardiovascular rehabilitation (CR)*. CR is an important, monitored and supervised aerobic and strength training exercise to improve quality of life, knowledge, physiological function, and functional capacity (9,15,29,32,46,51,52,53,54,56,58,59,64). Consistent, planned exercise, especially aerobic exercise, can help improve and protect the heart from future cardiovascular events (14,17,19,25,26,27,34,35,40,42,46,49,50,52,56,58,62,64,67).

Aquatic exercise is popular for all ages, healthy individuals, individuals with a disability, individuals with a diagnosed disease, individuals with special needs, and individuals in physical therapy (4,8,10,14,26,32,34,37,43,48,53,56,58,59,64,66). A huge variety of aerobic and strength exercises can be performed in water (4,20,30,32,66). For stable and low-risk heart patients, aquatic environment research has proven to provide more positives than negatives for cardiovascular health (10,14,40,42,53,64,66). Stable CR patients could maintain or slightly increase cardiovascular health benefits such as increase exercise tolerance (61,64), lower resting *heart rate (HR)* (8,14), and increased exercise *oxygen consumption (VO<sub>2</sub>)* (8,14,40,61).

## PROBLEM STATEMENT

Land CR is the most traditional, widely used, and scientifically studied form of aerobic and strength exercises for CR patients. Properties of land environments place different physiological demands on the body compared to properties of aquatic environments (5,11,30,32,53,64,66). Land exercise may not prove to be best for all patients in CR (26,32,37). Even though land CR exercise is low impact there is an increasing demand for low impact exercise options (26,32,39,53,66). Today, about seventy percent of the American population is inactive. With an expected growing population, CVD will also be on the rise with a need for the availability of exercise options which may include new advances in aquatic CR (46). Aquatic pools are a low-impact aerobic and strength training option that provide benefits for stable patients that require reduced weight-bearing stress (30,32,66,).

## PURPOSE

The purpose of this review paper is to summarize current research on the advantages and concerns of an aquatic environment for stable CR patients. The goal of aquatic CR programs is to initiate the same healing process as other programs, improve cardiovascular health, and minimize future cardiovascular events while inflicting less stress and strain on the body as a whole.

## DEFINITIONS

1. Acute myocardial infarction (MI): “occurs when myocardial ischemia, a diminished blood supply to the heart, exceeds a critical threshold and overwhelms myocardial cellular repair mechanisms designed to maintain normal operating function and homeostasis. Ischemia at this critical threshold level for an extended period results in irreversible myocardial cell damage or death (66).” Also known as a myocardial infarction (MI) (1).
2. Aerobic capacity: “the highest amount of oxygen consumed during maximal exercise in activities that use the large muscle groups in the legs or arms and legs combined. Aerobic capacity, aerobic power, functional capacity, functional aerobic capacity, maximal functional capacity, cardiorespiratory fitness, cardiovascular fitness, maximal oxygen intake, and maximal oxygen uptake are terms that are often used interchangeably (2).”
3. Aerobic fitness: “the capacity to exercise in aerobic activities for a prolonged period where the amount of activity depends on aerobic capacity and cardiorespiratory endurance (3).”
4. Blood lactate (BL): “Lactic acid that appears in the blood as a result of anaerobic metabolism when oxygen delivery to the tissues is insufficient to support normal metabolic demands (12).”
5. Blood lipids: ‘fats’ in the blood (36)
6. Blood pressure (BP): “pressure exerted by the blood upon the walls of the blood vessels (13).”

7. Cardiovascular fitness: the heart and blood vessels need to meet the cell's demand for blood transporting oxygen and nutrients, and removing waste (65)
8. Cardiovascular rehabilitation (CR): “the sum of interventions required to ensure the best physical, psychological and social conditions so that patients with cardiac disease may preserve or assume their proper pace in society and, through improved health behaviors, slow or reverse progression of the disease (29).”
9. Congestive heart failure (CHF): “Inability of the heart to keep up with the demands on it, with failure of the heart to pump blood with normal efficiency (21).”
10. Coronary artery disease (CAD): “when your coronary arteries — the major blood vessels that supply your heart with blood, oxygen and nutrients — become damaged or diseased. Cholesterol-containing deposits (plaque) in your arteries and inflammation are usually to blame for coronary artery disease (22).”
11. Ejection fraction: “A measurement of how much blood the left ventricle pumps out with each contraction (23).”
12. Exercise capacity: “the maximum amount of physical exertion that a patient can sustain (18).”
13. Functional capacity: “The extent to which a person can increase exercise intensity and maintain increased levels, dependent largely on cardiovascular fitness (24).”
14. Heart rate (HR): “The number of heartbeats per unit of time, usually per minute. The heart rate is based on the number of contractions of the ventricles (the lower chambers of the heart) (28).”
15. Maximum oxygen consumption (VO<sub>2</sub> max): “The point where a plateau of oxygen uptake occurs despite an increase in workload (30).”

16. MET: “A metabolic unit used to quantify the intensity of physical activity, which is defined as the ratio of the metabolic rate during exercise to the metabolic rate at rest (41).”
17. Peak VO<sub>2</sub>: the highest volume of oxygen taken in during exercise without a plateau (66).
18. Peripheral vascular resistance: “vascular resistance to the flow of blood in peripheral arterial vessels that is typically a function of the internal vessel diameter, vessel length, and blood viscosity—called also *peripheral resistance* (47).”
19. Rating of perceived exertion (RPE): “The Borg Rating of Perceived Exertion (RPE) is a way of measuring physical activity intensity level. Perceived exertion is how hard you feel like your body is working (45).”
20. Stroke volume: “the amount of blood pumped out of the heart (left ventricle - to the body) during each contraction measured in mL/beat (milliliters per beat) (55).”
21. VO<sub>2</sub>: oxygen consumption in milliliters (ml) related to body mass (kilograms (kg)) and time (minutes (min)) (2)
22. Xiphoid process: bottom tip of the sternum

#### DELIMITATIONS

1. Articles used were either available from University of Wisconsin – River Falls, Carleton College’s Laurence McKinley Gould Library in Northfield, MN, or PubMed.com.
2. Definitions were cited from reliable websites after searching on Google.
3. Relevant articles were searched for until March 2015.

## CHAPTER II

### LITERATURE REVIEW

#### HISTORY OF CARDIAC REHABILITATION

Beginning history of land CR is small, and aquatic CR is not found in the journal literature. The earliest land CR date found was in the late 1930's with researchers who examined an individual who passed away from a *myocardial infarction (MI)*. Researchers found that firm cardiovascular tissue scars develop within six weeks of an MI. Therefore, strict bed rest for six weeks was instituted as the best way to reduce scarring for post MI patients. Six weeks of bed rest resulted in individuals becoming weak, fearful of activity, anxious, depressed, and unemployed. Researchers started questioning the effectiveness of six weeks of bed rest. The next advancement in CR was the chair method (instead of lying in a bed, sitting upright in a chair) in the early 1950's by Levine and Lown. The duration of the chair method is not known. Researchers view the early 1950's as the start of CR as a formal treatment (29). Research since the 1960's has proven CR to be a preventative tool against future cardiovascular health events (46).

By the 1970's, CR bed rest had been reduced to only a few days because exercise tolerance was reduced by 50% if bed rest lasted up to three weeks. Since the 1970's more randomized control studies have been done to determine appropriate exercise for CR patients (29). I could not find in the journal literature the exact date when exercise was initiated a day after a heart procedure or event.

## CARDIAC REHABILITATION

CR is supervised aerobic and strength exercise along with monitoring of physiological responses (blood pressure, heart rate, and electrical heart rhythms). Included is education on exercise and lifestyle changes, risk factor control, cardiovascular pharmacology, and a psychological health screening (46,51,54,64). One definition summarizes CR as:

*“Cardiac rehabilitation is the sum of interventions required to ensure the best physical, psychological and social conditions so that patients with cardiovascular disease may preserve or assume their proper pace in society and, through improved health behaviors, slow or reverse progression of the disease (29).” Cardiovascular “rehabilitation should add life to years (52).”*

CR improves individuals physically, physiologically, and psychologically (51). CR can improve *cardiovascular fitness, functional capacity*, mobility, independence, quality of life, and modify risk factors (48,54). Participation in CR programs can help patients decrease their risk of morbidity, mortality and recurring cardiac events (46,51,52). Positively, the risk of a cardiac event in CR per 1,000,000 people is 8.6 people for cardiac arrest, 4.6 people for *acute myocardial infarction (MI)*, and 1.3 people for cardiac death (46); the risk of a cardiac event in CR is low (46).

## RISK FACTORS OF NO CARDIAC REHABILITATION

Individuals who practice sedentary, inactive behavior, increase their risk of poor cardiac health. Inactive individuals function differently physiologically compared to an individual who practices cardiovascular and strength exercises. It has been found that even if an individual's sedentary lifestyle is not physically visible in their body composition, it could eventually show in one or more increased triglycerides, total cholesterol, blood glucose, and insulin resistance. A linear relationship does exist between amount of sedentary behavior and increased risk of poor health outcomes (62). Sedentary behavior can increase risk of lower quality of life, social isolation, anxiety, and depression (54).

## HISTORY OF AQUATIC EXERCISE

According to some researchers aquatic exercise has been around for years for rehabilitation, but not CR specifically (8,9,53,66). Benefits of aquatic environments for healing in American history can date back to 1911 when Dr. Charles Leroy Lowman started using therapeutic tubs to treat his patients with various diseases (9).

According to other researchers, heart patients were cautioned for decades to avoid aquatic exercise, especially swimming, to avoid physiological cardiorespiratory changes (64). These cautions are responsibly safe and ethical considering there was very little research evidence of aquatic exercise for various cardiovascular health concerns. More research is needed even though it has increased in recent decades (8,42,58,64).

## PROPERTIES OF AQUATIC EXERCISE AND ENVIRONMENT

An aquatic environment is a great place to perform a variety of enjoyable, safe, easy to use, health beneficial cardiovascular and strength exercises (8,26,30,32,66). There are two main modes of aquatic exercise in cardiovascular rehabilitation important for cardiovascular health benefits: aerobic and strength. Finding the best aerobic aquatic exercise mode is important for enjoyment, thus benefiting greater acute physiological responses (30).

### **Modes of Exercise**

First, aquatic walking can be performed so many ways such as stationary, across the pool, in a flume, on a Flowmill (“treadmill at the base of a water flume (10)”), on aquatic treadmills, at different stride lengths, and with varying cadences (8,10,19,42,46,64). Aquatic walking can be performed at hip immersion depth up to *xiphoid process* immersion depth (8,10,61,). Walking on a non-motorized treadmill at xiphoid process immersion depths was comparable to treadmill walking on land in producing similar physiological responses such as HR, *maximal oxygen uptake (VO<sub>2</sub>)*, *blood lactate (BL)*, and *rating of perceived exertion (RPE)* (10). Non-motorized treadmills are harder than motorized treadmills. Treadmill walking at hip immersion depth is more demanding than xiphoid process immersion depth. Moderate to vigorous intensity can be achieved at hip or xiphoid process immersion levels. There is a linear relationship between walking speed, VO<sub>2</sub> and HR. Physiological responses are higher in water at a less RPE, while physiological responses are higher on land at a higher RPE. At greater cadences RPE is greater at hip than xiphoid process immersion depth. VO<sub>2</sub> and HR are higher at hip immersion levels than xiphoid process levels at high step cadences (10).

Aquatic running can be performed stationary (hip immersion depth) or dynamically (hip or higher immersion depth). Hip immersion depth is lower impact compared to land exercise resulting in less muscle use, blood flow, and oxygen need. Simultaneously, hip immersion depth is higher impact than xiphoid immersion depth resulting more muscle use, blood flow, and oxygen need (4). Xiphoid process immersion depth is lower impact aerobic exercise because buoyancy reduces body weight and leg muscle use, therefore, a great option for anyone with joint pain and limited range of motion (4,6,32). Increased range of motion and freedom of movement is probable with xiphoid process immersion depth (32). Xiphoid process immersion depth creates lower VO<sub>2</sub> max and heart rate responses compared to hip immersion depth and land treadmill running (4,6). This is a positive for cardiovascular tissue healing.

Aquatic aerobic exercise is popular (5,8). They are great for individuals who are seeking low impact exercise to maintain or improve physical fitness (4). Aquatic aerobic exercises are typically performed in place at hip immersion depth (32,53). There are many gymnastic exercises including: frontal kicks, stationary running, jumping jacks, cross-country skiing, side stepping, hopping, jumping, and step benching (4,5,8,30,39,59,64). These exercises can be great for interval aerobic cardiovascular training. They can positively produce similar VO<sub>2</sub> and HR physiological responses as land (4).

Researchers found interval training for *congestive heart failure (CHF)* is safe at 40-60% VO<sub>2</sub> max (46). Step benching produces lower heart rates and VO<sub>2</sub> maxes in water at same RPE intensity as on land (8). Three weeks into recovery, aquatic gymnastics was found to be tolerable for newly stable *coronary artery disease (CAD)* and CHF patients at a  $P < .05$  (59). Stable CHF and CAD patients both tolerated aquatic gymnastics at target heartrate for

50 minutes, five days a week, for three weeks. With *left ventricle ejection fraction (LVEF)* at 40% or lower, and  $VO_2$  peaks at 20 ml min kg or less, CAD and CHF patients both had improvements in their cardiorespiratory efficiency. An increase in resting LVEF and exercise HR are a result from aquatic gymnastic exercise was similar to the land gymnastic exercise group. A concern is for CHF patients hearts being over stretched and worked from the increased blood filing (59).

Aquatic cycling is not used as much. Aquatic immersion levels can vary for aquatic cycling. Intensity is adjusted by increasing or decreasing cadence. Increasing or decreasing cadence by intervals of 10 rpm (rotations per minute) changes intensity level. Cadences between 60-70 rpm can produce adequate levels of aerobic exercise for the inactive and elderly. Aquatic cycling produces similar max HR and  $VO_2$  max and lower BL as land cycling in young, healthy men (66). Aquatic cycling has been found to be the best aquatic aerobic exercise to most resemble land  $VO_2$  (32,53). CHF patients' ability to cycle at 70 Watts to 110 Watts in thermo neutral aquatic temperatures is an indicator that aquatic cycling is tolerable (53). A concern for aquatic cycling is the use of stronger muscle contractions for each revolution to maintain or increase intensity (66).

Swimming is popular and one of the most practiced aerobic cardiovascular exercises (14,40,53,58). "Swimming is a rhythmic, dynamic form of endurance exercise involving a large muscle mass (58)." There are several swimming strokes individuals can use to influence cardiovascular response. Swimming intensity and physiological responses are comparable to running on land (34). Swimming is great for individuals who are older, overweight, and/or need reduced weight bearing and joint stress (43). Swimming has been found to be safe for CHF individuals (46). Swimming could allow stable CR patients to

exercise longer from a reduced HR. A concern is cardiac remodeling from the increased BP in the heart chambers over time (34).

Strength training has positive effects on cardiovascular health (20,46). “Strength is the neuromuscular ability to overcome or oppose external resistance by means of muscular force production (20).” Within the past 15 years, strength training has been found to be important in the rehabilitative process. Studies have found individuals adapt to normal life quicker if strength and aerobic CR exercise are used together (64). The American Heart Association recommends at least two days of strength training per week (61).

Recommendations for strength training are 10-15 repetitions, at 70% age predicted HR max (14). Heart patients are allowed to strength train to the point of muscle fatigue. Form is very important to target specific muscle groups and to prevent injury (46).

Specialized aquatic tools exist to add resistance to exercises such as weights, elastic bands, air devices, surface tools, and flotation devices (14,19,20,30,31,64). Resistance training in water with elastic bands increases strength equivalent isokinetic machines on land (8). Older adults can increase strength within a twelve week aquatic cardio and strength program (37). Aquatic strength training opposed to land strength training may be better for individuals who are older, obese, or who have mobility limitations (40).

Rate of strength gains in low risk CAD patients is the same as the same exercise regimen and intensity on land (64). CAD patients’ strength exercise can be performed three days a week with lower weight and higher repetitions of one to three sets and 8-15 reps. Older CAD individuals can lift 30% of their max when they begin. For previous strength trainers, CAD patients should start with 50% of their max (46). Low weight, high reps is a safe strength prescription, this worked for CAD patients (46,61). A concern is CHF patients

should avoid isometric high resistance exercise (46). Muscle tension is created with flotation devices (less density than water), when the muscles resist the flotation of the device. Muscle tension with surface tools is created by the speed of movement creating drag force. Both are affected by the surface area of the object. Aquatic strength training is beneficial for muscular range of motion, and increasing blood circulation (20). All major muscle groups can be exercised (20,30). Aquatic strength training can be a concern for not providing enough to maintain or strengthen a regular exerciser (20).

### **Immersion Levels**

Immersion levels are typically hip or xiphoid process immersion depths. Hip immersion depth floor contact creates greater HR, *oxygen uptake (VO<sub>2</sub>)*, and RPE, compared to xiphoid process immersion depth. These greater physiological responses meet or exceed cardiovascular fitness ACSM recommendations (42). Hip immersion is harder because buoyancy is lower and increased ground reaction force creates more muscle activation (8,31,32,66).

Xiphoid process immersion depth running HR is similar at about 86-95% of land running, and VO<sub>2</sub> max is about 73-92% of land running (40). HR is decreased by about 7-13 beats per minute, BP stays about the same or increases, and *peripheral vascular resistance* decreases compared to hip immersion depth (32,40,53). Greater aquatic immersion activates less muscle which decreases breathing rate, increases hydrostatic pressure on the body which shifts blood volume centrally, increasing blood volumes and pressures in and around the heart (32,6). Both hip and xiphoid process immersion depth can increase cardiorespiratory fitness (40). Immersion is safe for CAD and CHF patients if it is in thermo neutral water (59).

## Temperature

Temperature is an important factor in an aquatic environment. Aquatic temperature in pools have ranged from 25 to 36.2 degrees Celsius (4,6,7,10,14,19,31,32,37,39,48,53,59,61,64,66). Thermo neutral water is about 35 degrees Celsius. Individuals should not sweat or shiver in thermo neutral water (8,53,60). The Aquatic Exercise Association (2008) standard of water temperature is 28-30 degrees Celsius for aquatic fitness programs (6,8). An 11-point thermal comfort (TC) scale exists for aquatic exercisers to grade aquatic temperature as the coldest (#0), neutral (#5), or the hottest they feel (#10) (66). Aquatic temperature can manage body temperature by way of conduction and convection. Body heat lost through water is conduction. Body heat lost by moving water is convection (8).

Heat injury is very low at thermo neutral temperatures and with conduction and convection (9,58). Thermo neutral water can create beneficial physiological responses (53). Neutral aquatic temperature (32-35 degrees Celsius) maintains body temperature, decreases BP and decreases HR (8,53,60). CHF patients can participate in aquatic exercise and swimming if the water is thermo neutral (53). Thermo neutral water can create positive physiological responses in individuals with CHF, and the elderly (26,53). Stable CHF patients with severe left ventricle dysfunction who have a VO<sub>2</sub> max of at least 15 ml/kg/min can tolerate thermo neutral aquatic exercise (53). Cycling is most comfortable in lower temperatures (66).

Warmer water (greater than 35 degrees Celsius) creates increased physiological responses such as increased blood flow, preload, *stroke volume (SV)*, *cardiac output (CO)*, peripheral vasodilation, systemic vasodilation, ventricular function, VO<sub>2</sub>, and HR, and

decreasing pulmonary and systemic vascular resistance (26,32,48,53,64,66). Svealv et al. (2009) found CHF patients can safely participate in warm aquatic exercise. HR reduction was the greatest physiological benefit of warm water immersion (26). Acute adaptations such as HR, VO<sub>2</sub>, and BL levels are lowest in warmer pool temperatures, and higher at colder pool temperatures (8,66). Exercisers can endure longer sessions and intensity in warmer water because their physiological responses are not as stressed (8). A concern in one study on aquatic cycling on young, men found, 31 degrees Celsius was harder and undesirable compared to 27 degrees Celsius (66). Increased temperature can cause fatigue sooner working at lower intensity levels (66). Studies of water immersion in 41 degree Celsius water for a short duration decreases pulmonary and right atrial blood pressure. Also, CO and ejection fraction has increased in elderly, systolic CHF patients who immersed themselves in warm water (19).

### **Density, Buoyancy, and Hydrostatic Pressure**

Aquatic density places more pressure on the body than air (10,14,15,31,32,40,53). Aquatic density and buoyancy greater than body density aid in reducing weight bearing, joint stress, and recruitment of muscle. Therefore individuals can exercise longer and more comfortably, with reduced risk of injury (14,31,32,40,48,58). Buoyancy lowers HR and VO<sub>2</sub> max (6,32). Aquatic buoyancy is ideal for the obese, elderly, arthritic, and less mobile (40,59). Hydrostatic pressure increases blood placement towards the center of the body and heart, increasing cardiovascular pressure which reduces workload of the heart (6,53,59). This would be a concern for patients with heart failure specifically because the same pressure poses a risk for these patients (59). Hydrostatic pressure is a natural alternative to

pharmaceuticals for individuals with CHF, and those trying to regulate bodily fluids (53).

Aquatic exercise is cautioned for heart patients with severe valve insufficiency.

The hydrostatic pressure causes cardiac enlargement, leaving valves having a harder time to close (19).

## **Equipment**

There are several types of equipment to monitor exercise intensity, increase strength workload, and increase cardiovascular intensity. First, a HR monitor is useful during aerobic and strength training (14,32,61,64). HR monitors provide a visual, easy to use and easy to assess at a glance (14). Aquatic equipment can include, but is not limited to, various flotation devices, various lightweight plastic resistance devices, step benches, ergo-bicycles, and treadmills (8,10,14,19,32,39,48,61). Flotation belts and vests are typically only used in the deep immersion levels to increase buoyancy for safe cardiovascular exercise. Flotation devices are great for beginner exercisers, individuals who need decreased joint pressure, and individuals who need decreased muscle activation (8).

CR patients can benefit improved acute and chronic physiological responses to aquatic exercise. Acute physiological adaptations are in a single exercise session (8). Frequency, intensity, type, and duration are all needed components of an acute exercise session (8,10). Chronic physiological adaptations are products of participating in multiple exercise sessions.

## ACUTE PHYSIOLOGICAL EFFECTS OF AN AQUATIC PROGRAM

### **Body Temperature**

Body temperature is affected by the aquatic temperature, air temperature, and humidity (66). Body heat is conducted and convected into the air and water (8,60). The lower the water temperature is from the ideal neutral temperature (thermo neutral), the greater the increase in HR and blood pressure BP (8). The higher the water temperature is from the ideal thermo neutral, the greater the decrease in HR and BP (26). Body temperature typically adapts to a thermo neutral aquatic pool in the first two minutes after immersion (60). It is estimated that individuals could be acclimated to pool temperature more quickly when participating in aquatic exercise for two to three weeks (60). CHF patients can exercise if water is thermo neutral and tolerate warm water immersion at xiphoid process (26,53).

### **Blood Pressure**

Blood pressures are taken at the beginning, during, and end of exercise (31,64). Hydrostatic pressure on the body and increased SV creates greater BP during exercise (53). Increased exercise BP, explains decreased HR (53). Temperature of water also changes BP (26,60). Acute systolic and diastolic BP decreases in warm water immersion (26,32,64). Diastolic and mean arterial BP decreases in warm water immersion for stable elderly CHF (26). Chest immersion depth decreases systolic and diastolic BP in CHF and CAD patients, and exercise raises systolic BP and diastolic BP slightly (53). Arterial BP specifically will rise during swimming more so than land exercise (58). Coronary BP increases in water at increasing immersion depth (32,53). Acute BP slightly decreases for CHF and CAD patients when just immersed at hip and xiphoid process depths (53). Acute BP increases for CHF and

CAD patients during swimming (53). In comparison to land, systolic BP is about 20% lower in water (9). BP should be a concern to watch in aquatic exercise (53).

### **Stroke Volume**

SV increases from water's hydrostatic pressure moving blood peripherally more centrally (32,53). An increase of about 25 mL is added when immersed at xiphoid process depth (9). A concern is a reduced SV in CHF patients. The concern is a combination of decreased left ventricular contraction with increased blood volume, further decreasing the left ventricle's ability to contract. SV increases in both CAD and CHF patients at xiphoid process immersion depths. SV is even greater in CAD and CHF patients when swimming (53). SV increases in warm water immersion (WWI), even for elderly stable CHF patients (9, 26).

### **Cardiac Output**

CO is a product of stroke volume and blood pressure (53). Acute and significant increases in CO are found in head-out-of-water exercise and swimming (26,32,53). CO increases from hydrostatic pressure shifting blood more centrally (53). CO can be increased or decreased by aquatic temperature (60). Again, a concern would be for heart failure (CHF) patients with reduced left ventricular contraction and increased blood volume combined. CO increases for CHF and CAD patients during swimming (53). CO increases in warm water immersion exercise for elderly, stable HF patients (26).

### **Heart Rate**

HR is a measureable factor to monitor exercise intensity in aquatic exercise (4,66). Acute heart rates are measured before, during, and after exercise. HR is lower at rest and with head-out-of-water exercise compared to the same exercise on land (5,6,32,66). The

hydrostatic pressure increases blood volume centrally, increasing blood filling into chambers, increasing SV and CO, therefore the heart does not have to work as hard (5,6,8,15,32).

HR during aquatic exercise increases depending on the type and intensity of the exercise. HR decreases with greater water immersion no matter what the exercise (8). HR max is lower in water (32,53). HR decreases for CHF and CAD patients in hip and xiphoid process immersion depths (53). However, HR increases for CHF and CAD patients when swimming (53). HR decreases in warm water immersion for elderly stable CHF patients (26). HR is affected by cadence change (66). Aquatic cycling produces similar max HR's as land cycling at the same work rate (66). There is a linear relationship between HR, VO<sub>2</sub>, and cadence, aquatic temperature, and specific exercises (66). A decrease in HR upon immersion could lead to bradycardia, possibly resulting in arrhythmias (14).

## **VO<sub>2</sub>**

VO<sub>2</sub> is the amount of oxygen consumed. Increased VO<sub>2</sub> values are associated with decreased risk for cardiovascular disease (58). Low VO<sub>2</sub> is an independent risk factor of CVD and all-cause mortality (42). VO<sub>2</sub> max is the standard for measuring cardiovascular fitness (19). VO<sub>2</sub> is best at thermo neutral or slightly warm temperatures (60). VO<sub>2</sub> can differ from so many combinations of factors such as mode of exercise, exercise environment, muscle recruitment of extremities, hydrostatic pressure, cadence, exercise techniques, and convection (4,5,32,66).

Cadence has been found to change VO<sub>2</sub> specifically in cycling. Aquatic cycling cadence is in linear relationship with VO<sub>2</sub> and HR, which is similar to land cycling (66). VO<sub>2</sub> is about 30% higher in aquatic cycling than land cycling at the same work rate. Also, if VO<sub>2</sub> is the same on land and in water, the workload is lower in water (15). Aquatic modes

of exercise typically produce lower VO<sub>2</sub> max compared to land because less muscle recruitment is needed. Although, perceived sub-maximal VO<sub>2</sub> is equal with land exercise (4). VO<sub>2</sub> max has also been found to be similar between the same mode of exercise on land and aquatic environments, specifically cycling and treadmill walking (4,66). Also, VO<sub>2</sub> is slightly higher in shallow immersion level exercise compared to xiphoid process immersion depths because of increased muscle activation (4,8,10,40). VO<sub>2</sub> max is higher in moving water and at shallow immersion levels compared to xiphoid process immersion depths (4,6,32). Although, VO<sub>2</sub> has been found to be unaffected by water immersion in CAD and CHF patients (53). VO<sub>2</sub> has been found to be not consistent, and therefore could be a concern to watch out for (4,32).

Xiphoid process immersion depth aquatic running can help sedentary, obese and elderly individuals improve *aerobic fitness* (40). CHF patients are able to participate in aquatic exercise and swimming if they have at least a VO<sub>2</sub> max of 15 ml/kg/min (53). VO<sub>2</sub> increases are greatly seen in individuals with lower initial fitness levels (19,40). Individuals with CAD can exercise in aquatics if their functional capacity is >7 METS, ejection fraction >50%, absence of arrhythmias, and absence of ischemia (61).

#### CHRONIC PHYSIOLOGICAL EFFECTS OF AN AQUATIC PROGRAM

Chronic adaptations are the long term results of single workouts added up over time. Chronic adaptation values can increase or decrease over time. If an individual ceases to exercise daily, the chronic adaptations of exercise will decrease until they no longer exist.

## **Blood Pressure**

Studies on this vary between finding increases, no changes, and slight decreases (8,58). One study found systolic and diastolic BP slightly increased after six months of swimming, which may be of concern (58). Systolic BP has shown to decrease with swimming in 12 weeks for 50+ year individuals who do not regularly exercise using the right exercise intensity, and frequency of sessions (43). In general, individuals with initial high BP will experience a decrease (58).

## **Heart Rate**

Researchers estimate, for each week of aquatic exercise for healthy individuals' HR could decrease one beat. An aquatic training program lasting at least seven weeks lowers resting HR and increases VO<sub>2</sub> max. The aquatic training programs can include deep water, aquatic step-benching, shallow-water walking and dancing (8). HR has been shown to decrease by 10% in older (62-75 yrs.) women who participated in a 12 week, three day, 60 minute aquatic program at an exercise intensity of 70% age predicted HR max at xiphoid process immersion depth. The significance was  $P < 0.05$ . HR decreased during a three week program consisting of partial aquatic and partial land exercise for CHF and CAD individuals (59).

## **VO<sub>2</sub>**

There are significant increases in VO<sub>2</sub> for CHF and CAD patients after a three week program at the significance of  $P < .05$  (59). When measuring VO<sub>2</sub> max there is a notable increase subsequent to training for seven weeks in an aquatic exercise program (8). Running at xiphoid process immersion depth improved VO<sub>2</sub> by about 20% in eight weeks with a significance of  $P < 0.05$  (6). VO<sub>2</sub> improved by 22% for post-one-year stroke patients in an

eight week program set at a significance of  $P < 0.05$  (19). Greater VO<sub>2</sub> is the result from greater muscle use (8).

### **Cardiovascular Fitness**

Cardiovascular fitness is an indicator of possible future cardiovascular events. Greater cardiovascular fitness is related to the higher number of CR sessions attended. Cardiovascular fitness can increase by about 1.5 METs in at least 36 sessions completed within 12 weeks in CR, but this is subject to exercise mode and intensity (52). One particular mode does not guarantee a better exercise capacity over another (14). Functional capacity can improve from warm water and a work rate of 20-30 minutes a day for eight weeks (26). Water-based programs are tolerated by CAD individuals (59). Deep aquatic running has been proven to increase *aerobic capacity* (6). Exercise capacity increases after eight weeks for CHF patients (53). The greatest cardiovascular fitness gains are experienced by individuals who initially were the most sedentary (52). Aquatic exercise was found to be as effective as land exercise for decreasing myocardial oxygen demands in stable CHF patients from a four week strength and aerobic program (64). Exercise tolerance can improve for CAD patients in aquatic exercise (61).

### **Blood Lipids**

It is well established that the risk of future cardiac events is reduced if blood lipids are lowered (40,64). Reduction in total cholesterol and triglyceride levels occur as well during aquatic exercise as land exercise (64). HDL cholesterol slightly increases with aquatic exercise (58,64). Aquatic exercise in thermo neutral water decreased total cholesterol and triglycerides, and increased HDL in sedentary individuals with stable CAD (64). There is no solid evidence that only swimming positively affects blood lipids. Research has indicated

both positively and negatively (40,58). However, in recent years, swimming has been discovered to be beneficial in producing high VO<sub>2</sub>'s and HR's (64).

### **Strength**

Researchers have found strength gains start appearing after at least eight weeks and are experienced by individuals with lower fitness levels (8,61). One study found noticeable strength gains in the elderly within two months at  $P < 0.05$  significance (31). Low weight, high reps is a safe strength prescription that worked for CAD patients at a significance of  $P < 0.05$  (61). A lower body strength program resulted in the same strength gains as a similar program on land set at a significance of  $P < 0.05$  (14). In another study lasting four weeks, strength increased slightly for stable CAD patients in thermo neutral water set at a significance of  $P < 0.05$  (64). Strength can increase for untrained women in a program lasting anywhere from 8-24 weeks (8). Maintaining muscular strength after a heart procedure is key towards continuing activities of daily living (64). Aquatic aerobic and strength exercise showed similar improvements as land exercise in the reduction of body mass, sum of skinfolds, total cholesterol, triglyceride levels, and increase in strength and exercise time after just four months for low risk CAD patients (61,64).

### **SUMMARY**

In all the studies found, stable CHF and CAD patients tolerate aquatic exercise. There are many properties of aquatic exercises and environments that can be adjusted to meet the exercise needs of cardiac patients. Aquatic exercise has been found to benefit cardiac exercise patients in acutely and chronically. Hydrostatic pressure of the water reduces weight bearing, and reduces the work of the heart at various immersion depths, and exercises.

Acute aquatic exercise produces a linear relationship of work rate with HR, VO<sub>2</sub>, SV, and CO. Chronic adaptations of reduced HR, BP, and blood lipids have been found, with increased VO<sub>2</sub>, cardiovascular fitness, and strength. Aquatic exercise has been shown to benefit the cardiovascular health of sedentary, and slightly active cardiac patients.

### CHAPTER III

#### FINDINGS OF THE STUDY

The research available for aquatic CR is widely undiscovered; the research possibilities are huge (9). Aquatic CR has been recently supported in research for certain heart patients, and cautioned for other cardiac patients (19). Aquatic exercise could be a great low impact exercise environment for stable CR patients to maintain or improve cardiovascular functional capacity.

#### ADVANTAGES OF AQUATIC EXERCISE FOR CARDIAC REHABILITATION

There are about the same huge variety of exercises that can be performed at varying levels of immersion depths as land for desired physiological adaptations such as HR, BP, VO<sub>2</sub>, and strength. A variety of immersion depths is very important to adjust for mobility and physiological adjustments. Higher immersion levels are very beneficial for individuals who need limited joint stress, increased flexibility and range of motion for comfort of exercise, and less visibility.

In one study, water exercise was scored as more enjoyable than land exercise (39). Researchers found pregnant and overweight individuals prefer aquatic exercise (58).

Enjoyment could improve individuals' motivation and acceptance to the idea of exercise (64). There is limited skill needed in head-out-of-water exercise (58). Psychologically, water's physical properties can be calming and make individuals feel good (8,39).

An aquatic environment can help individuals who cannot reach cardiovascular intensity with land aerobic exercises in CR. There are many simple, rhythmic and dynamic exercises using large muscle groups to induce aerobic and strength exercise. Submaximal and maximal cardiovascular tests can be performed. A standard six-minute walk test can be used with water immersion at hip level (61). The hydrostatic pressure of the water on the body can positively increase blood flow throughout the body, and increase blood volumes into the heart without the heart having to work as hard (includes chambering fillings, SV, and CO), therefore HR drops. Stronger BP decreases peripheral resistance. This is more apparent in greater immersion depths. More research needs to be completed, but the help from hydrostatic pressure pumping blood more than the heart could be beneficial for qualified stable heart patients' healing. Similar VO<sub>2</sub> can be reached in water as on land.

Aquatic environment is beneficial for maintaining and improving strength in major muscles. Aquatic environment is great again for disclosing the body. Strength training in the water is beneficial because individuals can increase strength while reducing joint pressure, increasing blood flow, and increasing strength range of motion.

The greatest benefits of aquatic environments are the reduction of weight bearing on joints, and increased blood flow from the hydrostatic pressure of the water. Immediately, weight bearing on joints is reduced. This is highly beneficial for anyone with low levels of fitness, elderly, orthopedic disabilities, neurological disabilities, recovering from surgery, and/or obese individuals. Hydrostatic pressure could elicit similar physiological responses as

BP medication. Injury is low with hydrostatic pressure. Hydrostatic pressure and buoyancy provide stability and ease for participants to perform exercise at increased ranges of motion.

Aquatic exercise can be great for promoting exercise to CR patients, and to maintain fitness for those who already exercise. Aquatic exercise would be great for stable CR patients who are beginner exercisers after checking with their doctor. There are so many more positives than negatives to aquatic exercise. The future research on this topic presents countless opportunities and will be beneficial for a variety of stable CR patients.

### CONCERNS OF AQUATIC EXERCISE FOR CARDIAC REHABILITATION

Aquatic exercise has not yet been extensively studied on a broad range of heart patients. There has been little research on certain types of heart patients, such as stable CHF and CAD patients. With there having been little research, the physiological benefits have been inconsistent. Physiological responses from aquatic exercise are dependent upon a lot of factors.

A concern of aquatic immersion, and even more so, in aerobic exercise, is BP and blood filling in the heart. Hydrostatic pressure of the water placed on the outside of the body decreases BP peripherally, and increases BP in and around the heart. Heart patients need tissue healing. A concern for CHF patients is the increased blood volume in the chambers, especially the left ventricle. CHF patients have weakened contractility. Therefore, adding a greater blood volume and BP to a weakened heart could cause a weaker heart. This risk is increased with greater immersion depths, exercise duration, and exercise intensity.

For individuals with CAD, a concern is increased BP to blood vessels with blockages from hydrostatic pressure. BP increases from simple water immersion. Aquatic immersion

at greater immersion depths and greater intensities is a concern. The concern is increased BP from exercise could cause a breakage in plaque build-up in the blood vessels posing potential risks such as a stroke.

There is limited research concerning other specific heart patients, such as open heart surgery patients, or MI patients.

Aquatic exercise for stable heart patients could be time consuming. CR in an aquatic environment could be time consuming for both the patients and the therapist for session preparation and takedown.

Having pools within clinical therapy departments would require additional facility costs, and management resources. However, additional revenue from the pool can be received through physical therapy and community use. The cost of equipment would need to be considered. An advantage is a therapy program would not need as much large surface area equipment for strength training because strength gains can take a long time, and individuals are going for endurance repetitions.

Exercise intensity can be harder to manage. HR and RPE have been the most popular and reliable methods. ECG is not the most and only way to predict a cardiovascular emergency event. For safety, aquatic exercise can pose a risk with CR being in the water. The advantage is the risk of a cardiovascular event is low already. With CR sessions being a small population per session, the therapist will be very close. Aquatic facilities also have lifeguards on duty, and they could be near the location of exercise in the pool. The pool does not have to be big. Exercise sessions could be close to the edge of the pool. In higher immersion depths, aquatic belts keep individuals floating with little to no effort. The risk of being in the water is reduced with the flotation belt.

## CONCLUSION OF AQUATIC EXERCISE FOR CARDIAC REHABILITATION

Aquatic exercise is highly promoted and very popular. Aquatic exercising can be recommended for rehabilitation, health promotion, and maintenance of physical fitness.

Aquatic CR already exists but in very few locations. CR is newly founded to be important for patients with CVD. CVD patients who feel uncomfortable moving on land with cardio equipment can feel more comfortable, increase range of motion, and reach higher VO<sub>2</sub> levels in water. Aquatic aerobic and strength training has been found to be more safe than risky for stable CHF and CAD patients. There is much optimism for future research on other specific stable heart patients using an aquatic environment for CR.

## CHAPTER IV

### RECOMMENDATIONS

1. Future research needs to be done on specific heart patients, such as myocardial infarction and open heart surgery, to find the physiological effects.
2. Future research needs to have very specific factors for each specific heart patient to find the physiological effects.
3. Future research needs to use greater sample sizes to validate physiological findings.
4. Future research needs to be on the elderly patients.
5. Future research needs to include the physiological benefits on the overweight and obese patients.
6. Cardiovascular rehabilitation standards need to be established for patients who already train aerobically and/or strength train on a regular basis for at least six months or more.
7. Future research needs to determine how soon cardiovascular rehabilitation patients can exercise following a cardiovascular event.
8. Future research needs to be on coronary artery disease stiffness from increased blood pressure during exercise.

## CHAPTER V

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