The Effects of Aquatic Exercise on Gait Parameters in Older Adults with Knee Osteoarthritis (OA)

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Kinesiology

By

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Dedication

To my parents, Kimberley and Gregory

Your love and support has made me the man I am today. I am thankful for you allowing me to return home to save money for graduate school. I am so appreciative to have such wonderful parents who inspire me to push myself to do great things. Without you both, I would have never made it this far.

To my brother, Collin

Our friendship has grown after you allowed me to return home and share our house once again. Our adventures eased my mind and allowed me to fully develop my character outside of school. I am thankful to have a brother who also shares a passion for the great outdoors and your willingness to share it together.

To the love of my life, Laura Morrow

You allowed me to leave you for a year to attend graduate school. You took the blunt of my stress and frustration and gave me happiness in return. You moved in with my family to help support me with school. Your support through my graduate studies has been unparalleled. Without a person like you in my life, none of this would have been possible. I look forward to sharing the rest of my life with you.

To my entire family,

All of your love and excitement for me has meant so much during this process. I am truly appreciative to have the life I am living. You have all made my experience during this time as a graduate student enjoyable to share and an experience truly special. I feel so lucky.

To my Grandparents Edmund & Margrett Lievense and Robert & Jimye Keezer,

You have all taught me many lessons in my life from the beginning of my days, and have given me a special love. I sometimes forget how lucky I am and how great things always were. The impact you have all made in my life is something that will live on with me forever. I would like to dedicate this Master Thesis to you all.

"And in the end, it's not the years in your life that count. It's the life in your years."
Acknowledgements

Thank you to my committee members for their support and guidance during my research.

Dr. Jung, you taught me so much and helped me achieve a realization I did not have before. You helped develop me into a successful graduate student, allowing me to finish the most difficult task in my current life. Dr. Dino, thank you for your time and expertise in statistics. Your biomechanics and quantitative analysis courses made me excited and confident in implementing advanced instrumentation to properly measure gait outcomes. Professor Mai Jara, thank you for being by my side during the entire thesis process. You helped me with so many different day to day aspects and continually went above and beyond. I could not have asked or chosen a better committee for my Master’s thesis.

Thank you to all our participants and their enthusiasm in being a part of this study. Each one of you made this research process unique in creating a fun and positive atmosphere.

Thank you David Watson for volunteering your time over the twelve week intervention. Your positive attitude made this process one of a kind. Your presence brought smiles to all the participants and mine.

Thank you Robert De La Cruz for your expertise in motion analysis. I continually bothered you with good intent to progress my understanding of difficult concepts. You helped me develop a mastery of VICON. You also kept me sane when I encountered problems with instrumentation. I am truly grateful for your time and commitment.
Thank you Ubaldo Gunzman for your continuous help with the VICON procedures including the tedious set up and tear down of instrumentation.

Thank you to the individuals who are a part of the VICON support team in Colorado.

Thank you to Becky, Carol, Larissa, Stacy, and Randy who were all apart of making this process successful. All of your support and compassion made this process rewarding and exciting. I am going to miss you all.

A big thank you to the Center of Achievement and all of the clients, staff, and students. I have become deeply attached to the COA and it has made a huge impact on my life. The opportunity to be a part of such an amazing program has really changed me. My three years at the COA have been the best experiences in my life that will remain some of my favorite memories.

To all my fellow graduate students: Jennifer O’Connor, Gioella Chaparro, Tommy Wee, Mike Jara, Byron Lai, Jessica McCamish, Maksim Seredov, Ryota Nishiyori, Eleftherios Zarpas, Leora Gabay, Paul Godina, Jae Lim, Yumi Kim, and Robert De La Cruz. You are all simply amazing and we will all remain forever connected from the APA program.

A special thank you to my amazing thesis partner, Gioella Chaparro. You were the heart of this research and your commitment and enthusiasm towards helping us complete this process is something I will never forget. Surprisingly, you ended up making the perfect partner and friend. I will miss seeing you on a continuous basis but we will keep in touch. I am happy I got to share one of the biggest milestones in my life with someone as passionate as me.
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Abstract

The Effects of Aquatic Exercise on Gait Parameters in Older Adults with Knee Osteoarthritis (OA).

By

Cameron Lievense

Master of Science in Kinesiology

Aquatic and land exercise programs are common intervention modes for people with knee osteoarthritis. Aquatic exercise offers several advantages over conventional land-based exercise and is often recommended by health care providers for patients with arthritis. However, there is limited literature that documented its effects on gait outcomes. The purpose is to examine the effects of aquatic exercise on gait parameters in older adults with knee osteoarthritis. A total of 21 participants (3 males; 18 females; average age 75.3 ± 11) with knee OA were randomly assigned to an aquatic exercise group or a land exercise group. The aquatic group participants completed a 45-minute Arthritis Foundation Aquatic Program (AFAP) 3 times a week for 12 weeks while the land exercise group performed the Arthritis Foundation Land Program (AFLP). Pre and post intervention gait data were collected from fastest walking trials on an 8-meter carpeted walkway using a 3-D motional analysis system (VICON, Oxford, UK, 2010). The data consisted of spatiotemporal and lower extremity kinematics in the hip, knee and ankle joints. MANOVA showed aquatic-based exercise had a significant group-by-time interaction in increased stride length (p=.017) when compared to land-based exercise.
after a 12-week intervention. Within group analyses of aquatic-based exercise revealed significant increases in speed (p=.008), cadence (p=.027), and stride length (p=.005), and within land-based exercise revealed significant increases in speed (p=.009) and cadence (p=.004). The results showed no significant difference in all kinematics variables in both groups. The results suggest that both aquatic and land-based exercise programs can be beneficial for older adults with knee osteoarthritis to improve their walking. However, aquatic exercise can be a valuable therapeutic exercise modality for individuals with knee OA looking to improve stride length.
Introduction

Older adults accounted for 12.9% (39.6 million) of the United States population, approximately 1 in every 8 Americans in 2009. The U.S. Administration on Aging estimates older adults reaching 72.1 million by 2030 (AOA, 2009). Older adults refer to people aged 65 years and older, as well as people aged 50-64 with clinically significant conditions or physical limitations that affect movement, physical fitness, or physical activity (Nelson et al., 2009). The biological process of aging cannot be stopped, but there is evidence showing regular exercise can reduce the physiological effects of a sedentary lifestyle and increase active life expectancy by minimizing the development and progression of chronic diseases and disabling conditions (Salem et al., 2009).

Physiological changes in aging include decreased cardiovascular function, reduced aerobic function, increased risk and occurrence of cardiovascular disease, elevated blood pressure, decreased lung capacity, and ventilation. Bones also become more fragile and less dense as the mineral content decreases. Muscles begin to lose mass, causing them to shrink. Flexibility decreases as joints become tighter from changes in ligaments and tendons. Cartilage begins to deteriorate creating less cushioning between bones causing joints to become inflamed and arthritic. This can evidently lead to Osteoarthritis, causing biomechanical changes that can affect mobility (American Academy of Orthopaedic Surgeons, 2011).

Osteoarthritis (OA) is the most prevalent musculoskeletal conditions affecting 27 million Americans (Lawrence et al., 2008). The total annual cost of OA per person living with OA is approximately $5700 (Maetzel et al., 2004). OA is characterized by loss of joint cartilage that leads to pain and loss of function, primarily in the hips and knees, and
affects 18% of women and 9.6% of men aged over 60 years (Woolf et al., 2003). 12.1% of adults aged over 60 years have symptomatic knee OA (Dillion et al., 2006). The effects of OA can significantly limit an individual’s ability to walk, rise from a chair, stand comfortably, or climb stairs leading to a loss of functional independence (Kaufman et al., 2001). During the gait cycle, speed, cadence, stride length, and joint excursions of the hip, knee, and ankle are distinctively inferior in those with OA compared to healthy individuals (Ko et al., 2011; Kiss, 2011; Deluzio et al., 2007; Al-Zahrani et al., 2002). However, research shows significant benefits from exercise for individuals with OA (Silva et al., 2008; Lund et al., 2008; Wang et al., 2006; Hinman et al., 2007; Foley et al., 2003; Thomas et al., 2002; Wyatt et al., 2001).

The American College of Rheumatology and the Arthritis Foundation have both established specific nonpharmacologic exercise guidelines for OA and researchers have reported positive effects on flexibility, strength, and fitness (Wang et al., 2006; Silva et al., 2008). Current guidelines recommend methods such as therapeutic exercise, as first line options in the management of OA. Therapeutic exercise may be provided on land or in an aquatic environment (Walker-Bone et al., 2000). Both land and aquatic exercise have shown positive benefits for individuals with OA. However, aquatic exercise receives an increased attention because of its wide-ranging benefits from its aquatic properties (Silva et al., 2008). The aquatic environment provides low-impact on the bones and joints. Buoyancy helps reduce loading across joints affected by pain and allows the performance of functional closed-chain exercises that otherwise may be too difficult on land (Hinman et al., 2007). Water turbulence can be used as a method of increasing resistance, and percentage of body weight bearing across the lower limbs can be decreased or progressed.
in proportion to the depth of immersion (Harrison et al., 1992). The warmth and pressure of the water may further assist with pain relief, swelling reduction, and ease of movement (Hinman et al., 2007).

Numerous studies have reported decreased pain (Thomas et al., 2002; Wyatt et al., 2001), increased knee strength and increased flexibility (Silva et al., 2008; Wang et al., 2006) from aquatic exercise in individuals with OA but few studies have examined the effects on gait characteristics. Previous studies have examined gait parameters in the older adults with arthritis after land-based exercise, finding significant improvements in gait parameters (Ettinger et al., 1997), while only one study has used motion analysis to examine the effects of aquatic group exercise on gait in people with arthritis (Alexander et al., 2001).

Even with the extensive establishment of aquatic exercise for people with OA, there is limited evidence indicating significant changes in gait parameters. Although many studies have reported favorable effects of aquatic interventions with various arthritic conditions, few have evaluated a sample selected on the basis of knee OA alone (Geytenbeek et al., 2002). Only one study has used motion analysis to document the effects on gait kinematics and spatiotemporal variables in individuals with arthritis. No studies have used 3-dimensional motion analysis to measure the gait changes in older adults with knee OA after an aquatic intervention program. Therefore, the purpose of this study is to examine the effects of aquatic exercise on gait parameters in older adults with knee OA.
Literature Review

Aging & Related Health Issues

Our body continuously changes as we age for better or worst. During the aging process, water content of tendons begins to dissipate, making the tissues stiffer and more susceptible to stress. Handgrip strength decreases making activities of daily living more difficult. The cardiac muscle has increased difficulties in pumping blood to the body, increasing recovery time after physical exertion (American Academy of Orthopaedic Surgeons, 2009). Balance and gait become affected with aging, showing decreased gait speed and stride length as well as an increased fall risk (Daley et al., 2000). In a study on dynamic postural balance in aging of knees in motion, Shimoyama et al. (2011) tested 407 participants aged 14 to 93 years old with a force plate that measured body sway using center of pressure. Participants performed various tasks such as standing upright with eyes open for 20 seconds and standing upright with eyes closed for 20 seconds. Other tasks included eyes open while standing upright for five seconds, keeping knees flexed for five seconds, and keeping knees extended for five seconds. Dynamic postural balance showed that age had a negative impact on balance. These results indicated that aging deteriorates postural balance, significantly increasing poor balance and gait.
To examine the correlation of walking and falling, Menz et al. (2003) measured the spatial-temporal gait parameters of 30 older adults (75-85 years old) with a low risk of falling and 30 young adults (22-39 years) while walking on an irregular surface. The purpose was to examine the effects of aging on the postural responses to challenging walking conditions, using linear accelerations of the body. The results showed that older adults walk slower, have a shorter step length, and increased step timing variability. These characteristics in gait are similar to previous studies examining participants with knee Osteoarthritis (OA) (Ko et al., 2011; Al-Zahrani et al., 2002; McGibbon et al., 2002).

McGibbon et al. (2002) examined the adaptations of gait kinematics and kinetics of thirteen older adults with knee OA compared to ten aged matched healthy older adults. Results showed that older adults with knee OA have reduced walking speed and step length. In addition, there was reduced ankle power during terminal stance, reduced concentric knee power, and increased power absorption in the hip. These results suggest that older adults with knee OA may have similar but evidently inferior gait mechanics compared to age matched controls. However, aging can accelerate the severity of knee OA significantly affecting gait (Mikesky, et al., 2006).
*Osteoarthritis*

The U.S. Administration of Aging estimates the population of older adults to change from 13% in 2010, to over 20% by 2040. Consequently, the universal burden of OA will have a negative impact on individuals, since more than 12.4 million individuals over the age of 65 are currently diagnosed with OA (Lawrence et al., 2008). OA will become the fourth leading cause of disability worldwide by the year 2020 (Woolf et al., 2003). The incidence and prevalence of OA will increase as the population ages unless actions are taken to improve health and fitness. OA is characterized by the breakdown of cartilage, the part of a joint that cushions the ends of the bones and allows easy movement where bones begin to rub against one another. This musculoskeletal disease can also damage ligaments, menisci, and muscles, which may create a need for joint replacements (Arthritis Foundation, 2011). OA causes pain, swelling, and reduces motion in joints and can occur in any joint (National Institute of Arthritis and Musculoskeletal and Skin Diseases, 2011). Gait patterns in individuals with OA are distinctively different when compared to healthy individuals (Kiss, 2011; Ko et al., 2011; Heiden et al., 2009; Silvia et al., 2008; Landry et al., 2007; Wang et al., 2006; Bejek et al., 2006; Kaufman et al., 2001), commonly showing reduced walking speed, step length, stride length, ankle plantar/dorsiflexion, knee flexion/extension, and hip flexion/extension (Al-Zahrani et al., 2002). Thus far, most research has examined gait parameters of participants with knee OA using 3-dimensional (3-D) motion analysis (Ko et al., 2011; Heiden et al., 2009; Landry et al., 2007; Thomas et al., 2002; Kaufman et al., 2001).
Knee OA Gait

Ko et al. (2011) and Heiden et al. (2009) both used Vicon 3-D motion analysis as well as a ground force plate to measure gait parameters of older adults with knee OA. Ko et al. (2011) measured the gait patterns of 41 participants with knee OA and 112 participants without, during three different walking conditions. Results showed that older adults with knee OA walked slower during usual-walking and usual-walking after 30 minutes. Knee OA participants also walked with a shorter stance during all three walking tasks and showed a greater ankle ROM in the sagittal plane compared to controls for usual walking and usual walking after 30 minutes. During fast walking, evidence suggested that older adults with knee OA adopt a distinct ankle kinematic pattern by enhancing forward momentum to minimize knee joint loading, reducing knee pain. Similar, Heiden et al. (2009) concluded that larger adduction moments were related to lower self perceived pain and symptoms. Of the 54 participants with knee OA and 34 controls without, the results found that participants with knee OA had greater knee flexion at heel strike and during early stance, along with reductions in the peak external knee extension moment in late stance. In comparison, both studies found that during walking, participants with knee OA alter walking characteristics in order to compensate for pain. These results indicate that individuals with knee OA have an altered gait in compared to healthy individuals (Ko et al., 2011; Heiden et al., 2009).

Al-Zahrani. et al. (2002) and Landry et al. (2007) used 3-D optoelectronic motion analysis to measure gait characteristics in individuals with knee OA and found similar results to previous studies (Thomas et al., 2002; Landry et al., 2007). Al-Zahrani
et al. (2002) examined 58 participants with knee OA as well as 25 without knee OA and found that knee OA participants demonstrate a reduced walking speed, shorter stride length and a more prolonged stance phase during the gait cycle. Consistent with other studies, participants also had less ROM at the hip, knee and ankle joints when compared to healthy participants (McGibbon et al., 2002). These results indicate that gait abnormalities were due to the instability of the knee joint during stance (Al-Zahrani et al., 2002). In a related study, Landry et al. (2007) found that individuals with knee OA compared to a control had larger adduction moment magnitudes during stance and it was sustained for a longer portion during the gait cycle, similar to Heiden et al. (2009). In addition, the OA participants had a reduced flexion moment as well as reduced external rotation moment during early stance.

Kaufman et al. (2001) used expert vision motion analysis to examine 139 participants with knee OA and 20 participants without knee OA during level walking, stair ascent, and stair descent. The participants with knee OA had a significantly reduced internal knee extensor moment compared to healthy participants. These differences were due to participants compensating to reduce the knee joint loading, similar trends to the study of Ko et al. (2011) and Heiden et al. (2009). Participants with knee OA and a higher body mass index also had a lower knee extensor moment (Kaufman et al., 2001). In comparison, Kiss et al. (2006) used an ultra-sound based motion analysis system to measure gait parameters of participants with knee OA on a treadmill. Results showed a decrease in knee joint extension and flexion, consistent with Kaufman et al. (2001). The participants with knee OA also had a decreased hip motion on the effected side compared to healthy participants, similar to Al-Zahrani., et al. (2002) findings. The decreased knee
motion was associated with increased motion occurring at the pelvis. With physical discrepancies of knee OA clinically identified, research has developed exercise programs that focus on improving health and fitness in individuals with knee OA.

*Exercise*

The American College of Rheumatology (ACR) and the Arthritis Foundation have developed specific nonpharmacologic practice guidelines for OA of the knee (Hochberg et al., 2012). First line options in the management of knee OA may be provided on land or in an aquatic environment (Walker-Bone et al., 2000). However, aquatic exercise is commonly used because of the low-impact on the bones and joints. Aquatic exercise is a wide-range of exercise activity performed in heated pools by a variety of providers and is one of the safest of 33 possible treatments for knee OA (Jordan et al., 2003). Aquatic-based exercise has more benefits when compared to land-based exercise for people with knee OA. For example, the soothing warmth and buoyancy of water make the aquatic environment ideal for relieving knee OA pain and stiffness. Immersion in warm water raises the body temperature which increases circulation by making blood vessels dilate. Water also helps support joints to encourage free movement and also can be used as resistance to build muscular strength (Arthritis Foundation, 2011). Most importantly, older adults have similar gait characteristics that are typical of younger adults when measured in water (Giaquinto et al., 2007). This scientifically shows that aquatic exercise can be valuable in aiding older adults with knee OA.
The Arthritis Foundation Aquatic Program (AFAP) offers exercises that are designed to allow joints to move safely and improve self efficacy. This recreational group exercise program was co-developed by the Arthritis Foundation and the YMCA in 1993. The AFAP has been scientifically evaluated with clinically significant benefits (Wang et al., 2006; Patrick et al., 2001; Suomi et al., 1997). Participants have experienced reduced level of pain, improved ability to function independently in activities of daily living, and decreased feelings of isolation or depression. The aquatic group exercise program is performed in warm water (84-88 degrees Fahrenheit) and implements exercise focusing on improving ROM, muscle strength, and endurance specifically for individuals with arthritis and related diseases. AFAP typically are hour long sessions held two to three times per week with a maximum of 20 participants. Essential components include a warm up, joint ROM for flexibility as well as strength, low-intensity endurance, cool down, and optional games or neuroboics (Arthritis Foundation, 2011).

**AFAP Research**

The arthritis foundation has four studies (Wang et al., 2006; Patrick et al., 2001; Suomi, 1997; Arthritis Foundation, 1987) that they have acknowledged which effectively evaluated their aquatic program. In 1987, the Arthritis Foundation examined 60 participants following 16-weeks of AFAP and found that physical function increased by
25%, as well as pain reduction of 18%. Similar, Patrick et al. (2001) found an increase in physical function, and an increased perceived quality of life and well being. In difference, Patrick et al. (2001) used a larger group of participants (249 individuals) and longer exercise program (20-weeks) that yielded a greater statistical power. However, both studies did not observe changes in strength, flexibility, or gait. On the other hand, Suomi et al. (1997) tested 30 participants with OA as well as rheumatoid arthritis and found that aquatic exercise 3-times a week for six weeks significantly increased ROM and isometric strength in the lower extremity joints compared to controlled participants. However, this study was limited by their duration of the exercise program and did not represent a specific arthritis population.

Wang et al. (2006), in contrast, examined the effects of 12-week aquatic program in older adults with OA of the hip or knee compared to a non-exercise condition. 38 participants were measured using a plastic goniometer, handheld dynamometer, 6-minute Walk Test, Multi-dimensional Health Assessment Questionnaire, and a Visual Analogue Scale for pain. Evidence showed increased knee and hip flexibility as well as strength and fitness. However, the effectiveness of aquatic exercise could not be determined due to the restriction of an exercise control. These findings are similar but also differ from other studies investigating the effects of aquatic exercise (Lund et al., 2008; Silva et al., 2008; Hinman et al., 2007; Alexander et al., 2006; Davey et al., 2004; Foley et al., 2003; Wyatt et al., 2001).
Aquatic Exercise vs. No Exercise

Davey et al. (2004) examined the effectiveness of a 12-month community-based aquatic exercise program compared to a non-exercise control. The study examined self-reported health and physical function in 106 sedentary older adults (over 60) with knee or hip OA using the disease-specific WOMAC (Western Ontario and McMaster University Osteoarthritis Index) scale and physical function tests. The 66 participants in the exercise group had significant improvement in physical function and reduction in the perception of pain. The decrease in pain differs from Wang et al. (2006) study, possibly due to the exercise intervention being four times longer, allowing greater effects over time. However, Hinman et al. (2007) found a decrease in pain after only 6-weeks of aquatic exercise. Davey et al. (2004) also found that the exercise group showed greater improvements in hip and knee ROM, relatable to Wang et al. (2006) findings. Other findings in the study included that the aquatic exercise group performed significantly better at ascending and descending stairs compared to the non-exercise control. In a similar, but shorter study (6-weeks), Hinman et al. (2007) examined 71 participants with knee or hip OA and found improved strength, function, and quality of life in participants in the aquatic exercise program compared to the non-exercise program. However, comparing a non-exercise group to an exercise group is a significant limitation in all of these previous studies.
Aquatic Exercise vs. Land Exercise

In order to fully evaluate the effects of aquatic exercise, Silva et al. (2008) compared an 18-week aquatic-based exercise versus land-based exercise program in 64 participants with knee OA. The measurements included in this study were a visual analog pain scale, WOMAC, pain during gait, and walking time at 50 feet. Results showed improvement in physical function, pain, mobility, and flexibility in the aquatic group concluding that aquatic exercise is superior to land exercise in reducing pain before and after walking. These results effectively represent the importance of aquatic exercise for individuals with knee OA. In a similar study, Foley et al. (2003) compared aquatic and land based exercise, but also used a non-exercise control group to examine the effectiveness of both exercise groups, comparing strength and function for the treatment of OA. Participants were randomly placed in one of the three groups (consisting of 35 participants per group). The exercise groups consisted of three exercise sessions a week for 6-weeks. Muscle strength dynamometry, 6-minute walk test, WOMAC, quality of life, Adelaide Activities profile, and the arthritis self-efficacy scale were used to take measurements. The results showed that aquatic and land exercise both have a significant impact on improving physical function in participants with OA. However, the study was restricted to 6-weeks, making major changes between groups less observable. This limitation caused the study to fail in reporting any significant differences between the aquatic and land exercise groups in walking speed or distance.

Wyatt et al. (2001) also examined the differences of aquatic and land exercise programs on participants with knee OA. Variables included knee range of motion, thigh
girth, subjective pain scale, and the 1-mile walk test. The pre and post comparisons showed positive changes in all variables. However, subjective pain was lower on individuals who participated in the aquatic exercise program. Walking speed and distance also increased in both groups considerably but showed no significant difference between the two groups other than pain, similar findings to Foley et al. (2003). Pain, strength, flexibility, and mobility have repeatability been shown to have positive effects from aquatic exercise; however, only one study has used motion analysis to examine the effects of aquatic exercise on gait (Alexander et al., 2001).

*Aquatic Exercise Gait Changes*

Alexander et al. (2001) examined the effects of an aquatic exercise program on gait, flexibility, strength, self-reported disability and other psycho-social measures on 32 older adults with arthritis. The aquatic exercise program was bi-weekly for 12-weeks in a therapeutic pool (90 degrees) following the Arthritis Society’s Water Works Program, a modified version of the AFAP. The program mainly consisted of low intensity joint movement exercises that included cardiovascular training. Before and after the program, participants were filmed on an indoor track walking self paced along a walkway using two cameras: Panasonic shuttered digital super VHS video camera (WV-D5100) and a Panasonic Omnivision camcorder (PV 460) at 60 frames per second. Both cameras filmed simultaneously at the sagittal and frontal views. Each subject’s film was digitized by storing each location of the 2-D coordinates for all 22 joints. The pre and post test comparison of temporal and descriptive gait showed a significant improvement in stride.
and step length. Of the kinematic gait variables, the inclination displacement of the lower limb segments increased significantly. Shank inclination (ROM of lower leg segment during walking) increased approximately five degrees, while thigh inclination (ROM of thigh segment) improved about three degrees, and shoulder displacement (ROM of arm swing) increased by four degrees. In addition, ankle displacement significantly decreased by two and half degrees as well as an increase in flexibility. Alexander et al. (2001) provided scientific evidence that aquatic exercise over 12-weeks improves gait characteristics in participants with arthritis.

Summary

Although Alexander et al. (2001) found significant changes in gait after aquatic exercise, the study was restricted with no control group to compare the effectiveness of aquatic exercise versus other exercise programs. Participants were currently exercising at a wellness center before beginning the aquatic exercise intervention. No specific type of arthritis or site was examined, making the conclusions to aquatic exercise vague to the arthritis population. The aquatic exercise program was also restricted to 2-times a week, having less impact compared to individuals participating 3-times a week. Gait and film analysis was also restricted to 2-D motion analysis.

No studies have used 3-D motion analysis to measure the gait changes in individuals with OA after an aquatic exercise program. In regards, the purpose of this study is to examine the effects of aquatic exercise on gait parameters in older adults with knee OA. We hypothesize that participants with knee OA will have a greater increase in
kinematic (maximal plantar/dorsiflexion, maximal knee flexion/extension, and maximal hip flexion/extension) and spatiotemporal (cadence, velocity, stride length, and step length) gait variables after a 12-week aquatic-based exercise program when compared to a land-based exercise program. The clinical significance is to show that aquatic exercise can be beneficial in restoring or aiding proper gait mechanics in older adults with knee OA.
METHODS

Participants

Participants were recruited through fliers and word of mouth from the community surrounding California State University, Northridge (CSUN). Eligibility criteria for this investigation were men or women aged over 55 years, a medical diagnosis of knee osteoarthritis (OA), able to safely enter and exit a pool, and able to stand independently for 10 seconds without an assistive device. Participants were excluded if they had multiple major joint involvement, dementia, recent joint injections (≤ 6 months), a fear of water, currently participated in an organized group exercise, or has cardiovascular, metabolic, pulmonary, or neurological disease. A total of 21 participants with knee OA (3 males; 18 females; average age 75.3 ± 11) were randomized into 1 of 2 groups. 10 participants were placed in the aquatic-based exercise group and 11 participants in the land exercise group.

Instrumentation

Gait was evaluated using a 3-Dimensional gait analysis system, VICON Bonita (VICON, Oxford, UK, 2010) that uses seven high speed infra-red motion analysis cameras designed to locate and track retroreflective markers moving in a calibrated measurement space. Specifications included a 0.3 megapixel resolution, 2ms latency, 240 Hz frame rate, and a gigabit Ethernet (RJ45 interface). 15 (8mm) reflective markers were used for identifying anatomical landmarks for capturing gait. The data was processed using the biomechanical model contained in the VICON Nexus software (version 1.8.1). Using this program, the gait cycle was defined by identifying heel-strike and toe-off. The gait
events of the heel-strike and toe-off were identified by the computer operator with a
frame-by-frame inspection of each participant’s biomechanical model. The results of the
analysis were presented using the VICON Polygon software (version 3.5.2) in a graphic
form of the 3-plane joint excursions at the hip, knee, and ankle in the sagittal and
descriptive plane. This allowed variations of the spatiotemporal parameters to be
identified. These gait parameters included speed, cadence, and stride length. A High
Definition digital camera (Basler Pylon, version 2.3.5) was used to visually record
walking of the participants.

Test Procedures

A pre and post test design was used to examine the effects of both exercise
groups. Pre-test collection took place two weeks prior to the 12-week exercise
intervention. The post-data was collected immediately after the intervention. Data
collection took place at the Center of Achievement Therapeutic Exercise Lab, California
State University, Northridge. Written informed adult consent forms and medical
clearance through their physician to participate were obtained before the initial data
collection. Testing procedures were verbally explained and a written summary was
given. The following anthropometric measurements were taken: height, weight, ASIS
distance, leg length, knee width, and ankle width. These measurements were taken after
participants changed into tightly fitted clothing. 15 reflective markers were placed
bilaterally on the participant’s lower extremities according to the VICON plug in gait
model: anterior-superior iliac spine, midway on the lateral femur, lateral epicondyle of
the knee, lateral malleolus, 2\textsuperscript{nd} metatarsal head, calcaneous, and one marker placed on the
sacrum (mid-way between the posterior-superior iliac spine). Following the reflective
marker placement, static trails of each participant were recorded. Participants were then asked to walk barefoot along an 8-meter walkway at their regular walking speed twice for familiarization. Participants were then instructed to walk at their fastest walking speed for three data collection trials. One minute rest period were provided after each trial. Each participant’s best trail was later processed and used for data analysis. The whole data collection process took approximately 30 minutes for each participant.

Anthropometric measurements, marker placements, calibrations, data collection, and processing were performed by the same researcher. All human subject protocols were approved by the Institutional Review Board at California State University, Northridge.

Exercise Intervention

The aquatic-based exercise program was conducted at the Brown Center’s main therapeutic pool, CSUN. The pool has a water depth of 3.5 ft (1.05m)-4.5 ft (1.37m) and a water temperature averaging 90°F (32.2°C). The exercise group participated in the Arthritis Foundation Aquatic Program for 12-weeks (45-minute sessions, 3 days/week). The frequency, intensity, and duration of this program were based off of the AFAP protocol. The participants entered the pool by stairs or by wet ramp. Participants were instructed to exercise at chest deep level. Each aquatic exercise session began with a 10-minute warm-up that consisted of exercises such as backwards walking, sidestepping, wooden soldier, and active flexibility for the upper and lower extremities. Gait and balance training exercises such as single leg stance, heels-to-toes, and clam-shell walk were performed for 5-10 minutes. Lower and upper extremity strength exercises such as baseball swings, touchdowns, and mini-squat were performed for 5-10 minutes. Cardiovascular exercises such as flutter kick, breaststroke kick, bicycle kicks, and leg
scissors were performed for 10 minutes. The last 5 minutes focused on cooling down with stretches such as finger tips to shoulders, ankle circles, hamstring stretch, piano, shoulder blade squeeze, and pelvic circles. An example of the aquatic lesson plan is in Figure 1. All sessions were taught in a group setting with one AFAP instructor and certified lifeguard. The amount of group exercise sessions taught was divided up equally by two instructors.

The land exercise program was conducted at the Center of Achievement Therapeutic Exercise Lab, CSUN. The land exercise group participated in the Arthritis Foundation Land Program for twelve weeks (45-minute sessions, 3 days/week). The frequency, intensity, and duration of this program were based off of the Arthritis Foundation Land Program protocol. Each land exercise session began with a 10-minute warm-up that consisted of exercises such as walking forwards, stepping sideways, the crawl, and hand claps. Gait and balance exercises such as backwards walking, tandem walking, single leg walking, toe walking, and weight shifts were performed for 5-10 minutes. Strength exercises such as bicep curls, leg abduction, heel raises, arm circles, and mini-squats were performed for 5-10 minutes. Cardiovascular exercises such as the box trot, speed squats, steps, help taps, and swimming arms were performed for 10 minutes. Cardiovascular exercises could be done in a seated position, standing, or a combination of both. The last five minutes would consist of cool down exercises such as: upper/lower body stretching and range of motion exercises. An example of the land exercise lesson plan is in Figure 2. All session were taught in a group setting by one certified AFEP instructor. The amount of exercise sessions taught was divided up equally by two instructors.
All participants were advised to exercise at their self-selected pace and had the choice to rest at any given time. Exercise modifications were given for each exercise. The graduate researchers collaborated to design the lesson plans to match exercise prescriptions for the participants in both programs. Subjects were required to attend a minimum of 27 classes (75%) of the 36 classes offered. Attendance was taken daily by each instructor at the end of class. Participants were asked to refrain from starting any additional exercise program.
**Figure 1**  Example of Aquatic Exercise Lesson Plan

- **Warm-up:** walking forward, walking backwards, wooden soldier, side stepping, baseball swings, stirring the soup
- **Lower Extremity:** forward leg swings, backwards leg swings, side leg lifts, heel taps, toe taps, squats, heel raises, leg circles, hamstring curls, knee extension
- **Upper Extremity:** bicep curls, forward and backward claps, touchdowns, internal/external shoulder rotation, pronation/supination, the chop, arm circles, tricep extension
- **Balance:** narrow stance, tandem stance, heel stance, balance walking, tandem walking, single leg stance, single leg stance w/ upper extremity exercise.
- **Cardiovascular Endurance:** breaststroke kick, flutter kick, knees in and out, hip abduction/adduction, bicycle forwards, bicycle backwards, diagonal knees in and out, scissors, hip flexion/extension
- **Warm-down:** Mini-squats, hip circles, calf stretch, hamstring stretch, hand flexion/extension, side bend, ankle circles, neck flexion/extension, piano, cherry-o’s
**Figure 2**  Example of Land Exercise Lesson Plan

| Warm-up: walking forward with arm swing, walking backwards with wrist curls, wooden soldier, side stepping with touchdown, shoulder stretch, hamstring stretch, wall reaching |
| Lower Extremity: sit to stand, leg swings, backwards leg swings, side leg lifts, heel taps, toe taps, squats, lunges, heel raises, leg circles, hamstring curls, knee extension/flexion, toe star excursion |
| Upper Extremity: wall push-ups, bicep curls, forward and backward claps, touchdowns, internal/external shoulder rotation, pronation/supination, arm circles, tricep extension |
| Balance: narrow stance, high five reaching, tandem stance, heel stance, balance walking, tandem walking, single leg stance, single leg and tandem stance w/ upper extremity exercises |
| Cardiovascular Endurance: marching with arm circles, the fox trot, breaststroke pull with heel taps, freestyle pull with side toe taps, pulling rope with calf raises, side arm raises in squat, side leg lifts with arm claps |
| Warm-down: open hands, hip circles, calf stretch, hand flexion/extension, side bend, ankle circles, neck flexion/extension, piano, cherry-o’s, neck rotation, the hug |
Statistical Analysis

Statistical analysis was processed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 17.0. A 2 x 2 repeated measures MANOVA was used to assess overall group (aquatic-based exercise group compared to land-based exercise group) by time (pre- to post-test) interactions. Within groups was compared with a paired-samples t-test and baseline data between groups was compared with an independent samples t-test for equality of means. A significant difference for the 6 dependent variables in this study was based on an alpha level set at p <.05. The independent variable in this study is mode of exercise (aquatic-based exercise or land-based exercise). Dependent variables were spatiotemporal characteristics (speed, cadence, and stride length,) and gait kinematics (joint excursion of the angles of the hip, knee, and ankle joint). The affected side was used for data processing and statistical analysis. If the participant was affected bilaterally, the right side was selected. Microsoft Excel was used to further process data and generate figures and graphs.
RESULTS

The purpose of this study was to investigate the effects of aquatic exercise on gait parameters in older adults with knee OA. A total of 21 participants were recruited initially. Due to medical recommendations, some participants had to be reassigned to a different exercise group. Before completion of the study, 4 participants from the aquatic exercise group and 3 participants from the land exercise group dropped out for personal reasons not related to the study. The final participant count for this study consisted of 6 in the aquatic-based exercise group (aged 76.3 ±9.5) and 8 (aged 75 ± 6.9) in the land-based exercise group seen in summary of participant profiles Table 1. There was a statistical difference in BMI between groups at the baseline (aquatic= 34.15 ± 3.09 versus land= 23.63 ± 2.18). There was a statistically significant difference between baseline data in speed (aquatic= .907 m/sec versus land= 1.34 m/sec; p=.026) between groups (table 1). Both groups were tested before and after the 12-week period for all spatiotemporal and kinematic gait parameters.

MANOVA showed aquatic-based exercise had a significant group-by-time interaction in stride length (p=.017) seen in Table 2. The aquatic group significantly increased stride length from .903 to 1.088 meters while the land group showed insignificant improvement from 1.1424 to 1.1925 meters (Graph 1). Independent t-test revealed no significant differences in stride length between groups at the baseline (Table 4).

The aquatic group demonstrated significant improvements in 3 of the 6 variables. The aquatic group increased speed from .907 to 1.42 meters/ second (56.5% ↑,  p=.008). Cadence increased from 120 to 160.8 steps/ minute (33.9% ↑,  p=.027), and stride length
increased from .903 to 1.09 meters (20.7% ↑, p=.005). The land group showed significant improvements in 2 of the 6 variables: The land group increased speed from 1.34 to 1.68 meters/second (26.1% ↑, p=.009) and increased in cadence from 137.88 to 168 steps/minute (21.84% ↑, p=.004). Both groups showed no significant changes in all 3 kinematic variables. See Dependent variables of Aquatic Exercise and Land Exercise Table 3.
Table 1 Summary of participant profiles

<table>
<thead>
<tr>
<th>Variable</th>
<th>Aquatic n=6</th>
<th>Land n=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>76.3 (±9.5)</td>
<td>75 (±6.9)</td>
</tr>
<tr>
<td>Gender</td>
<td>6 females</td>
<td>7 females, 1 male</td>
</tr>
<tr>
<td>Body mass index (kg/m²)*</td>
<td>34.15 (3.09)</td>
<td>23.63 (2.18)</td>
</tr>
<tr>
<td>Use of walking aid</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Right knee affected</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Lf &gt; Rt knee affected</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Rt &gt; Lf knee affected</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Fibromyalgia</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>High blood pressure</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Diabetes</td>
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<td>1</td>
</tr>
<tr>
<td>Spinal Stenosis</td>
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<td>0</td>
</tr>
<tr>
<td>Sciatica</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>0</td>
<td>1</td>
</tr>
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</table>
Graph 1  Comparison of Stride Length

*Statistical Significance p<.05.
Graph 2  Speed Comparisons

*Statistical significance p<.05
Graph 3  Cadence Comparisons

*Statistical significance p<.05
Discussion

The primary purpose of this study was to examine the effects of aquatic exercise program on gait parameters in older adults with knee osteoarthritis compared to land exercise. Results showed aquatic-based exercise had a significant group-by-time interaction in stride length with an increase from .903 to 1.09 meters. The aquatic group demonstrated significant improvements in all 3 spatiotemporal variables with a 56.5% increase in speed (.907 to 1.42 meters/second), 33.9% increase in cadence (120 to 160.8 steps/minute), and a 20.7% increase in stride length (.903 meters to 1.09 meters). The land group showed significant improvements in 2 of 3 spatiotemporal variables with a 26.1% increase in speed (1.34 to 1.68 meters/second) and 21.84% increase in cadence (137.88 to 168 steps/minute). See Graph 1, 2, & 3.

Aquatic exercise had a significant group-over-time interaction in stride length when compared to land exercise. This supports previous research which also found a significant increase in stride length (p=.01) following a similar 12-week aquatic exercise program with no control (Alexander et al., 2001). Research shows there is a significantly decreased stride length in adults with knee OA when compared to non-arthritic population (Al-Zahrani et al., 2002) stressing the importance of aquatic exercise. The significant difference in stride length from aquatic-based exercise compared to land-based exercise could be contributed by the water properties.

Buoyancy and hydrostatic pressure may have assisted a person training in water by allowing greater body support and a pain-free ROM in the hip joint achieving greater stride length practice which could be too difficult to achieve during land training. At
shoulder/chest depth in water, the upward force of buoyancy, opposite to gravity, offloads body weight by 85% decreasing compression stress on joints which can ease movement and improve flexibility (Sova et al., 2000). Decreased weight bearing allows a safe and effective practice of walking. Aquatic environments naturally promote increased control of movement with less impact force reducing the speed of movements which provides softer landings. Both Alexander et al. (2001) and this current research support that aquatic exercise can be clinically significant in improving stride length and gait efficiency in older adults with knee OA.

There were no significant group over-time interaction in all of the kinematic variables between aquatic exercise and land exercise group (Figure 3). These results differ from Davey et al. (2004) who found a significant increase in hip ROM (p<.05) using goniometry after 12-months of aquatic exercise. Research shows a significant relationship and risk factor for the presence of locomotor disability associated with decreased hip ROM (Escalante et al., 1999; Odding et al., 1996). Aquatic exercise can be a safe atmosphere, although not significant in this current study, to practice lower extremity joint movement strategies which could minimize difficulties with tasks such as walking and climbing stairs.

Within groups, aquatic-based exercise significantly demonstrated an increase in all spatiotemporal variables including speed, cadence, and stride length (Graph 1, 2, 3). Al-Zahrani et al. (2002) reported that individuals with knee OA have a significantly reduced speed, cadence, and stride length when compared to non-arthritic controls. This current research shows that aquatic exercise can improve these gait parameters. These improvements can be as result of walking in water with resistance being 12-times more
than movement in air. The resistance perhaps increased muscle strength that is used during gait. The surface area, speed, and size of movement are the dependent factors of resistance in water and can all be easily modified to progress or regress exercise intensity for each participant’s ability. This allowed participants to easily adjust their own intensity. The 3-D drag forces in water act in all 3 planes of movement reducing injury with the decrease in eccentric muscle activity and the use of safe concentric muscle action from constant multidirectional resistance. Warmer water temperatures may have also assisted in the restoration of movement from collagen distensibility (Sova et al., 2000). These aquatic properties and contributions make a superior training atmosphere for older adults with knee osteoarthritis compared to land exercise.

However, land-based exercise demonstrated similar results with a significant increase in speed and cadence. The significant increase in speed and cadence on land could be as a result that land training promotes functional practice at a faster stepping rate and increased velocity. In comparison, aquatic exercise tends to show slower stepping rates at a decreased velocity from the increased viscosity. Land exercise exhibits challenging body control with greater dynamic force from gravity allowing practice in a more functional setting which could explain differences in training.

The overall results on the three variables speed, cadence, and stride length indicate that either aquatic or land exercise will improve these gait parameters. However, the results that showed a significant difference between the two groups in stride length is possibly due to the aquatic group having significantly lower baseline measurements and the land group not improving significantly. There was a greater range for improvement from baseline measurements for participants in the aquatic group compared to land
group, although only speed was considered significantly different. These significant differences can be explained by some participants being re-assigned to the aquatic-based exercise group because of health conditions based on physician’s approval. These individuals typically had increased pain and were overweight, drastically altering the Body Mass Index (BMI) between groups making the baseline measurements significantly higher in the aquatic group. Overtime, the initial gap between groups decreased, showing that individuals who were overweight or in pain can safely exercise in water as opposed to on land and improve gait significantly while minimizing risk of injury. These results support that aquatic exercise can be a valuable exercise modality for overweight and obese population by reducing the percentage of weight bearing by lower extremity and stress on joints used for ambulation. Participants with greater BMI values will find aquatic exercise to be a safer and more controlled environment allowing practice of locomotor tasks. However, both aquatic and land exercise can improve spatiotemporal parameters and are effective tools for managing gait.

In a recent study, Roper et al. (2013) reported that acute aquatic treadmill exercise improves gait and pain in people with knee OA. After only 3 exercise sessions, participants in the aquatic-based exercise program exhibited improved angular velocities and pain when compared to a land-based exercise program. These findings show that significant changes in gait and pain can be apparent as early as one week. Similar, Davey et al. (2004) showed significant gait changes after 12-months of aquatic-based exercise compared to a non-exercise control. Roper et al. (2013), Davey et al. (2004), and this current research support that aquatic exercise can be a valuable therapeutic exercise
modality for individuals with knee OA looking to improve gait and pain as early as a week and continue to see significant improvements when performed over a year.

**Conclusion**

The aquatic environment is ideal to practice gait training, although it is unclear whether or not aquatic exercise is a better alternative to land exercise. Our findings suggest that both aquatic and land-based exercise programs can be beneficial for older adults with knee osteoarthritis to improve walking. However, aquatic exercise can be a clinically significant therapeutic exercise modality for individuals with knee OA looking to improve stride length when compared to a land exercise.

**Limitations**

This study was limited to its small sample size. There was no inactive control group. Reflective markers may have caused slight movement during walking trials from skin or clothing. Although marker placement was performed by the same principle investigator for all participants, marker placement at the exact joint site may not be completely accurate. During data collection, it was assumed that all participants expended their maximum effort during the gait trials, as well as gave their maximum effort during each exercise sessions. Some participants had to be reassigned to a different group for medical purposes preventing a true randomization of groups.
Future Research

Future research should examine a larger sample size of individuals with knee osteoarthritis and further compare the effects of aquatic-based exercise. Further testing should be implemented during the intervention (midway point) to observe rate of change over time more closely. Self selected walking speed and fastest walking speed can both be analyzed and compared together. A follow-up test should be taken to observe if significant gait variables remain after 12-weeks post intervention.
References


Appendix A

Tables

Table 2  Between-Group Comparisons: Aquatic Exercise & Land Exercise

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
<th>Noncent Parameter</th>
<th>Observed Power^a</th>
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<tbody>
<tr>
<td>Cadence</td>
<td>195.35</td>
<td>1</td>
<td>195.35</td>
<td>.584</td>
<td>.460</td>
<td>.046</td>
<td>.584</td>
<td>.108</td>
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<tr>
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<td>.049</td>
<td>1.216</td>
<td>.292</td>
<td>.092</td>
<td>1.216</td>
<td>.174</td>
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<tr>
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<td>.031</td>
<td>7.593</td>
<td>.017*</td>
<td>.388</td>
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<td>95.787</td>
<td>7.604</td>
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<td>.716</td>
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<td>.617</td>
<td>.022</td>
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<td>.076</td>
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<td>.154</td>
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<td>.074</td>
<td>.957</td>
<td>.147</td>
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<td>.549</td>
<td>.473</td>
<td>.044</td>
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<td>.105</td>
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Table 3: Dependent variables- Aquatic Exercise & Land Exercise.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Aquatic Group</th>
<th>Land Group</th>
<th>Aquatic Group</th>
<th>Land Group</th>
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</thead>
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<tr>
<td></td>
<td>Mean (SD)</td>
<td>SS</td>
<td>Mean (SD)</td>
<td>SS</td>
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<tr>
<td>Speed</td>
<td>Pre</td>
<td>Post</td>
<td>Sig.</td>
<td>Pre</td>
</tr>
<tr>
<td></td>
<td>.907 (.298)</td>
<td>1.42 (.256)</td>
<td>.008*</td>
<td>1.34 (.320)</td>
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<tr>
<td>Cadence</td>
<td>120.03 (.20)</td>
<td>160.83 (16.48)</td>
<td>.027*</td>
<td>137.88 (12.16)</td>
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<td>Stride Length</td>
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<td>1.09 (.238)</td>
<td>.005*</td>
<td>1.14 (.24)</td>
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<td>Hip Joint Excursion</td>
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<td>.284</td>
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<td>46.38 (12.08)</td>
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<td>Ankle Joint Excursion</td>
<td>30.89 (10.70)</td>
<td>24.29 (9.57)</td>
<td>.188</td>
<td>29.17 (8.56)</td>
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*Statistically significant p<.05
**Table 4**  Spatiotemporal Equality of Means

<table>
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<tr>
<th></th>
<th>Levene’s Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
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</thead>
<tbody>
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<td></td>
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<td>Sig.</td>
<td>t</td>
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<td>Pre Cadence</td>
<td>Equal variances assumed</td>
<td>0.563</td>
<td>0.467</td>
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<tr>
<td>Pre Speed</td>
<td>Equal variances assumed</td>
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<td>0.717</td>
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<td>Pre Stride Length</td>
<td>Equal variances assumed</td>
<td>1.305</td>
<td>0.276</td>
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Independent Samples Test
*Statistically Significant p<.05
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<th>Joint Excursion</th>
<th>Equal variances assumed</th>
<th>Levene's Test for Equality of Variances</th>
<th>t-test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
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<tr>
<td>Pre Hip</td>
<td>.082</td>
<td>.779</td>
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<td>.853</td>
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<td>Joint Excursion</td>
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<td>Pre Knee</td>
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<tr>
<td>Pre Ankle</td>
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<td>.430</td>
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<td>.743</td>
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<tr>
<td>Joint Excursion</td>
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Independent Samples Test
*Statistically Significant p<.05
Table 6  Multivariate Tests

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Appendix B

Graphs

Graph 4  Aquatic-Group Mean Average Hip Kinematics
Graph 5  
Land-Group Mean Average Hip Kinematics

Degrees

Gait Cycle %

Land Pre HipAngles(Flex/Ext)

Land Post HipAngles(Flex/Ext)
Graph 6  
Aquatic-Group Mean Average Knee Kinematics

![Graph showing Aquatic-Group Mean Average Knee Kinematics](image)

- **Aquatic Pre KneeAngles (Flex/Ext)**
- **Aquatic Post KneeAngles (Flex/Ext)**
Graph 7
Land-Group Mean Average Knee Kinematics

![Graph showing Land Group Mean Average Knee Kinematics](image)

- **Land Pre Knee Angles (Flex/Ext)**
- **Land Post Knee Angles (Flex/Ext)**

Degrees

Gait Cycle %
Group 8

Aquatic-Group Mean Average Ankle Kinematics

![Graph showing Aquatic Pre and Post Ankle Angles (Dorsiflexion/Plantar) over the gait cycle percentage. The graph compares the degrees of ankle movement at different stages of the gait cycle. The x-axis represents the gait cycle percentage, ranging from 0 to 100, and the y-axis represents the degrees, ranging from -5 to 25 degrees. The blue line represents Aquatic Pre Ankle Angles, while the red line represents Aquatic Post Ankle Angles. The peaks and troughs indicate the range and pattern of ankle movement during the gait cycle.]
Graph 9  
Land-Group Mean Average Ankle Kinematics

[Graph showing Land Pre and Land Post Ankle Angles (% Gait Cycle) with degrees on the Y-axis and Gait Cycle % on the X-axis.]

- Land Pre Ankle Angles (Dorsiflexion/Plantar)
- Land Post Ankle Angles (Dorsiflexion/Plantar)
Appendix C

California State University, Northridge

CONSENT TO ACT AS A HUMAN RESEARCH PARTICIPANT

Comparison of balance outcomes between an aquatic vs. land-based program in older adults with knee Osteoarthritis (OA).

You are being asked to participate in a research study. Participation in this study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to participate. A researcher listed below will be available to answer your questions.

Researcher: Cameron Lievense, Graduate Teaching Associate
Center of Achievement through Adapted Physical Activity at CSUN.
818-636-4621. CameronLievense@gmail.com

Faculty Advisor: Taeyou Jung, PhD, ATC, CAPE, Associate Professor & Director
Center of Achievement through Adapted Physical Activity
(818) 677-2182. taeyoujung@csun.edu

PURPOSE OF STUDY

The purpose of this study is to examine the effects of aquatic exercise on gait parameters in older adults with knee osteoarthritis.

SUBJECTS

Inclusion Requirements
You are eligible to participate in this study if you are aged greater than or equal to 55, have a medical diagnosis of knee osteoarthritis, are able to safely enter and exit a pool, and have obtained medical clearance.

Exclusion Requirements
You are not eligible to participate in this study if you have multiple major joint involvement, conditions which severely limits local ambulation, use gait aids for ambulation, dementia, unable to give informed consent, had recent joint injections (≤6 months), participate in aquatic exercise (≤ 6 months), and have cardiovascular, metabolic, pulmonary, or neurological disease.
Time Commitment

This study will involve approximately 12 weeks of your time during Mondays, Wednesdays, and Fridays for 45 minutes of exercise. An additional one hour of testing will be added for both pre and post data collection procedures.

PROCEDURES
You will first be contacted by phone and interviewed to ensure you are qualified to participate. You will later be randomly selected to either an aquatic or land exercise program and choose a date to meet at CSUN’s Center of Achievements for data collection before and after the exercise program. Testing procedures will be verbally explained to you in addition to a written summary of what you will be asked to do during testing procedures. You will then sign the informed consent. Body measurements will be measured and recorded. You will next change into tight fit shorts so reflective markers can be attached to your lower body. You will be asked to walk along a 10-meter walkway at your fastest walking speed twice for familiarization and four times for data collection trials. One minute rest period will be provided after the first two walking trials.

During walking trials, you will be recorded. Your initials here ______ signify your consent to be videotaped. All recordings are collected as part of this study and will disposed of after the conclusion of the study.

RISKS AND DISCOMFORTS The potential risks during this study may include skin irritation from chlorine, physical fatigue, dehydration, and water hazards. Physical fatigue during exercises will be monitored by a certified group instructor. You will be advised to drink plenty of water prior to each exercise session and to wear water shoes for hygienic purposes outside of the pool. A certified lifeguard and certified group instructor will monitor your safety. Showers and lotion should be used to minimize skin irritation from chlorine.

BENEFITS

Subject Benefits
All participants will not directly benefit from this investigation. However, indirect benefits include decreased body fat, pain, increased independence, social interaction, improved gait, flexibility, strength, balance, and fitness. Engaging in exercise will also promote a healthy lifestyle and reduce the risk of cardiovascular disease and other secondary complications associated with OA.

ALTERNATIVES TO PARTICIPATION
The only alternative to participation in this study is not to participate.
COMPENSATION, COSTS AND REIMBURSEMENT

Compensation for Participation

You will not be paid for your participation in this research study.

Costs

There is no cost to you for participation in this study.

Reimbursement

You will not be reimbursed for any out of pocket expenses, such as transportation fees.

WITHDRAWAL OR TERMINATION FROM THE STUDY AND CONSEQUENCES

You are free to withdraw from this study at any time. If you decide to withdraw from this study you should notify the research team immediately. The research team may also end your participation in this study if you do not follow instructions, miss scheduled visits, or if your safety and welfare are at risk.

CONFIDENTIALITY

Subject Identifiable Data

All identifiable information that will be collected about you will be kept with the research data.

Data Storage

- All research data will be stored electronically on a secure computer with password protection.

Other privacy options:

- The video recordings will also be stored on a secure computer with password protection; then transcribed and erased as soon as possible.

Data Access

The researchers and Dr. Jung will have access to your study records. Any information derived from this research project that personally identifies you will not be voluntarily released or disclosed without your separate consent, except as specifically required by law. Publications and/or presentations that result from this study will not include identifiable information about you.
All documentation/data/videos will be secured in a locked file cabinet located in the center’s main office up to three years and after three years they will be destroyed. Only Cameron Lievense, the primary researcher, and Dr. Taeyou Jung, research advisor, will be allowed to access the data and the videos.

IF YOU HAVE QUESTIONS
If you have any comments, concerns, or questions regarding the conduct of this research please contact the research team listed on the first page of this form.
If you are unable to reach a member of the research team listed on the first page of the form and have general questions, or you have concerns or complaints about the research study, research team, or questions about your rights as a research subject, please contact Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or phone 818-677-2901.

VOLUNTARY PARTICIPATION STATEMENT
You should not sign this form unless you have read it and been given a copy of it to keep. Participation in this study is voluntary. You may refuse to answer any question or discontinue your involvement at any time without penalty or loss of benefits to which you might otherwise be entitled. Your decision will not affect your relationship with California State University, Northridge. Your signature below indicates that you have read the information in this consent form and have had a chance to ask any questions that you have about the study.

I agree to participate in the study.

__________________________________________________________
Participant Signature Date

__________________________________________________________
Printed Name of Participant

__________________________________________________________
Researcher Signature Date

__________________________________________________________
Printed Name of Researcher Date
Appendix D

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

EXPERIMENTAL SUBJECTS

BILL OF RIGHTS

The rights below are the rights of every person who is asked to be in a research study. As an experimental subject I have the following rights:

1) To be told what the study is trying to find out,
2) To be told what will happen to me and whether any of the procedures, drugs, or devices is different from what would be used in standard practice,
3) To be told about the frequent and/or important risks, side effects or discomforts of the things that will happen to me for research purposes,
4) To be told if I can expect any benefit from participating, and, if so, what the benefit might be,
5) To be told the other choices I have and how they may be better or worse than being in the study,
6) To be allowed to ask any questions concerning the study both before agreeing to be involved and during the course of the study,
7) To be told what sort of medical treatment (if needed) is available if any complications arise,
8) To refuse to participate at all or to change my mind about participation after the study is started. This decision will not affect my right to receive the care I would receive if I were not in the study.
9) To receive a copy of the signed and dated consent form.
10) To be free of pressure when considering whether I wish to agree to be in the study.

If I have other questions I should ask the researcher or the research assistant, or contact Research and Sponsored Projects, California State University, Northridge, 18111 Nordhoff Street, Northridge, CA 91330-8232, or phone (818) 677-2901.

X ____________________________________________

Signature of Subject Date