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An Exploratory Study of Aquatic Walking on Symptoms and Functional Limitations in Persons with Knee Osteoarthritis: Part 1

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Abstract

This paper represents Part 1 of a study that explored the effects of an underwater treadmill (UT) walking program on pain and function in adults with knee osteoarthritis (KOA). The Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC), numerical rating scale (NRS), timed up-and-go (TUG), and 10-m walk were assessed in 6 adults (62.7 ±14.2 years) who participated in an 8-week (3x/wk) UT walking intervention based on the Arthritis Foundation's Walk With Ease (WWE) program. Walking pace was self-selected, and walking duration of each session was increased from 10 to 45 minutes throughout the study. Knee pain and function were assessed pre-control (PRC), pre-intervention (PRI) and post-intervention (PST). NRS improved from PRC and PRI to PST ($p = .03$, $d = .37$). WOMAC subscale scores of pain, ($d = .36$); stiffness ($d = .44$); pain during daily activities ($d = .41$); and total scores ($d = .42$) improved ($p < .05$) from PRC to PST. Self-selected walking speed increased concurrently with decreased knee pain (NRS) from PRI to PST. The results support the WWE as a model for an UT walking program for improving knee pain in KOA.

Keywords: aquatic exercise, underwater treadmill walking, knee osteoarthritis, pain, functional performance, Walk with Ease

Introduction

Osteoarthritis (OA) is a degenerative joint disease that greatly limits the use of affected joints and impacts over 32.5 million individuals in the United States (Centers for Disease Control, 2020). Knee osteoarthritis (KOA) contributes to approximately 83% of global cases of OA, with an estimated 14 million having symptomatic knee OA (Vina & Kwoh, 2018). Primary consequences of OA include pain, stiffness, and loss of function. The dominant symptom of OA is pain (Neogi, 2013). Pain experienced by individuals with OA is chronic and varies in nature, ranging from a persistent dull ache to intermittent severe pain, both of which can interfere with activities of daily living (Neogi, 2013). In the lower extremity, pain is considered to be a central cause of mobility impairment, especially among older adults (Neogi, 2013).

There is an abundance of evidence demonstrating loss of function (mobility) in persons with OA (Al Amer et al., 2013; Guccione et al., 1994), notably during level walking and stair descent (Childs et al., 2004; Mills et al., 2013). Persons with knee OA have demonstrated significantly less knee excursion in the stance (loading) phase of level walking (Childs et al., 2004), possibly a result of increase pain and stiffness. Data from the Framingham Study identified stair climbing and walking as activities that induce the greatest limitations in persons with knee OA (Guccione et al., 1994). Treatment of KOA often focuses on improving functional outcomes that are most affected by the disease.

While the standard OA treatment approach centers around pharmacological modalities, evidence continues to support exercise as an essential component of the comprehensive medical treatment of OA (Bartels et al., 2016). A notable recent study revealed that physical therapy was more effective at reducing pain and functional disability than the use of medication in patients with knee OA (Deyle et al., 2020). Walking is a commonly recommended exercise therapy because it is inexpensive, safe, and can improve the functional status of persons with OA. Because of these benefits, walking programs, such as the Arthritis Foundation's Walk with Ease (WWE) program, have been developed to facilitate management of OA. The WWE program has proven to be effective at improving pain (Bruno et al., 2006; Wyatt et al., 2014), stiffness and disability (Callahan, 2009) in persons with OA. Despite the encouraging findings from these studies, land-based walking has been shown to increase knee joint load in persons with KOA (Baliunas et al., 2002).

Aquatic exercise may serve as an alternative to land-based exercise in persons with OA because the buoyancy that water provides serves to "unload" arthritic joints (Denning et al., 2020). Furthermore, studies have demonstrated that aquatic exercise in persons with OA is superior at decreasing pain, increasing muscle strength, and improving balance, coordination, and joint stability when compared to land-based exercise (Bartels et al., 2016, Denning et al.; Silva et al., 2008). One type of aquatic exercise that has been utilized as a mode of rehabilitation is walking on an underwater treadmill (UT). Advantages of using an UT include the ability to control water depth, temperature, and belt speed (Byrne et al., 1996).

Combining an established walking program with the UT while controlling water depth and temperature may produce positive adaptions on pain and function in persons with KOA. Exploratory studies are needed to uncover needed information to conduct larger comparative studies between land-based and aquatic-based interventions. Therefore, the purpose of this exploratory study was to investigate the effects of an aquatic walking program that was based on an established walking program (Arthritis Foundation's WWE). We hypothesized that there would be significant decreases in pain (NRS) and significant increases in function (decreased TUG score and increased 10m walking speed) after an aquatic WWE program. We also hypothesized that we would observe significant decreases in the Western Ontario & McMaster Universities Osteoarthritis Index (WOMAC) subscale (pain, stiffness, and functional limitations) and total scores after participating in an aquatic WWE program.

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Method

Participants

To be eligible for the preliminary study, participants were required to have physician diagnosis of KOA and physician clearance to participate in the aquatic WWE program. Men (*n* = 3) and women (*n* = 3) between the ages of 51 and 87 years (all measurements mean ± SD, age = 62.7 ± 14.2) were recruited from the local community. The age range of the study participants was reflective of 88% of the current population diagnosed with OA being 45 years or older (United States Bone and Joint Initiative, 2018). Mean height and body mass were 172.8 ± 10.9 cm and 105.4 ± 28.9 kg, respectively. This study was approved by the University Institutional Review Board before data collection. All participants were screened for health risks and each participant read and signed an informed consent prior to beginning the study.

Procedures

Each participant had their height (cm) and body mass (kg) measured, completed the WOMAC, rated pain in the most painful knee through the NRS, and measured functional performance three times (i.e., before the 8-week control period (PRC), before the 8-week UT walking intervention (PRI), and after the 8-week UT walking intervention (PST)).

WOMAC

The WOMAC is a self-administered questionnaire consisting of 24 items divided into 3 subscales: pain (5 items); stiffness (2 items); and physical function (17 items) that has been used extensively to track changes in OA patients (Clement et al., 2018). Each survey question was scored on a scale of 0-4 (0 = None; 1 = Mild; 2 = Moderate; 3 = Severe; 4 = Extreme). Subscale scores (pain, stiffness, & function) and overall (pain + stiffness + function) scores were used for analyses. The NRS measured pain in the most painful knee on a scale from 0-10 with 0 indicating no pain, 5 indicating moderate pain, and 10 representing worst possible pain.

Functional Performance Tests

Functional performance was assessed through timed-up-to-go (TUG) and 10m walking speed. The TUG test assesses basic mobility and dynamic balance (Denning et al., 2010) and has been shown to be a valid and reliable assessment of physical function in those with KOA (Alghadir et al., 2015; Hale et al., 2012). Prior to data collection, participants were familiarized with each test through verbal instructions and a demonstration. The instructions for the TUG test were to have the participant stand up from an armed chair with a seat of 45 cm from the floor, walk 3 m at a comfortable speed, cross a line on the floor, turn around, walk back, and sit down. Timing of the TUG test was achieved using a stopwatch with the test beginning when the participant's back was no longer in contact with the back of the chair and ending when the participant's buttocks touched the seat of the chair upon return. Time walking across a level surface was measured using a 10m walking course with a level surface. Participants were instructed to walk at a comfortable speed and were timed with a stopwatch. The 10m walk and TUG were conducted by the same tester throughout the study.

After an initial 8-week control period, participants completed an 8-week aquatic-based walking program that was modeled after the Arthritis Foundation's WWE program. The UT walking program was performed 3x/week for 8-weeks using a self-contained UT (Hydrotrack, Ferno, Wilmington, OH). While the WWE program is typically 6-weeks in duration, an 8-week program was chosen to represent existing UT walking studies for other conditions (Conners et al., 2014; Stevens at al., 2014). In week 1, the duration of walking was 10 minutes at a self-selected pace intensity. The intensity was self-paced throughout the entire intervention and duration was increased by 5 minutes per week accumulating to a final duration of 45 minutes of walking in week 8. Water temperature was set between 32°-36° Celsius, and water height was to each individual's xiphoid process (Bartels et al., 2016; Denning et al., 2010). Knee pain (most painful knee) and speed were recorded half-way through each session. The NRS was used to measure pain in the most painful knee and speed of the treadmill (m·sec) was measured by timing belt revolutions. For inclusion in the study, participants were only allowed to miss 2 sessions across the entire 8-week program and the missed sessions were not allowed to be within the same week.

Statistical Analysis

Alternative statistical procedures were used to fit the exploratory nature of the study. In accordance with Tabachnick and Fidell (2013) suggestions to compensate for the small pilot sample size (i.e., low statistical power) and to improve generalizability, *t*-tests were conducted to control issues related to power and overfitting of multiple variables in a model with a small sample size. Cohen's *d* calculations for paired-samples *t*-tests were used to determine effect size. An alpha level of $p = .05$ was used for all statistical analyses.

Results

Compliance with the UT walking program was 98.6% with 2 participants missing one session each for non-health related issues. No exercise-related injuries were reported during the intervention. Mean preferred walking speed (m·sec) and mean pain (NRS: 0-10) per week of UT walking intervention are shown in Figure 1.

Mean pain scores (NRS) among participants was not different from PRC to PRI. A significant reduction in NRS from PRC to PST did occur with a large effect size, $t(5) = 2.97$, $p = .03$, $d = .37$, and a significant reduction in NRS from PRI to

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PST occurred with a large effect size, *t* (5) = 2.92, *p* = .03, *d* = .37. With respect to functional performance, preferred walking speed and TUG scores were not significantly changed across any of the measurement points (see Table 1).

Table 1
Pain and mobility measures of the study (N = 6)

Variable	PRC *M* *SD*	PRI *M* *SD*	PST *M* *SD*
NRS (0-10)	5.3 ± 2.3	4.3 ± 2.1	2.1±1.4
10m (m·sec)	1.11 ± 0.25	1.19 ± 0.29	1.18 ± 0.27
TUG (sec)	9.7 ± 2.5	9.8 ± 2.4	9.6 ± 2.6

Note. PRC = pre-control; PRI = pre-intervention; PST = post-intervention; NRS = numeric rating scale for pain; 10m = speed used during 10 meters at preferred pace; TUG = timed up-to-go test.

There were no significant differences in the subscale (PAIN, STIFF, DAILY) and total WOMAC scores from PRC to PRI. There were significant decreases with a large effect size in average scores of PAIN (*t* (5) = 2.78, *p* = .04, *d* = .36; STIFF, *t* (5) = 3.95, *p* =.01, *d* = .44; DAILY, *t* (5) = 3.42, *p* = .02, *d* = .41; and TOTAL, *t* (5) = 3.63, *p* = .02, *d* = .42) from PRC to PST. Subscale and overall WOMAC scores from PRI to PST were not significantly different (see Table 2).

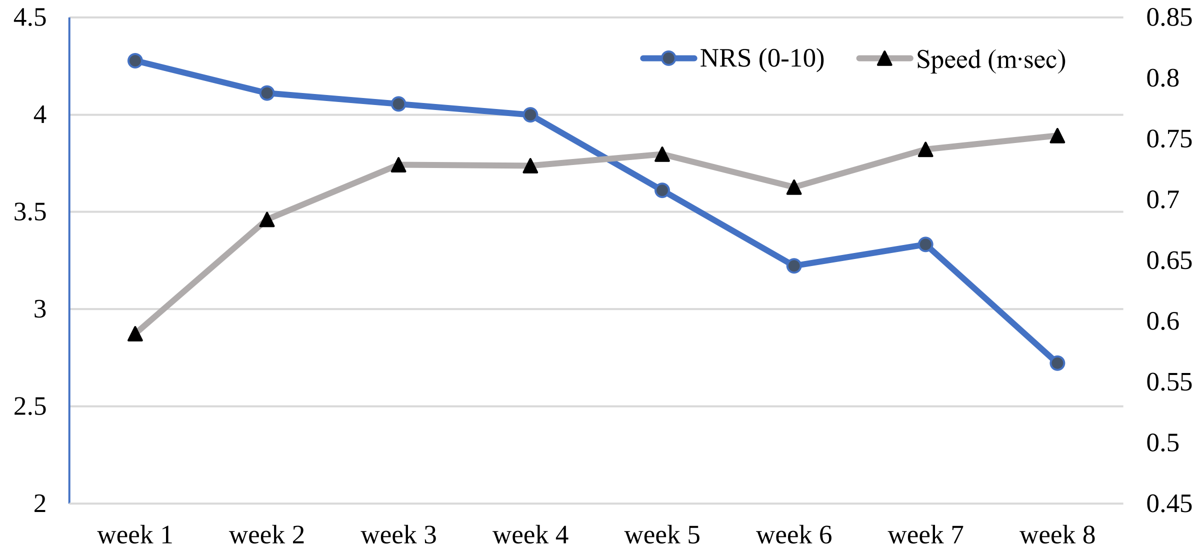
Table 2
Subscale and total WOMAC scores of the study (N = 6)

Variable	PRC *M* *SD*	PRI *M* *SD*	PST *M* *SD*
PAIN	8.0 ±2.8	8.3 ±3.4	4.8 ±1.5
STIFF	3.5 ±1.0	2.7 ±0.8	1.8 ±1.0
DAILY	29.8 ±8.0	25.3 ±12.0	15.0 ±6.3
TOTAL	41.3 ±10.8	36.3 ±15.8	21.7 ±8.5

Note. PRC = pre-control; PRI = pre-intervention; PST = post-intervention; PAIN = mean score for questions 1-5 on pain; STIFF = mean score for questions 6-7 on stiffness; DAILY = mean score for questions 8-24 on difficulty performing daily activities; TOTAL = mean score for all questions (1-24).

Figure 1

Mean pain (NRS) and self-selected speed (m·sec) by week during training sessions



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Discussion

The objective of this preliminary study was to examine the effects of an aquatic version of an established walking program (WWE) on pain and function in persons with KOA. While the acute effects of UT walking have been studied (Denning et al., 2010), this is the first study, to our knowledge, that has investigated the training effects associated with UT walking. We based our training program on the Arthritis Foundation's WWE because of its adaptability and effectiveness (Bruno et al., 2006; Callahan, 2009; Wyatt et al., 2014). It was hypothesized that the UT walking program would significantly decrease measures of pain and improve functional performance in participants with KOA.

The major finding of our study was the decrease in pain after the UT walking intervention. These findings were consistent with previous land-based walking (Bruno et al., 2006; Callahan, 2009; Wyatt et al., 2014) and aquatic exercise (Hinman et al., 2007; Fisken et al., 2015; Silva et al. 2008; Wyatt et al., 2001) studies for persons with OA. The large effect size represents the strength of the intervention despite the exploratory nature (and low statistical power) of the current study. Pain is the paramount symptom of OA, and its associations to the degree of functional limitations are well established (Lespasio et al., 2017; Neogi, 2013). Considering these factors, mediating pain is a necessary goal of therapeutic programs prescribed to persons with OA. The results from this preliminary study suggest that UT walking will meet this objective.

While exercise is recommended for improving pain and function, it is suggested that persons with KOA avoid activities that increase joint loading and subsequently worsen symptoms (Lespasio et al., 2017). One notable observation of this study was the progressive increase in self-selected UT walking speed and concurrent decrease in knee pain during training sessions (see Figure 1). This is a valuable finding as OA pain is often described as activity-related pain (Neogi, 2013). The reduction in self-reported knee pain could be explained by the joint unloading from the buoyancy that water provides during aquatic activities as well as the therapeutic effect of exercise. This finding demonstrates the efficacy of our aquatic-based intervention in modifying pain to allow those with KOA to progressively increase exercise intensity while reducing symptomology.

The WOMAC Osteoarthritis index is a self-report questionnaire with good reliability and construct validity (White & Master, 2016) which is commonly used to measure pain, stiffness, and function in persons with hip and knee OA (Bellamy et al., 1988). The subscale and total scores of this measure between the PRC and PST were significantly improved. While not statistically significant, visual comparisons of the subscale and total means from PRI to PST do show descriptive improvement. These findings are similar to larger land-based walking (Evcik &

Sonel, 2002) and water-based exercise (Silva et al., 2008) studies. The improvements in WOMAC scores after completing the WWE-based aquatic walking program indicated it may be an effective intervention model for those with KOA.

Functional performance (preferred TUG and 10m walking speed) was not changed after the UT walking intervention despite significant reductions in knee pain. This is contrary to evidence that has suggested pain contributes to functional limitations (Lespasio, et al. 2017; Neogi, 2013). One explanation is that our chosen functional performance tests did not mimic the activities in which pain was improved. The physical function (DAILY) subscale of the WOMAC survey assesses pain during specific activities, ranging from ascending/descending stairs to performing light/heavy domestic duties. When we examined each question, we noted an improvement in the questions pertaining to standing ($p = .004$), bending to the floor ($p < .001$), getting out of bed ($p = .013$), getting in/out of the bathtub ($p = .013$), sitting ($p = .041$), getting on/off the toilet ($p = .042$), and performing light ($p = .04$)/heavy ($p = .05$) household chores. Future studies should explore developing objective functional measures that better represent the self-report activities of the WOMAC.

The therapeutic effects of heat, buoyancy, and hydrostatic pressure make aquatic-based interventions attractive for persons with KOA. Specifically, it has been suggested that persons who are symptomatic (Zhang et al., 2008) or who have moderate-to-severe grades of OA (Yuen et al., 2019) would greatly benefit from aquatic exercise. It has long been a common strategy to use aquatic therapies on those with symptomology and more severe injuries (Prentice & Voight, 2001). Classification of severity of KOA often includes clinical (Altman et al., 1986) and radiographic (Kohn et al., 2016) criteria. While research indicates weak associations between KOA severity and pain or function (Wluka et al., 2004), the amount of joint space narrowing, identified through radiography, has been shown to alter responses to land-based exercise interventions (Fransen et al., 2001). Severity classifications were not used in the current study. It is likely that our methodology would greatly benefit persons with moderate-to-severe KOA due to the unloading effects of the water. Future studies utilizing similar interventions should focus on persons with clinical and radiographic evidence of moderate-to-severe KOA, as indicated by the American College of Rheumatology and Kellgren-Lawrence classifications.

Study Limitations

In conclusion, the results from this initial study demonstrated improvements in general pain and self-report outcomes on the WOMAC after an 8-week UT walking intervention. Functional performance outcomes were unchanged after the intervention. Due to the therapeutic benefits of UT walking, it is likely that focusing the intervention we used on those with moderate-to-severe KOA would achieve greater improvements than what was observed in this study. The findings of this study support using the Arthritis Foundation's WWE as a model for an UT walking program.

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