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ORIGINAL RESEARCH

THE EFFECTS OF AN AQUATIC MANUAL THERAPY TECHNIQUE, AQUASTRETCH™ ON RECREATIONAL ATHLETES WITH LOWER EXTREMITY INJURIES

Timothy Alejo, PT, DPT
Corey Shilhanek, PT, DPT
Michael McGrath, PT, DPT
John D. Heick, PT, PhD, DPT, OCS, NCS, SCS

ABSTRACT

Background: When paired together, manual therapy and exercise have been effective for regaining range of motion (ROM) in multiple conditions across varied populations. Although exercise in an aquatic environment is common, research investigating manual therapy in this environment is limited. There is little evidence on AquaStretch™ an aquatic manual therapy technique, but anecdotal clinical evidence suggests its effectiveness.

Purpose: To investigate the effects of AquaStretch™ on ROM and function in recreational athletes with self-reported lower extremity injury and pain.

Study Design: Quasi-experimental design.

Methods: Injured recreational athletes participated in a 30-minute intervention session of AquaStretch.™ Injuries ranged from ankle (sprains and overuse), knee (contusions, sprains, and overuse), and hip conditions (contusions, overuse, and pain). Before a single intervention (preintervention) and within 24 hours after the intervention (postintervention), participants completed the following patient-reported outcome instruments: the Lower Extremity Functional Scale (LEFS) and the Foot and Ankle Ability Measure (FAAM) Sports subscale. AROM measurements of the ankle, knee, and hip and the following muscle length tests were measured: Ober's test, measurement of the popliteal angle, and the modified Thomas test. Finally, the overhead deep squat test was performed as a test of function.

Results: Twenty-six recreational athletes with lower extremity injuries of the ankle, knee, and hip, aged 18-60 years (18 males, 8 females, mean age 27.4 years) completed the study. The overall group by time interaction for the mixed-model Generalized Estimating Equations analysis was statistically significant for the LEFS (all $p < .002$) and for the FAAM Sports subscale ($p < .01$). There were no statistically significant time (pre vs post) by group interactions for range of motion and other measures, including the Ober's test, the overhead deep squat test, popliteal angle, and the modified Thomas test for injured athletes.

Conclusion: One session of AquaStretch™ in recreational athletes improved the patient-rated outcome measures of function specifically the LEFS and FAAM Sports subscale. These results suggest that AquaStretch™ may be an effective form of manual therapy to improve lower extremity function in injured athletes.

Levels of Evidence: 2b, Individual Cohort Study

Key words: AquaStretch™, lower extremity, movement system

[1] Spring Valley Hospital, Las Vegas, NV, USA
[2] One Accord Physical Therapy, Mesa, AZ, USA
[3] The Center for Total Back Care, Mesa, AZ, USA
[4] Northern Arizona University, Flagstaff, AZ, USA

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CORRESPONDING AUTHOR
Timothy Alejo, PT, DPT
Spring Valley Hospital, 5400 S Rainbow Blvd,
Las Vegas, NV, 89118
Phone: 702-853-3000
E-mail: talejo@atsu.edu

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INTRODUCTION

Recreational exercise activities are common in the United States probably because of the health benefits associated with cardiovascular exercise.[1,2] For those individuals who run for recreational exercise, lower extremity musculoskeletal injuries vary in frequency and type depending on the population studied, and prevalence rates range from 6.8 to 59 injuries per 1000 hours of running.[3] In recreational runners, it is estimated that approximately half will sustain an injury in a given year.[4] Musculoskeletal injuries are commonly related to overuse of the musculoskeletal system but are considered multifactorial.[3] Most recreational runners experience musculoskeletal injuries in the lower extremities.

Interventions to address lower extremity musculoskeletal injuries in athletes vary and range from soft tissue mobilizations, modalities, pharmaceuticals, instrument-assisted mobilizations, such as instrument-assisted soft tissue mobilization or instrumented soft tissue mobilization, manual therapy techniques for the low back and lower extremity, and specific exercise approaches to address muscular imbalances.[5-13] One of the most common interventions to address lower extremity injures is soft tissue mobilization, which varies in both approach and technique when addressing these injuries. In a systematic review, Piper et al[14] investigated the effectiveness of soft tissue mobilizations in the lower extremities compared with other interventions across the lifespan of individuals. The authors classified soft tissue mobilization as a mechanical form of therapy where soft tissue structures were passively pressed, kneaded, or stretched using physical contact with the hand or a mechanical device. They concluded that the effectiveness of most types of soft tissue therapy was not adequately investigated.[14] For the lower extremity, soft tissue mobilization was effective for plantar heel pain, and trigger point approaches seemed to provide limited to no benefit.[14] The authors found limited evidence for the effectiveness of soft tissue mobilization for other lower extremity injuries.[14]

Clinically, soft tissue mobilizations may be combined with other manual therapy interventions such as active assisted movement of an extremity while applying physical pressure to a muscle to facilitate a muscular release. Some examples of manual therapy techniques and approaches include: soft tissue mobilization, joint mobilization, spinal manipulation, and manipulation of joints of the extremities. In addition, authors strongly suggest that manual therapy techniques be combined with exercise to be most effective.[15-18] Thus, for lower extremity injuries, manual therapy combined with exercise is effective in decreasing pain and improving function.[15-18] As such, specific exercise combined with manual therapy is often used to address muscle imbalances in the lower extremity. For example, interventions to address patellofemoral pain syndrome, a common condition in female runners, involves strengthening the hip.[19-21] However, there are several classifications of patellofemoral pain syndrome and it is unknown what specific exercises are best matched with specific classifications of this diagnosis. It is clear to the clinician that more evidence is needed to investigate specific exercises in combination with manual therapy techniques to determine appropriate approaches that are most useful for treating lower extremity conditions.

AquaStrech™ is a technique that combines manual therapy and active assisted exercise in a gravity-reduced aquatic environment. This intervention has been reproduced in clinical settings and has shown improvement in range of motion (ROM) after a single treatment session in non-injured individuals.[22] Aquastretch™ has anecdotal clinical evidence but limited research evidence to show its usefulness to restore ROM and function. The purpose of the current study was to investigate the effects of AquaStretch™ on ROM and function in recreational athletes with self-reported lower extremity injury and pain. The hypothesis that AquaStretch™ would improve ROM and function in recreational athletes was tested.

METHODS

Adult, recreational athletes with self-reported lower extremity injury were recruited for the current study from a health sciences university using flyers and convenience sampling. Potential participants had to be aged 18-60 years and currently training for at least seven hours per week for sport or exercise or be involved in intense physical training for at least four hours a week. They also had to have a current lower extremity injury or pain in the prior 6 months and a deficit in any active lower extremity ROM values on the injured side compared with the contralateral extremity. In the current study, injury was defined as any physical dysfunction that limited a person's participation in physical activity, and training was defined as activities related to any exercise directed toward improving function for sport (eg, running, cycling, sprinting). Intense physical training was considered high impact or plyometric movement that involved power and explosive movements, such as CrossFit. Exclusion criteria included surgery in the prior six months; a ligament, tendon, or meniscus tear in the prior six months, or general aquatic therapy precautions and contraindications. Specifically, AquaStretch™ precautions and contraindications[23] include the following: fractures, muscle tears, joint laxity, postoperative considerations, joint replacements, osteoporosis, anticoagulant medications (possible bruising), long-term steroid usage, edema of unknown cause (medical clearance recommended), active cancer, current or past radiation, heavy medications or substance abuse, litigation cases, non-responsive first treatment (ie, hydrophobic), active infection, cauda equina symptoms, ankylosing spondylitis, and aortic aneurysm. Demographic information about the participants was collected and included age, sex, and type of recreational activity participation. The local institutional review board approved the current study, and all participants signed an approved informed consent form prior to participation. No adverse events occurred during this study.

Outcome Measures

Prior to the AquaStretch™ intervention (preintervention) and within 24 hours after the intervention (postintervention), participants completed the following patient-reported outcome (PRO) instruments: the Lower Extremity Functional Scale (LEFS) and the Foot and Ankle Ability Measure (FAAM) Sports subscale. The preintervention PRO instruments were completed when the participant arrived at the facility and were included as part of the required study paperwork. Additionally, AROM measurement tests of the ankle, knee, and hip were performed and measured with a goniometer. Additional measures commonly used in physical therapy practice were performed and measured with a digital inclinometer on the IPhone iOS7 and the Hudl Technique application (IPhone application) to include: Ober's test, measurement of the popliteal angle, and the modified Thomas test, and the overhead deep squat test. Preintervention ROM measurements were performed immediately prior to the AquaStretch™ intervention. Postintervention measurements, including PRO instruments, were completed immediately after the intervention to limit outside factors that could influence the effects of the intervention. Even though the FAAM requires the participant to recall effects from the past week, the investigators still included it as part of the postintervention measurements because the investigators wanted to investigate the effect of the participant's injury on their daily activities before the intervention.

The preintervention and postintervention test measurements were performed by two third-year physical therapy students trained in performing the test measures. To improve accuracy, the student physical therapists conducted repeated tests for all measures on volunteers and during their clinical rotations prior to performing the tests on research participants in the current study. Preintervention and postintervention measurements were performed by the same tester for each measure for each participant.

Ankle, Knee, and Hip ROM Measurements—A single ROM measurement was taken for all available ROM actions and was measured bilaterally using a standard 12-inch goniometer for the hip and knee joints and a 6-inch protractor goniometer for the ankle joint (Prestige Medical, Northridge, CA). These goniometers were used throughout the study, and measurements were performed from proximal to distal to avoid the participant moving around too much. Ankle ROM measurements included dorsiflexion, plantarflexion, inversion, and eversion. Knee ROM measurements included flexion and extension. Hip ROM measurements included flexion, extension, internal rotation, external rotation, adduction, and abduction. The following positions were used for the ROM and other measurements: participants were in supine for ankle dorsiflexion, ankle plantarflexion, knee flexion, knee extension, hip flexion, hip abduction, hip adduction, the modified Thomas test, and the popliteal angle test. Participants were in long sitting for ankle inversion and ankle eversion; participants were in short sitting at the edge of a plinth for hip external rotation and hip internal rotation; participants were in side-lying for the Ober's test; and participants were in prone for the hip extension ROM measurement. Landmarks for all lower extremity ROM measurements were standardized. The following landmarks were used:

- Hip flexion: axis at the greater trochanter, moving the arm directed at the lateral epicondyle of the femur and stabilizing the arm directed at the midline of the torso.
- Hip extension: axis at the great trochanter, moving the arm at the lateral epicondyle and stabilizing the arm directed at the midline of the torso. Hip extension is performed with a bent knee.
- Hip abduction: axis at the same side ASIS, moving the arm bisecting the quadriceps directed at the patella and stabilizing the arm directed at the opposite ASIS.
- Hip adduction: axis at the same side ASIS, moving the arm bisecting the quadriceps directed at the patella and stabilizing the arm directed at the opposite ASIS.
- Hip internal rotation: axis at the midpoint of the patella, moving the arm at midway between the lateral/medial malleoli and stabilizing the arm directed perpendicular to the floor.
- Hip external rotation: axis at the midpoint of the patella, moving the arm at midway between the lateral/medial malleoli and stabilizing the arm directed perpendicular to the floor.
- Knee flexion: axis at the lateral epicondyle of the femur, moving the arm directed at the lateral midline of the fibula, referencing the lateral malleolus/fibular head, and stabilizing the arm directed toward midline of the femur, referencing the greater trochanter.
- Knee extension: axis at the lateral epicondyle of the femur, moving the arm directed at the lateral midline of fibula, referencing the lateral malleolus/fibular head, and stabilizing the arm directed toward midline of the femur, referencing the greater trochanter.
- Ankle dorsiflexion: axis at the lateral malleolus, moving the arm directed to the lateral aspect of the 5th metatarsal and stabilizing the arm directed toward the lateral midline of the fibula, referencing the fibular head.
- Ankle plantarflexion: axis at the lateral malleolus, moving the arm directed to the lateral aspect of the 5th metatarsal and stabilizing the arm directed toward the lateral midline of the fibula, referencing the fibular head.
- Ankle inversion: axis over the anterior aspect of the ankle between the malleoli, moving the arm directed toward the anterior midline of the 2nd metatarsal and stabilizing the arm directed toward the midline of the lower leg, referencing the tibial tuberosity.
- Ankle eversion: axis over the anterior aspect of the ankle between the malleoli, moving the arm directed toward the anterior midline of the 2nd metatarsal and stabilizing the arm directed toward the midline of the lower leg, referencing the tibial tuberosity.

Ober's test—Ober's test was used to measure the flexibility of the iliotibial band in the current study. The Ober's test has excellent intrarater reliability (intraclass correlation coefficient [ICC] = 0.90). Standard procedures were followed for the Ober's test as described by Reese and Bandy.[35] The participant was positioned on an examination table in side-lying with the hip and knee of the left lower extremity flexed to 45° and 90°. The tester stabilized the participant's pelvis with one hand and placed the other hand under the participant's thigh just above the knee to support the leg. The tester then passively abducted and extended the hip in line with the trunk. The tester asked the participant to relax while allowing the uppermost limb to drop toward the table through the available hip adduction ROM. The end point of hip adduction was defined as the point at which lateral tilting of the pelvis was palpated, when the hip adduction movement stopped, or both. At the end point of hip adduction, the tester maintained the alignment to ensure no pelvic tilting or internal rotation and flexion of the hip occurred. An iPhone smartphone with an iOS7 (Apple Inc., China) digital level inclinometer app was placed over the mid-thigh. If the leg was below horizontal, the measurement was recorded as a negative number; if it was above horizontal, it was recorded as a positive number. End range of motion was determined to be the onset of tightness with overpressure to the onset of discomfort. We used the smartphone app because it was convenient, and authors suggest good reliability. Vohralik et al[25] demonstrated excellent interrater and intrarater reliability when comparing the use of smartphone apps to the inclinometer when measuring ROM. In a systematic review, Milani et al[26] investigated the reliability of smartphone apps for determining ROM in static position of the lower extremity (hip, knee flexion, and ankle dorsiflexion) and found good to excellent intraobserver (ICC range, 0.80-0.96) and interobserver (ICC range, 0.80-0.99) reliability.

Popliteal Angle Test.—The popliteal angle was measured as described by Winslow et al.[24] The popliteal angle was measured on both sides, but measurement of the right popliteal angle is described here. The participant was positioned in supine on an examination table with the tester stabilizing the anterior superior iliac spines and mid-thigh of the left lower extremity. The participant was asked to bring the right thigh towards the chest, supporting it with both hands clasped behind the knee. The tester placed the participant's anterior thigh perpendicular to the table. The participant was then asked to actively straighten the lower leg. Using a goniometer, the popliteal angle measurement was taken at the end of the range of active knee extension, which is the degree of knee flexion from terminal knee extension.

Modified Thomas Test.—The modified Thomas test was measured as described by Kendall et al[27] and was used to determine lower extremity flexibility for the iliopsoas and quadriceps musculature. The modified Thomas test is commonly used in the clinic and has moderate intrarater reliability (ICC = 0.51).[27] Testing was done bilaterally, but measurement of the left lower extremity is described here. The participant sat with the gluteal fold positioned at the end of the examination table. The tester placed one hand behind the participant's back and the other hand under the right knee, flexing the thigh toward the chest and assisting the participant into supine position. The participant then stabilized the right thigh against the chest to limit lumbar spine motion. The participant was then instructed to relax the left lower extremity, allowing the hip to extend and the knee to flex over the edge of the table. Hip range of motion was measured parallel to the femur compared with the trunk, and knee range of motion was measured parallel to the fibula compared with the femur with use of a goniometer.

Overhead Deep Squat Test.—The Functional Movement Screen™ (FMS) overhead deep squat test was used in the current study to analyze shoulder, hip, knee, and ankle ROM measures.[28] Following the FMS protocol, participants of the current study held a dowel overhead during the movement. Cuchna et al[29] state that using the dowel improved test reliability and scoring and makes the testing more functional. The FMS overhead deep squat test starts with the participant standing and placing the feet approximately shoulder width apart with the feet aligned in the sagittal plane. The participant places the dowel on the head and adjusts hand placement to 90° elbow flexion. Next, the dowel was pressed overhead with the elbows fully extended. The participant was then instructed to descend into as deep a squat position as possible. If required, verbal cues were given by the tester so that the participant kept the heels on the floor and pressed the dowel maximally overhead. The participant was allowed to repeat the movement up to 3 times. For consistency, the participant's squat was recorded 92.5 inches away with the smartphone Hudl Technique app from the left sagittal view. The video was stopped at the deepest squat position, which was determined visually; and shoulder, hip, knee, and ankle ROM were measured using features of the smartphone app. Shoulder ROM was measured to determine how the trunk of the participant influenced motion.

Lower Extremity Functional Scale (LEFS)—The LEFS consists of 20 questions that evaluate lower extremity functional activities and has a possible score of 80 points. Higher scores on the LEFS indicate a better level of function. The LEFS has excellent test-retest reliability (ICC = 0.88)[30] and validity as well as responsiveness to change in patients with lower extremity disorders. The minimal clinically important difference (MCID) of the LEFS is 9 points, and this difference reflects a clinically important functional gain.[30]

Foot and Ankle Activity Measure (FAAM) Sports Subscale—The FAAM sports subscale is a region-specific, self-report questionnaire with 21 Likert-like response questions, which range from 0 (unable to do the activity) to 4 (no difficulty). Scores are added together and multiplied by 4 for scoring. The FAAM Sports subscale has excellent test-retest reliability (ICC = 0.87) and validity.[30] The MCID is 9 percentage points on a 0%-100% scale, and this difference reflects a clinically important improvement in activities.[30]

AquaStretch™ Intervention

The AquaStretch™ intervention was performed by a certified AquaStretch™ clinician. The AquaStretch™ clinician providing the intervention in the current study was a third-year physical therapy student who was interested in AquaStretch™ and had learned it outside of the course curriculum. The clinician had been using AquaStretch™ in a recreational manner for over a year before the current study was initiated. The clinician learned and practiced AquaStretch™ under the supervision of the developer of the technique and a physical therapist who had been using AquaStretch™ as an intervention since 2010. The AquaStretch™ clinician who performed the intervention in the current study received certification prior to initiation of the study. Certification involved performing the intervention on 50 healthy participants under the direction of a certified AquaStretch™ instructor and receiving 25 hours of training. The AquaStretch™ intervention was performed following the approach by Eversaul et al.[23] The intervention was performed in a chlorinated pool that ranged from 3.5 feet to 6 feet in depth. Participants in the current study were treated at the 3.5 foot depth. The average temperature of the pool was 33°C.

Each AquaStretch™ session was 30 minutes. Specific protocol positions were used to focus the AquaStretch™ intervention on the lower extremity addressing all available bilateral joints (ankle, knee, and hip). The positions used in the study were the following:

- Wall hang positions: foot grip, ankle grip, toe grip, iliotibial band pump, hip rock, and hip roll (Figures 1-5 for positions)
- One-leg standing with fulcrum performed bilaterally (Figure 6)
- Two heavy feet positions: lean back, arch forward, assume the position, back against the wall, and shoulder roll (Figures 7-10 not pictured: shoulder roll)
- Head hang (Figure 11)

For every position, except for the wall hang, 5- to 15-lb weights were used to adjust resistance and maintain foot contact with the bottom of the pool. The ankle weights were applied to one or both ankles just superior to the malleoli. The clinician was directly in front of the participant for wall hang positions, iliotibial band pump, hip rock, and hip roll; lateral to the participant for one-leg standing; behind the participant for two heavy feet; and directly lateral of the participant for head hang. The clinician adjusted the resistance weights based on participant size and presentation. All participants performed all protocol positions bilaterally during the 30-minute session.

Figure 1. *Wall Hang, Foot grip. a. Lateral view: clinician hand grip of the lateral aspect of foot. b. Superior view: clinician hand grip of lateral aspect of foot and posterior aspect of calcaneus.*

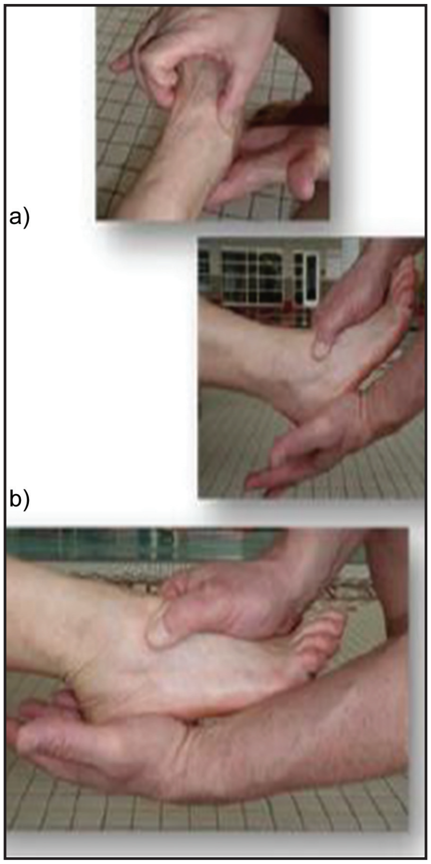

Figure 2. *Wall Hang: Ankle grip. a. Superior view: clinician placement of thumb between the talus and cuboid bones; middle finger placed in the talo-navicular joint. b. Lateral view: plantar surface of calcaneus on palm of hand.*

After entering the pool and before beginning the four-step AquaStretch™ basic procedure, the participant was instructed to immediately say stop or less if they experienced any discomfort or pain. The AquaStretch™ clinician encouraged movement during treatment by telling the participant to "move if you feel the need to move" while the clinician applied manual pressure. Manual pressure was applied to the area the participant felt pain and gradually increased until a stretch reflex movement was elicited. The gradual increase in pressure was performed after the clinician had determined the voluntary movement of the participant. The increase in pressure assisted the participants by allowing them to go into bigger ranges of movement not attainable by themselves. For example, during the foot grip, the stretch was directed in the movement of plantarflexion and inversion (Figure 1 and 2). Participants were allowed to move if they needed to. The pressure applied in those directions was increased until the

Figure 3. *Wall Hang:,Toe grip. a: Superior view: clinician thumb placement on proximal phalanx of great toe and thumb placement on distal end of first and second metatarsal. b: Medial view of big toe: zoomed in view of hand placement on medial aspect of foot.*

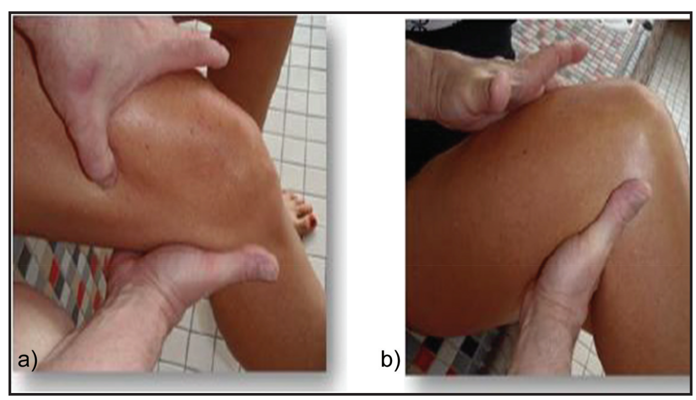

Figure 4. *Wall Hang, Iliotibial band pump. 4. Superior/ Lateral View: clinician inferior hand cradles behind knee joint and superior hand grasps anterior aspect of thigh.*

participant's extremity began to move freely in the water. The clinician could then direct the movements in different ranges to better facilitate the stretch and increase the amount of pressure needed to achieve

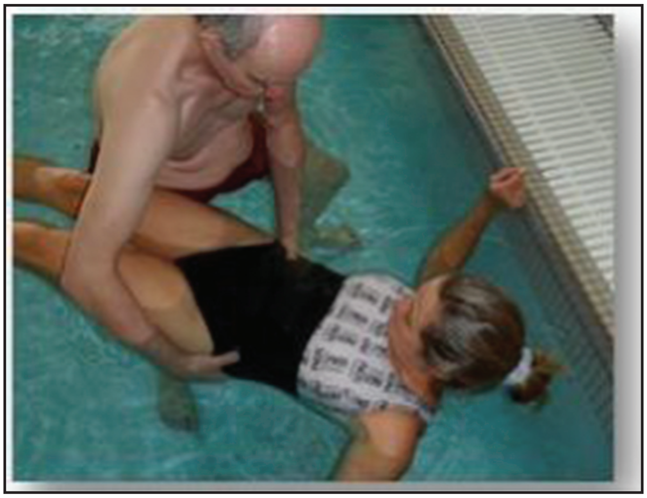

Figure 5. *Wall Hang, Hip rock and roll. Superior view: clinician hand grasps superior aspect of iliac crests.*

a release. The participant's reflexive movement was then directed by the clinician into end range. If necessary, the participant was asked to "move with me," and the clinician directed the movement.

Before moving onto different positions, the clinician directed the participant through specific stages of movement as termed by AquaStretch™ "play, freeze, pressure, and move" sequencing. First, the participant was asked to play with the body's movement and find any position where pain, discomfort, restrictions, or asymmetries were experienced between the lower extremities. Second, the participant was asked to freeze the body in the position where pain or restriction was felt. The clinician carefully observed the movement of the extremity from above the water just prior to this freezing to determine the vector to continue assisted stretching. Third, the clinician placed manual pressure where the participant felt pain or restriction. Pressure was added while the participant maintained the position so that tension was held in the extremity. Fourth, the participant's stretch reflex was engaged by increasing pressure until movement was elicited, while indicating the participant should move if inclined. The participant was encouraged to move the entire body as the clinician continued pressure, accenting the movement, until greater ranges of movement were achieved.

Statistical Methods

Tests for normality were run for all outcomes through visual analysis of histogram and Q-Q plots. Since normality was achieved, mixed model generalized estimating equations (GEE) analyses were used. The p values of the β coefficients were analyzed by 2-tailed Wald tests to compare preintervention and postintervention outcomes for the primary patient-rated outcome measures of the LEFS and FAAM Sports subscale as well as for lower extremity ROM measurements and for the additional measures, eg, the Ober's test, popliteal angle, the modified Thomas test, and overhead deep squat. An α of .05, 2-tailed, was set a priori for the current study, 95% confidence intervals, and effect size were reported as appropriate. SPSS version 24.0 (IBM, Armonk, New York) was used for the analyses.

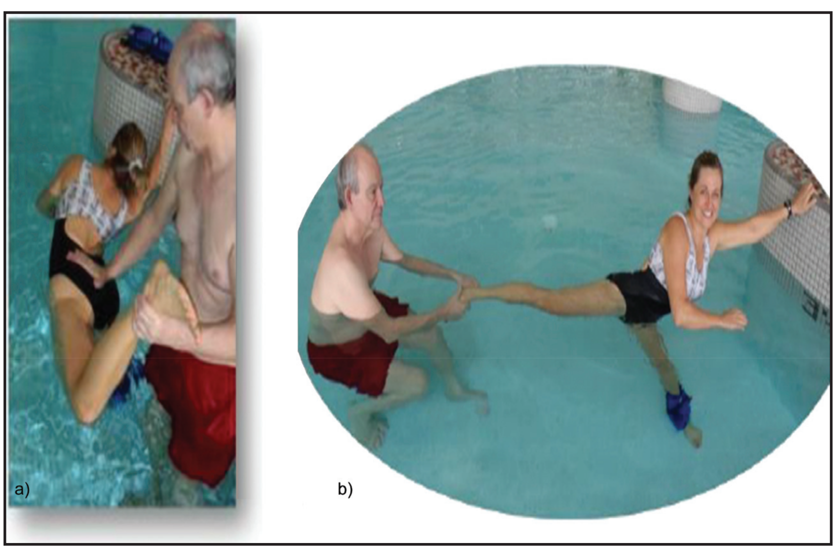

Figure 6. *One Leg Standing with Traction. a. clinician provides anterior hand pressure to posterior aspect of sacrum (advanced facilitation of hip joint). b. Full view: clinician performs foot grip (1b) with traction applied while participant is holding onto a stable surface.*

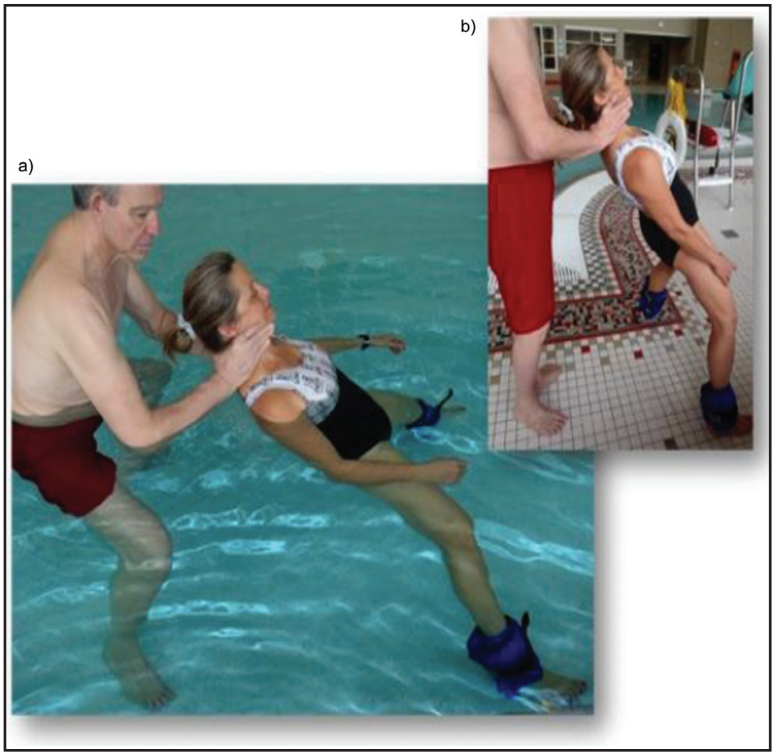

Figure 7. *Two Heavy Feet, Lean back. a. Full view: clinician provides bilateral hand support of participant neck close to the occiput while participant leans back. b. Full view: same interpretation as 7a; except done on land.*

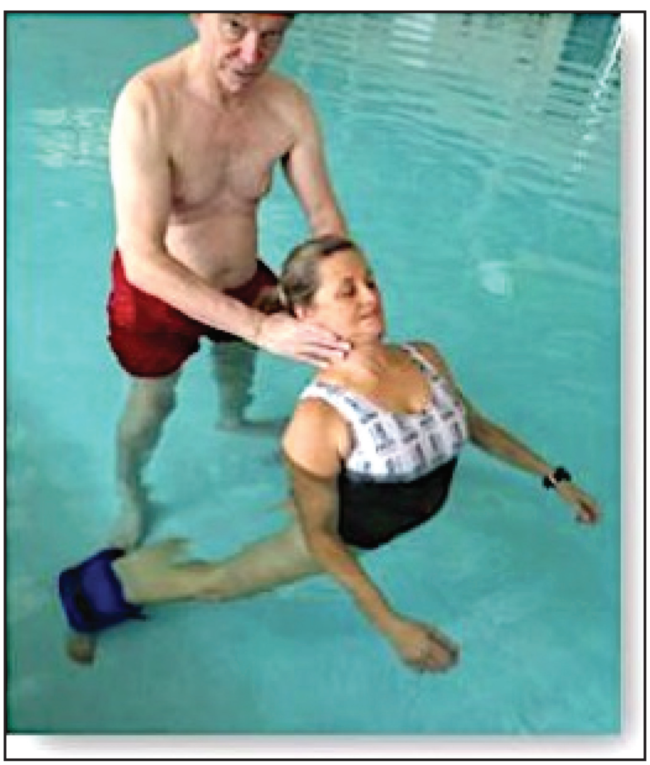

Figure 8. *Two Heavy Feet: Arch forward. Full view: clinician provides bilateral hand support of participant neck close to the occiput while participant arches forward.*

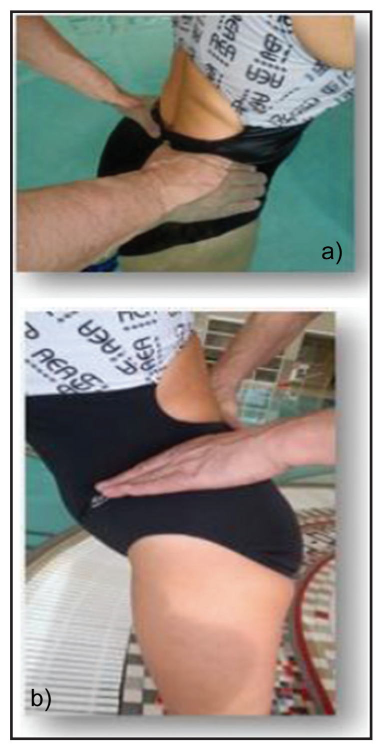

Figure 9. *Two Heavy Feet, Assume the Position (Cops). a. Lateral view: clinician hands on upper rim of ilium with thumbs on SI joint / paraspinals. b. Posterolateral view: same interpretation as 9a.*

Figure 10. *Two Heavy Feet, Back against the wall. a. Lateral view: clinician provides bilateral hand support of neck close to occiput with knee placement toward mid-scapula. b. Lateral view (close up): same interpretation as 10a with adaptation of hand placement for better control.*

Figure 11. *Head Hang. 11a. Lateral view: clinician posterior hand at base of skull and anterior hand supporting chin. 11b. Lateral view: participant kneels in water while clinician supports.*

RESULTS

Twenty-six recreational athletes (18 males, 8 females) aged 18-60 years (mean age, 27.4 years) with varied self-reported lower extremity injuries participated in the study. All participants in the current study had existing lower extremity injuries of the hip, knee or ankle with specific demographic characteristics of study participants presented in Table 1.

Statistically significant differences were found between preintervention and postintervention outcomes for 11 of the 24 ROM measurements on the uninjured limb of the athletes (Table 2). However, none, of the measurements at the ankle, knee, and hip were significantly different pre- to postintervention for injured athletes

Table 1. *Demographic Characteristics of the Recreational Athletes (N = 26) of the Current Study.*

Demographic Characteristic	No. (%) or Mean (SD)*
Sex	
Male	18 (69)
Female	8 (31)
Age (years)	27.4 (1.0)
Sports	
Runners	25 (96%)
Triathletes	7 (27%)
Marathoners	4 (15%)
Mixed martial arts	2 (.07%)
Region of injury	
Hip	9 (35%)
Knee	9 (35%)
Ankle/foot	8 (30%)

* Age is reported as mean (SD).

Table 2. *Preintervention and Postintervention Measurements for Range of Motion in Recreational Athletes of the Current Study (N = 26). No injury indicates the uninjured limb, while injury indicates the injured limb. Subjects served as their own controls.*

ROM, degrees	Preintervention in degrees, Mean (SD) 95% CI	Postintervention in degrees, Mean (SD) 95% CI	*p* Value	Effect size
Ankle dorsiflexion (no injury)	7.09 (4.19) 5.31 to 8.87	11.27 (5.22) 10.02 to 13.51	<.001*	.88
Ankle dorsiflexion (injury)	8.00 (5.11) 6.27 to 9.73	11.76 (5.13) 10.02 to 13.51	.58	.73
Ankle plantarflexion (no injury)	54.92 (9.67) 51.02 to 58.83	58.69 (6.84) 55.93 to 61.45	.002*	.46
Ankle plantarflexion (injury)	56.31 (9.36) 52.53 to 60.09	59.77 (9.06) 56.11 to 63.43	.55	.38
Ankle inversion (no injury)	34.12 (6.60) 30.01 to 38.79	36.57 (7.19) 32.86 to 40.70	.01*	.35
Ankle inversion (injury)	33.59 (10.96) 30.03 to 37.58	36.57 (9.45) 33.81 to 39.89	.72	.29
Ankle eversion (no injury)	11.64 (6.60) 8.69 to 14.59	16.05 (6.14) 13.27 to 18.83	<.001*	.69
Ankle eversion (injury)	11.37 (5.77) 9.39 to 13.36	15.60 (5.23) 13.65 to 17.56	.85	.77
Knee flexion (no injury)	144.86 (7.21) 141.56 to 148.24	148.29 (8.55) 144.29 to 152.40	<.001*	.43
Knee flexion (injury)	143.13 (7.39) 140.63 to 145.68	145.87 (8.08) 143.07 to 148.73	.50	.35
Knee extension (no injury)	-1.54 (2.00) -2.44 to -0.64	-2.48 (2.30) -3.27 to -1.70	.00*	-.44
Knee extension (injury)	-0.72 (3.02) -1.79 to 0.35	-2.12 (2.44) -3.10 to -1.14	.44	-.51
Hip flexion (no injury)	121.84 (7.88) 118.46 to 125.33	125.42 (9.41) 121.95 to 128.99	<.001*	.41
Hip flexion (injury)	120.89 (11.77) 117.27 to 124.62	125.381 (9.54) 122.40 to 128.43	.56	.42
Hip extension (no injury)	8.75 (4.20) 6.26 to 11.25	13.19 (6.27) 10.54 to 13.87	<.001*	.84
Hip extension (injury)	7.81 (5.03) 6.33 to 9.30	13.55 (6.38) 10.77 to 16.34	.08	1.00
Hip internal rotation (no injury)	34.94 (6.43) 31.68 to 38.54	38.58 (6.91) 35.99 to 41.35	.001*	.54
Hip internal rotation (injury)	36.78 (8.55) 33.96 to 39.85	39.68 (8.24) 36.51 to 43.12	.65	.34
Hip external rotation (no injury)	30.97 (7.42) 27.85 to 34.45	37.37 (7.16) 33.76 to 41.36	.01*	.87
Hip external rotation (injury)	28.09 (7.81) 25.57 to 30.87	33.55 (8.75) 30.95 to 36.36	.78	.66
Hip adduction (no injury)	14.37 (4.79) 12.31 to 16.78	17.21 (5.09) 14.66 to 20.19	<.001*	.57
Hip adduction (injury)	13.43 (4.44) 11.81 to 15.27	15.97 (5.45) 14.08 to 18.10	.89	.51
Hip abduction (no injury)	39.06 (7.07) 35.56 to 42.90	41.21 (6.42) 38.27 to 44.38	.23	.32
Hip abduction (injury)	41.07 (8.35) 38.63 to 43.68	41.85 (6.29) 39.52 to 44.32	.43	.11

* Denotes a statistically significant difference.
Abbreviations: CI, confidence interval; SD, standard deviation.

(Table 2). Statistically significant differences were found between preintervention and postintervention outcomes for three of the eight special tests or muscle length measurements on the uninjured limb of the athletes (Table 3). However, the special tests or muscle length measurements of ankle, knee, and hip were also not significantly different pre- to postintervention for injured athletes (Table 3). The functional measures for uninjured athletes were statistically significantly different for the FMS™ deep squat knee, the LEFS, and the FAAM (Table 4). Cohen's definition of effect size was used; effect size of 0.2 was considered a small effect size, 0.5 was considered a moderate effect size, and 0.8 was considered a large effect size.[36] Effect sizes

Table 3. *Preintervention and Postintervention Measurements for Special Tests and Muscle Length Tests in Recreational Athletes of the Current Study (N = 26). No injury indicates the uninjured limb, while injury indicates the injured limb. Subjects served as their own controls.*

Special or Length Tests, degrees	Preintervention in degrees, Mean (SD) 95% CI	Postintervention in degrees, Mean (SD) 95% CI	*p* Value	Effect size
Ober test (no injury)	19.01 (7.45) 15.43 to 23.42	22.86 (8.54) 19.17 to 27.25	.00*	.48
Ober test (injury)	17.06 (6.45) 14.94 to 19.47	21.71 (7.55) 18.56 to 25.40	.597	.66
Popliteal test (no injury)	164.25 (10.35) 160.65 to 167.92	166.33 (10.27) 162.24 to 170.51	.01*	.20
Popliteal test (injury)	163.00 (8.97) 159.29 to 166.80	165.94 (10.01) 162.08 to 169.90	.68	.31
Thomas hip test (no injury)	4.69 (5.56) 2.66 to 6.72	7.12 (6.92) 4.34 to 9.91	.001*	.40
Thomas hip test (injury)	3.11 (11.71) .95 to 5.28	6.67 (9.24) 4.49 to 8.84	.44	.34
Thomas knee test (no injury)	46.43 (17.12) 42.57 to 50.65	47.68 (4.93) 43.23 to 52.59	.16	.11
Thomas knee test (injury)	48.02 (10.59) 42.97 to 53.67	51.86 (9.50) 48.50 to 55.44	.47	.38

* Denotes statistically significant.
Abbreviations: CI, confidence interval; SD, standard deviation.

Table 4. *Preintervention and Postintervention Measurements for Functional Tests in Recreational Athletes of the Current Study (N = 26). No injury indicates the uninjured limb, while injury indicates the injured limb. Subjects served as their own controls.*

Functional Tests, degrees or score	Preintervention, in degrees or score, Mean (SD) 95% CI	Postintervention, in degrees or score, Mean (SD) 95% CI	*p* Value	Effect size
FMS deep squat shoulder	167.04 (9.24) 163.59 to 170.56	165.38 (14.19) 161.33 to 169.55	.16	-.14
FMS deep squat hip	121.04 (19.09) 114.05 to 128.45	125.35 (16.39) 119.72 to 131.68	.06	.24
FMS deep squat knee	114.19 (24.21) 105.42 to 123.69	121.23 (26.53) 111.63 to 131.66	.01*	.27
FMS deep squat ankle	18.46 (15.23) 13.48 to 25.28	17.88 (15.39) 12.93 to 24.73	.54	-.03
LEFS	69.69 (10.88) 65.71 to 73.92	74.31 (8.80) 71.09 to 77.67	.002*	.47
FAAM	7.08 (7.54) 4.23 to 9.92	4.31 (6.18) 1.99 to 6.62	.01*	-.40

Abbreviations: CI= confidence interval; FAAM= Foot and Ankle Ability Measure Sports subscale; FMS™=Functional Movement Screen; LEFS= Lower Extremity Functional Scale; SD= standard deviation.

varied between the ROM and additional measures and are reported in Tables 2, 3, and 4. The reader should note those measures that are statistically different (*asterisk) and also note the effect size to determine the magnitude of the difference between the measures.

DISCUSSION

Recreational athletes showed statistically significant differences preintervention to postintervention after 30 minutes of AquaStretch™ for the LEFS and the FAAM Sports subscale but the differences were not clinically significant as they did not reach the MCID for both self-reported functional outcome measures. In the current study, the investigators measured bilateral lower extremity differences in ROM and additional measures commonly used in physical therapy practice because research suggests bilateral differences are found in recreational athletes and may influence risk factors for lower extremity injury.[31] The additional measures used were selected to identify muscle flexibility. Statistically significant differences were found for the uninjured limb of the athletes for the Ober's test, the popliteal angle test, modified Thomas hip test, and for the overhead deep squat hip measurements. The effect sizes for the ROM and additional measures varied from small to large across all measures. Effect size is the magnitude of the differences between measures and is not dependent on the sample size.[36] To determine statistical significance, both the p value and the effect size should be evaluated. Authors[32] found that the Ober's test (n = 28) and modified Ober's test (n = 34) do not just measure or determine iliotibial band tightness and seem to assess tightness in structures located proximally to the coxafemoral joint.[32] For the current study, the results of the Ober's test may suggest that AquaStretch™ improved the flexibility of more than the lower extremities but only for the uninjured limb of the athletes. This was a surprising finding as the expectation was that the athletes would improve on the injured limb based on previous literature suggesting lower extremity goniometric measurement improvements after one 30-minute session of AquaStretch™ intervention.[22] The authors suggest that it may take more than one session to create significant soft tissue changes in muscle in order to improve the extensibility of the muscle tissues and demonstrate change in muscle length testing.

No statistically significant differences were found for the modified Thomas knee measure, but differences were found for the overhead deep squat test as measured at the hip, knee, and ankle albeit with small effect sizes. This functional gain was also found for the LEFS but the MCID of 9 points was not reached indicating this gain may not be due to the intervention.[30] The MCID was also not obtained for the FAAM Sports subscale. Perhaps this was due to the AquaStretch™ intervention being performed only once for 30 minutes. Another possibility is that the participant continued to compensate for the injured limb but was still able to perform without a movement limitation. Additionally, the significant findings of improvement in movement on the uninjured limb could be because the athlete over-compensated for the injured limb; thus, leading to antalgic motor patterns reflected in AROM measurements. Future studies should evaluate the appropriate intervention dosage needed to obtain both statistically significant and clinically significant differences.

The mechanism for AquaStretch™ has not been established. The AquaStretch™ intervention is purported to be a soft tissue technique that breaks up fascial adhesions, and the manual therapy techniques are similar to those a manual therapist would perform on a patient in clinical setting for common treatments on musculoskeletal conditions. Manual therapy is thought to influence afferent nociceptors, which reduces the pain perceived by the patient, improves the sensorimotor mismatches, and potentially actuates anti-nociceptive pathways[33] thereby decreasing spinal hyperexcitability.[34] This may result in an improved motor pattern of movement potentially with a return to normal movement. The effects on the patient that are found after manual therapy is performed may also be true for AquaStrech™ but more research is needed to determine if these effects occur after this technique is implemented. The mechanism of this intervention allows the clinician to address each joint in a multi-planar motion. The methodology behind AquaStretch™ suggests that the ability to address each joint in all planes of movement at once allows the clinician to address fascial adhesions that, when once freed, allow for ease of movement. In a preliminary study by Sherlock and Eversaul[22] the effects of a single AquaStretch™ session on lower extremity ROM in healthy student athletes were investigated. The authors[22] found a significant improvement in various lower extremity ROM goniometric measurements, similar to the current study. Sherlock and Eversaul[22] utilized healthy participants and the same 30-minute session as the participants in the current study. In the current study the investigators added in ankle inversion/eversion and functional performance measures and PRO instrument measures. Sherlock and Eversaul[22] found that 25% of the goniometric measurements from pre-/post-intervention were statistically significantly different whereas in the current study the investigators found that uninjured limbs statistically improved their goniometric measurements but none of the injured limbs showed statistically significant differences. This was surprising to the investigators of the current study. The only range of motion measurement that trended towards a significant difference in the injured limb was hip extension while all other range of motion measurements were not significantly different. These results do not reflect the findings of Sherlock and Eversaul.[22] The results of the current study suggests that follow-up studies need to extend the intervention for longer than one intervention of 30 minutes to explore the effect of more than one treatment session and to determine the appropriate dosage of intervention over time for specific lower extremity dysfunctions.

The current study had several limitations. The recreational athletes in the current study were not restricted from participating in athletic activities prior to or immediately after testing sessions. This lack of control may or may not have contributed to the effects of the intervention as well as participants were not blinded to the intervention performed and were a sample of convenience which may have impacted how they responded to the intervention. Another limitation was that the testers were third-year physical therapy students. The students practiced repeated measures of all tests to improve their testing reliability and were supervised by a faculty member, but lack of experience and not repeating measurements may have contributed to possible error in testing measurements. Future studies should include experienced physical therapists to improve reliability of the testers. Finally, the current study used a single session of AquaStretch™ with the participants completing questionnaires and postintervention measurements immediately after the session without long-term, follow-up investigation. The long-term effect of AquaStretch™ is unknown and requires more investigation.

CONCLUSIONS

The results of the current study indicate that a single 30-minute AquaStretch™ intervention session improved the function of the recreational athletes with LE injury, as measured by the LEFS and FAAM Sports subscale. However, these changes in function were not clinically significant. The athlete's uninjured limb improved compared to the injured limb. While AquaStretch™ improved functional outcome measure scores; the short-term benefits on ROM, muscle length, and functional movements were not statistically significantly different. Future studies may need to extend the intervention for longer than one intervention of 30 minutes in order to explore the effect of more than one treatment session and to explore the appropriate dosage of this type of intervention for specific lower extremity dysfunctions.

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