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COMPARISON OF WATER AND LAND-BASED BALANCE TRAINING IN FUNCTIONAL ANKLE INSTABILITY

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ABSTRACT

Background and purpose: With increasing competition and growing stress on players to perform has led to increased injuries. An ankle sprain is one of the most common sports injuries which requires an effective rehabilitation protocol. The primary purpose of this study is to determine which training medium is better (water versus land) when training balance for functional ankle instability.

Methods: Thirty subjects with unilateral functional ankle instability were randomly assigned to two groups-water training and the land training group. They completed the balance retraining protocol of 4 weeks (thrice a week) in the respective mediums (water and land). The balance improvement was assessed on Star Excursion Balance Test (for dynamic balance) and the One Leg Stance Test (for static balance) on 3 intervals-days 0, week 2, and week 4.

Results: The results show that both groups improved significantly from day 0 to week 4. The within-subject factor was significant for static as well as dynamic balance. The between-subject factor was non-significant for static as well as dynamic balance. The time into group interaction was significant for 4 directions-anterior, posteromedial, posterior, and anterolateral, and nonsignificant for the other 4 directions-anteromedial, medial, lateral, and posterolateral. The time into group interaction was non-significant for the one-leg stance test.

Conclusion: Both the mediums were equally effective when training static as well as dynamic balance. The pattern of improvement for dynamic balance differed across the period of 4 weeks for dynamic balance with the water group performing marginally better than the land group. The pattern of improvement across the period of 4 weeks was similar for static balance thus showing that water is a clinically better medium for training dynamic balance.

Key Words: Functional Ankle Instability, Balance, Land, Water.

INTRODUCTION:

With increasing amounts of leisure time and the current emphasis on physical fitness, the incidence of sports injuries has increased dramatically. (1) One of the body parts injured most frequently has been the ankle joint, with the most common injury occurring at this joint being the ankle sprain. (1) Ankle sprains (especially those involving lateral ligament complex) have often been reported as the most common injuries in sports.(2) It accounts for 19-23% of all sports injuries presented to accident and emergency departments.(3) About 90% are inversion injuries affecting the lateral ligament complex. (4) It has been estimated that an ankle injury occurs every day per 10,000 of the population.(5) Ankle sprains occur in all sports but are particularly prevalent in sports such as basketball and soccer with ankle sprains representing approximately 50% of all basketball injuries and 30% of all soccer injuries.(6) Yet an estimated 55% of people who experience an ankle sprain will not seek professional treatment.(7) This is unfortunate since most of these individuals are young athletes with good rehabilitation potential.

Chronic ankle instability (CAI) is a frequent consequence of lateral ankle sprain and it is estimated that approximately 40% of the individuals suffering an initial ankle sprain will develop long-standing ankle dysfunction.(8) The chronic symptoms of ankle dysfunctions include pain, swelling, recurrent injury, and having the ankle gives way. These chronic symptoms are most often due to functional instability and less frequently to mechanical instability. (4,9) Mechanical ankle instability (MAI) refers to objective measurements of ligament laxity; whereas Functional ankle instability (FAI) is defined as recurrent/or the subjective feeling of "giving way". (10,11) Tropp et al. described FAI as joint motion beyond voluntary control not necessarily exceeding the physiological range of motion and MAI as ankle joint motion that exceeds the physiologic range. (12) Clinical diagnosis of FAI is predicated on the patient's self-reported episodes of "giving way". Manual examination and stress radiographic measurements of joint translation and increased ROM are useful in the clinical diagnosis of MAI.(13) Some authors reported symptoms of functional instability in the absence of mechanical instability.(14,15) Vaes recently reported only 35% of 117 functionally unstable ankles demonstrated mechanical instability.(16) This percentage is consistent with similar, previously reported studies which show joint laxity itself does not predict the presence/severity of functional instability.(17,18) These studies support the notion that mechanical instability alone is of little clinical significance. However, the combination of mechanical instability and decreased neuromuscular control resulting from deficits in joint proprioception may result in functional instability of the ankle joint.

The stabilizing elements of the normal ankle are the capsular and ligamentous structures, the musculotendinous units, and the anatomical alignment of the osseous components of the joint.[18] Stability of the ankle joint during functional activities such as standing, walking, and running, exists in the presence of intact neural input from proprioceptors in the joint capsule, ligaments, tendons, and skin.[18] Proprioceptive information is generated by ligamentous mechanoreceptors, Golgi tendon organs (GTO), and muscle spindles, which transducer mechanical distortion of surrounding connective tissue. It has been suggested that diminished sensory input from damaged articular mechanoreceptors at the ankle in turn may promote decreased motor control (balance) leading to the clinical concern of functional instability. [18]

Balance is defined as the ability to maintain the center of body mass within stability limits largely determined by the base of support. [19] Stability limits are boundaries of an area of space in which the body can maintain its position without changing the base of support. [19] For convenience, balance is often classified as being either "static or dynamic". Static balance is said to exist when an adopted position is maintained for a while. Alternatively, dynamic balance is the maintenance of balance when on the move. Quantification of balance or postural control is often necessary to function to initiate an appropriate plan of care. [20] Tests used to evaluate the ability of a subject to maintain balance was developed as early as 1851. Since that time, a wide variety of balance tests and their modification have been used. Two such tests that hold promise in detecting deficits related to FAI and have been consistently used are the One Leg Stance Test (OLST) and Star Excursion Balance Test (SEBT) for static and dynamic balance respectively. The OLST is more difficult for the subject to perform than either the Sharpened Romberg (SR) or the Romberg test because of the decreased area of weight bearing and the narrowed base of support. [21] The OLST requires the subject to maintain balance while standing on one leg. The SEBT is a clinical test purported to detect functional performance deficits associated with lower extremity pathology in otherwise healthy individuals. [8]

Studies have shown that FAI results in a decreased ability to maintain balance [14] and a decrease in joint position sense. [22] The visual, somatosensory, and vestibular systems all contribute to the maintenance of balance. [23] Several authors [8,24] have speculated that somatosensory deficits are the primary cause of CAI and should be the primary target of conservative intervention strategies. Somatosensory sensations consist of pain, temperature, tactile (touch, pressure, and vibrations), and proprioceptive senses. [25] Proprioceptive sense appears to be the most important contributing factor to functional instability of the ankle. Its presence has been extensively documented for ankle instability. [26,27

The use of water for rehabilitation spans centuries. [28] Whether you have a sports-related injury or have experienced severe weakness, aquatic physical therapy can help you regain freedom of movement without pain. [28] The water provides a wonderful environment for helping patients restore balance, strength, and range of motion. [28]

Exercising in water may be more appropriate than on land for those with musculoskeletal impairment. An aquatic training program can decrease compressive forces, vibration forces, and torsional forces that an athlete may endure while training on land. [28] Thus, it is of considerable importance to determine whether exercise in the aquatic environment, which has been advocated as means of keeping physically active, has an impact on balance ability.

The purpose of this study was also to extend the sphere of its application. The primary purpose of this study is to determine which training medium is better (water versus land) when training balance for functional ankle instability.

METHODOLOGY

Sample size

(1) Number of Subjects

Water training group (Group 1): 15 subjects with unilateral FAI.

Land training group (Group 2): 15 subjects with unilateral FAI.

(2) Source of Subjects

Subjects were recruited from Talkatora Stadium, Jawaharlal Nehru Stadium, Yamuna sports complex (NCR, Delhi, India) and various other places volunteered for this study.

(3) Method of selecting subjects

15 male Water subjects with unilateral FAI (age=25.1 ± 3.0 years; height=175.4 ± 8.4 cms; mass=70.7 ± 2.4 Kg) and 15 male Land subjects with unilateral FAI (age=23.7 ± 2.4 years; height=176.9 ± 5.4 cms; mass=71.4 ± 3.0 Kg) were recruited according to the following criteria:

Inclusion criteria: [14,31,32,36]

- Subjects with a history of a minimum of 2 inversion ankle sprain to unilateral ankle in the past 1 year out of which one episode required protected weight bearing and/or immobilization.
- Subjects with a subjective feeling of "giving way" during sporting activity.
- Subjects who were pain-free at the onset of the study.
- Subjects within the age range of 18 to 35 years.

Exclusion criteria: [8,29,36,32]

- Subjects with a history of cerebral concussion, vestibular disorders, and lower extremity injuries for 3 months before testing.
- Subjects with a history of ear infection, or upper respiratory infection at the time of the study.
- Subjects with a history of fracture in either of the lower extremity.
- Subjects with a history of ligamentous laxity in the knee and hip of lower extremities.
- Subjects involved in current "formal" balance training for the involved ankle.

Method of assigning Subjects

Subjects were assigned to the water/land training group randomly, based on the lottery method. However, water training was completed first due to the limited availability of pool facilities.

Design of Study

The study is an experimental design with 2 groups of repeated measure design which compared the effects of Land and Water based Balance Training in Functional Ankle Instability over 4 weeks.

Each subject in both groups underwent a similar balance training protocol for 4 weeks (thrice a week) with at least one day of rest between 2 training sessions.

Instrumentation

The following types of equipment were required during the study:

- Stopwatch.
- Measuring tape.
- 3 inches wide adhesive tape.
- Protractor.
- Ball.
- Air Squab.
- OHP markers.
- Theraband (Red).

Space and facility

Water-based training was performed in an indoor swimming pool at Talkatora stadium with thermoneutral temperatures between 33 degrees Celsius to 34 degrees Celsius. [35] Water level was between the floating ribs and the anterior superior iliac spine. The pool had lanes of varying depths for the accommodation of variable heights of the subjects. Land exercises were conducted indoors at a site that was familiar to subjects to ensure compliance and to reduce attrition.

Protocol for Data Collection

(1) Who collected the data- This study was carried out by 2 investigators:

The primary investigator supervised all the training sessions of all the subjects and the readings were also taken by her.

The secondary investigator was there for the safety of subjects while performing tests, balance protocol, and to keep a check on performance errors of exercises and tests.

(2) Instructions to the participants – They explained the procedure and demonstrated the task once.

(3) Step-by-step process for collecting data:

After satisfying the inclusion/exclusion criteria and giving their informed consent, each subject was randomly assigned to two groups.

(1) Day 0(Non-Training Day) - Readings on Star Excursion Balance Test (SEBT) were taken.

Star Excursion Balance Test (Pre-test):

- Initially, a verbal and visual demonstration of the testing procedure was given to each subject by the primary investigator.
- Then subjects were asked to perform 5 minutes of warm-up (casual jogging) session followed by 5 active stretches of quadriceps, hamstrings, and triceps surae muscle groups. [32]
- Then they took a five-minute break and then 6 practice trials [33] in each direction for each leg were given to become familiar with the task.
- A five-minute rest was given before the subject underwent the pre-test.
- To minimize the learning effect subjects were asked to randomly select 3 chits with different directions mentioned in them to determine the starting excursion direction, right/left leg, and clockwise/counterclockwise direction. [32]
- To perform the SEBT, the subject maintained a single-leg stance on the injured leg/uninjured leg and with contralateral leg reach as far as possible.
- The subject was asked to lightly touch the furthermost point on the line with the most distal part of the reaching foot in any way possible to achieve maximum reach distance without moving the support foot.
- Then return the reaching leg to starting position (for at least 10 seconds) without allowing contact to affect the base of support.
- The reaches were performed in either clockwise directions or counterclockwise directions.
- 3 such trials were performed with each leg and alternating the clockwise or counterclockwise direction in the next trial i.e. if the first trial was in a clockwise direction then the second trial was in a counterclockwise direction.
- The same procedure was performed with the other leg after a rest of 30 minutes in all 8 directions while standing at the center of the grid.
- The examiner then manually measured the distance from the center of the grid to the touch point with a tape measure in centimeters.

Instructions for the test

Reach as far as possible in any way and gently touch the tape with the tip of your shoe for 1 sec.

Guidelines followed for the performance of the test

- Subjects were instructed to keep their hands on their hips.
- Keep the heel of the stance leg on the ground at all times.
- They were given rest between trials as desired.
- The secondary investigator was standing near the subject at all times to prevent falls while reaches were performed in either clockwise directions or counterclockwise directions.
- Star excursion balance test was performed with shoes on as mentioned by previous investigators. [23]
- The geometric center of the shoe was matched with the center of the star.

A trial was discarded and repeated if the subject [32]

- Did not touch the line with the reaching foot while maintaining stance leg.
- Lifted stance foot from the center grid.
- Lost balance at any point in the trial.
- Did not position reach foot for one full second.
- If the subject touched down with the non-dominant leg to provide considerable support.

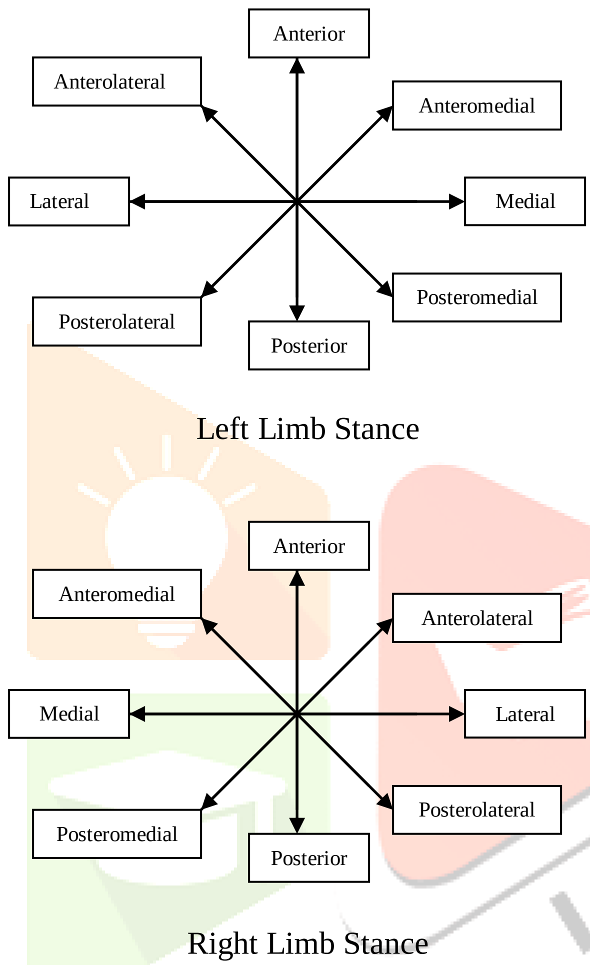

Figure1. The 8 directions of the Star Excursion Balance Tests are based on the stance limb

Note: 3 trials were performed and the best was considered for data analysis.

(2) Day 1- The day when training was started.

(a) One-legged stance test (OLST): was performed before the training session.

- Initially, a verbal and visual demonstration of the testing procedure was given to each subject by the primary investigator.
- Then he was asked to pick up a chit with the left or right leg mentioned in it.
- The subject was asked to cross his arms across his chest and close his eyes.
- The timing started when the subject rose the appropriate foot of the ground.

- The timing was stopped if the subject[21]
- Displaces the foot they were standing on.
- Touched the suspended foot to support the weight-bearing limb.
- Open the eyes.
- Uncrosses the arms.
- Reached the maximum balance time of 30 seconds.

Instructions for the test

Stand as long as possible on a single leg with your eyes closed without moving your leg.

Guidelines followed for the performance of the test[21]

- Subjects were permitted to rest between trials as desired.
- The secondary investigator was standing near the subject at all times to prevent falls attributable to loss of balance.
- The test was performed with shoes on.

Note: Three trials were performed and the longest balance time of the recorded trials was used for data analysis.

(3) Criteria for dominant leg- The subject was asked to kick the ball 3 times. The leg with which he kicked a maximum number of times was taken as a dominant leg.

Balance training protocol

The following balance training was performed in both groups:

- Group 1- performed the below-mentioned set of exercises in water.
- Group 2- performed the below-mentioned set of exercises on land.

It was performed after 15 minutes after the performance of OLST. Each training session lasted for around 20-30 minutes. Initially, a verbal and visual demonstration of the exercises was given to each subject by the primary investigator.

Exercises and the instructions

The exercise protocol that was used is as follows: [34,37]

(A) Following exercises were performed 3 times each:

1.Walking backward 11m

Instruction: Walk backward in a straight line between two marked points and repeat the procedure until I ask you to stop.

2.Tandem walking 11m

Instruction: Walk in a straight line with the heel touching your toes between two marked points and repeat the procedure until I ask you to stop.

3.Walking on toes 11m

Instruction: Walk on your toes in a straight line between two marked points and repeat the procedure until I ask you to stop.

4.Walking on heels 11m

Instruction: Walk on your toes in a straight line between two marked points and repeat the procedure until I ask you to stop.

(B) Following exercises were performed 15 times each:

1.Toe raises/heel raises (for both legs).

Instruction: Rise on your toes of both feet simultaneously then come back and repeat the procedure until I ask you to stop and now do the same procedure on your heels.

2.Shallow knee bends

Instruction: Bend down on your knees to the same level as mine and repeat the procedure until I ask you to stop.

3.Standing on an injured/uninjured leg and catching and throwing the ball.

Instruction: Go to the marked point (5.5 meters away) and stand on one leg and pass the ball to me from over your head and repeat the procedure until I ask you to stop. Repeat the procedure for both legs.

4.Theraband exercises (hip flexion/ extension, hip abduction/adduction) while standing on a single leg (for both legs).

Instruction: Kick the leg in front and repeat the procedure until I ask you to stop. Repeat the same procedure while kicking your leg backward and on your two sides.

(C) Standing on a balance trainer for 5 minutes and trying and maintain balance.

Instruction: Stand on the cushion with knees straight and try and maintain your balance while moving your foot up, down and side to side, and repeat the procedure until I ask you to stop.

Note: Similar instructions were given to all the subjects by the primary investigator

Frequency of Training [30,38]

The training was carried out for 3 sessions a week for 4 weeks.

Guidelines followed for the performance of the exercises

• Subjects were permitted to rest between the exercises as desired.

• The secondary investigator was standing near the subject at all times to prevent falls attributable to loss of balance.

Note: The post-test 2 and 4 were performed to the exact specifications as the pre-test and were completed the next day following the final training session of the second and fourth week.

Dependent variables

• Normalized reaching distance value to the height (in centimeters) in 8 directions of Star Excursion Balance Test (SEBT)-Anterior (A), Anteromedial (AM), Medial (M), Posteromedial (PM), Posterior (P), Posterolateral (PL), Lateral (L) and Anterolateral (AL).

• Total reach distance (TR) in centimeters of Star Excursion Balance Test in centimeters.

• Reading of One Leg Stance Test in hundredth of Second.

Independent Variable

Balance training using different mediums- Water and land.

Intervention

All the data of dependent variables were recorded on three intervals:

• 1st: Before the starting of training (D0).

• 2nd: At the end of 2 weeks of training (W2)

• 3rd: At the end of 4 weeks of training (W4)

Note: Recording of SEBT and OLST was carried out on separate days to avoid the carryover effect of one dependent variable on another. SEBT reading was never taken on the days of training and OLST if required on the day of training was taken before the training session.

General guidelines for the subjects

• Subjects were asked to be regular for the training as deemed by the researcher.

• Subjects were asked to refrain from any kind of balance training except that is required for the study.

• Subjects were asked to report any discomfort during the study period.

• Subjects were also asked to report any participation in any activity

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RESULTS

Demographic Data and Clinical Data

Thirty subjects were used in this study who were athletes with functional ankle instability between the age group of 18 to 30 years from various sports complexes. All subjects were males.

Baseline Characteristics

There was no significant difference between the two groups on baseline characteristics like age, height, weight, BMI (body mass index), reaches in all 8 directions, total reach distance, and one leg stance test reading on day 0 (at the start of the study) i.e. the two groups were similar on the onset of the study.

There was a significant difference between injured and uninjured legs on day 0.

Anterior Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the anterior direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=3.820,p=0.028) which demonstrated significant differences between pre and post-test scores for 2 groups.. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=1.570, p=0.221). Both main effects as qualified by the time*group interaction effect; ($F_{(2,56)}$=3.681, p=0.031) were significant.

Post Hoc analysis results for the water group

There was a significant improvement from day 0 to week 4 (2.23%). There was a nonsignificant improvement from day 0 to week 2 (2.23%) as well as from week 2 to week 4 (1.55%).

Post Hoc analysis results for the land group:

There was a nonsignificant decline from day 0 to week 4(0.46%). There was a significant decline from day 0 to week 2 (2.29%) but a nonsignificant improvement from week 2 to week 4 (1.88%)

There were significant differences between water and land training groups in week 2 and week 4.

Anteromedial Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the anteromedial direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=13.838,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=0.205, p=0.654). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=0.052, p=0.949) , failed to achieve significance.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(3.24%). There was a nonsignificant improvement from day 0 to week 2(0.43%) but a significant improvement from week 2 to week 4-Significant (2.8%)

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4 (3.3%). There was a nonsignificant improvement from day 0 to week 2 (0.22%) but a significant improvement from week 2 to week 4-Significant (3.1%).

There were no significant differences between water and land training groups at week 2 and week 4.

Medical Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the medial direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=46.608,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. groups failed to achieve significance ($F_{(1,28)}$=1.753,p=0.196). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=1.202, p=0.308) , failed to achieve significance.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(4.78%). There was a nonsignificant improvement from day 0 to week 2 (0.79%) but a significant improvement from week 2 to week 4-Significant (3.95%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(6.95%). There was a nonsignificant improvement from day 0 to week 2(1.26%) but a significant improvement from week 2 to week 4(5.6%).

There were significant differences between water and land training groups in week 2 and week 4.

Posteromedial Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the posteromedial direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,52)}$=162.531,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=3.311, p=0.080). Both main effects were qualified by time*group interaction effect; ($F_{(2,52)}$=10.837, p<0.001) and were significant.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(8.32%). There was a non-significant improvement from day 0 to week 2(1.1%) but a significant improvement from week 2 to week 4(7.13%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(5.03%). There was a nonsignificant improvement from day 0 to week 2(0.58%) but a significant improvement from week 2 to week 4-Significant (4.42%).

There were significant differences between water and land training groups in week 2 and week 4.

Posterior Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the posterior direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=113.916,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups.

However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=1.801, p=0.190). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=3.514, p=0.037) and were significant.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(6.75%). There was a nonsignificant improvement from day 0 to week 2(1.5%) but a significant improvement from week 2 to week 4(5.18%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(5.07%). There was a nonsignificant improvement from day 0 to week 2(1.17%) but a significant improvement from week 2 to week 4(3.85%).

There were significant differences between water and land training groups in week 2 and week 4.

Posterolateral Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the posterolateral direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=11.759,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=0.267, p=0.609). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=1.109, p=0.337), failed to achieve significance.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(2.85%). There was a nonsignificant improvement from day 0 to week 2(0.61%) but a significant improvement from week 2 to week 4(2.23%).

Post Hoc analysis results for the land group:

There was a nonsignificant improvement from day 0 to week 4(1.23%). There was a nonsignificant decline from day 0 to week 2(0.41%) but a nonsignificant improvement from week 2 to week 4(1.65%).

There were no significant differences between water and land training groups in week 2 but significant differences were observed in week 4.

Lateral Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance in the lateral direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=21.379,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=1.984, p=0.170). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=2.095, p=0.133), failed to achieve significance.

Post Hoc analysis results for the water group:

There was a nonsignificant improvement from day 0 to week 4(1.48%). There was a nonsignificant decline from day 0 to week 2(0.3%) but a significant improvement from week 2 to week 4(1.79%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(3.45%). There was no change from day 0 to week 2 but a significant improvement from week 2 to week 4(3.45%).

There were significant differences between water and land training groups in week 2 and week 4.

Anterolateral Direction of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced balance in the anterolateral direction during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=44.200,$p<0.001$) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=1.432, p=0.241). Both main effects were qualified by the time*group interaction effect; ($F_{(2,56)}$=12.228, $p<0.001$) and were significant.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(1.87%). There was a nonsignificant improvement from day 0 to week 2(0.53%) as well as from week 2 to week 4(1.33%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(5.59%). There was no change from day 0 to week 2 but a significant improvement from week 2 to week 4(5.59%).

There were significant differences between water and land training groups in week 2 but no significant differences were depicted in week 4.

Total Reach Distance of Star Excursion Balance Test (Injured Leg)

The analysis revealed that balance training both on land and in water influenced dynamic balance during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=173.543,$p<0.001$) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=2.092, p=0.159). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=1.069, p=0.350), failed to achieve significance.

Post Hoc analysis results for the water group:

There was a significant improvement from day 0 to week 4(4.23%). There was a nonsignificant improvement from day 0 to week 2(0.73%) but a significant improvement from week 2 to week 4(3.47%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(3.76%). There was a nonsignificant improvement from day 0 to week 2(0.14%) but a significant improvement from week 2 to week 4(3.62%).

There were significant differences between water and land training groups in week 2 and week 4.

One Leg Stance Test

The analysis revealed that balance training both on land and in water influenced static balance during the study period. There was a significant main effect for the within-subjects factor i.e. time ($F_{(2,56)}$=52.357,p<0.001) which demonstrated significant differences between pre and post-test scores for 2 groups. However, the main effect of the between-subject factor i.e. group failed to achieve significance ($F_{(1,28)}$=0.979, p=0.331). Both main effects were qualified by time*group interaction effect; ($F_{(2,56)}$=2.275, p=0.112), failed to achieve significance.

	Sum of Squares	Degree of Freedom	Mean Square	F Values	Level of Significance
Between-Subject Effects					
Group	224.076	1	224.076	3.311	0.080
Error	1895.054	28	67.680		
Within-Subjects Effects					
Time	229.746	2	114.873	162.531	<0.001
Time*Group	15.319	2	7.659	10.837	<0.001
Error	39.579	56	0.707		

Post Hoc

analysis results for the water group:

There was a significant improvement from day 0 to week 4(83.1%). There was a significant improvement from day 0 to week 2(69.4%) but a nonsignificant improvement from week 2 to week 4(13.7%).

Post Hoc analysis results for the land group:

There was a significant improvement from day 0 to week 4(91.43%). There was a significant improvement from day 0 to week 2(43.6%) and also from week 2 to week 4(47.83%).

There were no significant differences between water and land training groups at week 2 and week 4.

Analysis of Variance (ANOVA) for Posteromedial Direction of SEBT

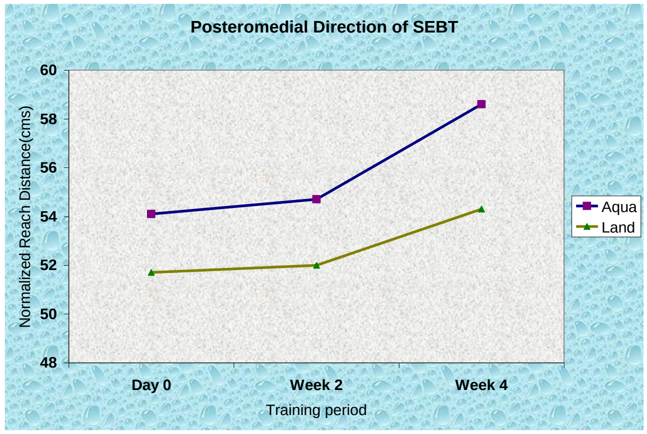

Figure 2. Comparison of Normalized Reach Distance (Posteromedial Direction of SEBT) of 2 groups from day 0 to week 4.

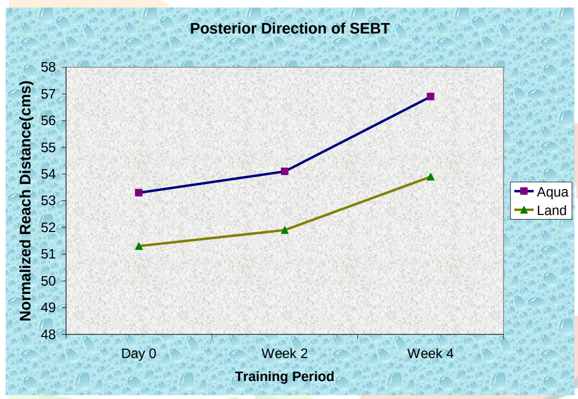

Figure 3. Comparison of Normalized Reach Distance (Posteromedial Direction of SEBT) of 2 groups from day 0 to week 4.

Data Analysis

All data were analyzed using statistical tests, which were performed using SPSS 10.00 software package. Demographic data of patients including age, height, body mass index, involved, and dominant leg was descriptively summarized to project the results. The dependent variables for statistical analysis were analyzed using parametric tests like 2 X 3 ANOVA and independent t-test/paired t-test. The data were analyzed both between and within groups. Post-hoc analysis for ANOVA was done using Tukey's HSD. A 0.05 level of significance was used for all comparisons.

Discussion

The results of this study demonstrate that regardless of training medium (water versus land); significant improvements in balance were achieved by both groups.

Various reasons can be attributed to the improvement in balance within each group. It has recently been discovered that the plantar surface of the foot plays a critical role in providing sensory input to the central nervous system for balance and postural control. [30,40] There are 3 distinct types of mechanoreceptors on the sole and they include Merkel cell complexes, Meissner's corpuscles, and Pacinian corpuscles (all responding to pressure). These proprioceptive receptors send somatosensory input to the brain by sensing pressure and stretching motions in the tissues that surround them. Impulses that come from the bottom of the feet, in particular, are of great importance as they indicate the movement of the body over the base of support. These plantar proprioceptive inputs are the dominant sensory information for balance when the body is standing still on a fixed firm surface or moving through the environment. [41]

Secondly, weight-bearing exercises will stimulate joint mechanoreceptors leading to improved proprioceptive inputs. [42] The above-explained phenomenon can be related to the reasons for the improvement in both groups from day 0 to week 4.

On detailed analysis, we find that there are discrepancies between groups though statistically non-significant. Marginally better improvements in the water group could be explained by the fact that the movement of a body part through water results in a greater somatosensory input to the receptors than the movement of a body part through the air. Richley Geigle and colleagues[43] argue that somatosensory input is increased more by moving an object through a viscous liquid than by moving through a less viscous gas (air). They postulated that resistance to movement may "cause distension or stretch of the skin resulting in stimulation of rapidly adapting mechanoreceptors, perhaps contributing to better proprioception".

Secondly, movement errors have been documented as guidance for motor skill acquisition. [44] Similarly, the failure to correct postural errors leads to a loss of skill in performing postural tasks. [44] Postural tasks are unlike many other motor skills as the consequences of failing to correct a postural error can produce an injury resulting in the "fear of falling" that many elderly individuals express. [44] Thus, if postural errors are to be practiced, they must be done in a safe environment. [44] Water is a dense and viscous medium that rapidly decelerates movements. [44] Because of these physical properties a person is cushioned from injury in the event of a fall, especially when submerged at a level of waist deep or more where at least 50% of his weight is supported by the water. [44] As the risk of injury from falling is minimal in water, the subject's fear of falling is decreased. [88] It is speculated that by decreasing this fear of falling or losing balance when performing challenging tasks these subjects were willing to increase the movement magnitude and thereby experience greater movement variability and errors.[44] Thus, making errors guides learning. [44] In the water a participant might be more willing to practice the movements that are needed to prevent a fall and produce movement errors while practicing, as the risk of injury while exercising at waist deep in water is minimal.[44]

The main findings of this study were in somewhat accordance with work done by Peter Douris et. al[37] and a case study by A.G.Beneka and P.C.Malliou. [42] Peter Douris et. al[37] concluded that regardless of treatment medium significant improvements were evidenced on Berg Balance Scale between pretest and posttest. The utilization of lower body exercises, whether on land or in water, was accompanied by improved balance. Neither medium however was superior for retraining balance in older adults. One substantial limitation of their study was the small sample size (6 subjects in the water group and 5 in the land group) and lack of random assignment. Secondly, only one outcome measure (Berg Balance score) is not enough when assessing balance. Beneka et al[42] presented a case study of 17 years old female athlete with Achilles tendinopathy. They too found that aquatic and land-based programme offered an effective rehabilitation protocol for the female athlete. However, a single case does not allow the generalization of the conclusions.

However, the findings of this study conflict with the conclusion of Simmon and Hansen. [44] They concluded that postural control improved greatest in the aquatic group as compared to the land group (although both groups showed improvement) when measured using forward reach. Analysis of their raw data indicates that both aquatic and land groups had end scores that were the highest possible for the Berg Balance Score. Their raw data when converted to inches from centimeters, demonstrate that forward reach for both land and aquatic groups was more than ten inches. Greater than ten inches receives the highest score for the Berg Balance Score for the forward reach item in the Berg balance score. Therefore, Simmon and Hansen[44] would have realized a ceiling effect, if the Berg Balance score was used to score forward reach.

Although both the groups improved significantly on the dynamic as well as on static balance, the pattern of improvement across the period of 4 weeks differed in the two groups for dynamic balance. Dynamic balance as assessed by Star Excursion Balance Test (from Day 0 to week 2 to week 4) showed differences in improvement trends between the water and land training group namely in four directions-anterior, anterolateral, posterior, and posteromedial. While in the other four directions-anteromedial, medial, lateral, and posterolateral both groups exhibited a similar pattern of improvement from day 0 to week 2 to week 4.

In the anterior direction of SEBT, there was a decline in performance from day 0 to week 2 for the land training group. According to Earl and Hertel,[47] to perform the anterior excursions, subjects leaned backward extending the trunk to maintain their balance. There is a backward shift of COG which accentuates instability. This poses a greater amount of challenge in front of subjects. Water training instills better confidence when performing challenging tasks owing to its physical properties as explained above. This could be the probable reason for differences in the pattern of improvement from day 0 to week 2. Though with subsequent training both the groups improved from week 2 to week 4, there were significant differences at week 4 between the two groups with the water group performing better. This is because the study by Earl and Hertel[47] shows that during anterior excursion vastus medialis activity was significantly greater on SEBT than during any other direction. A possible explanation for dissimilar results between the water and land training groups could be linked to the strengthening effect while moving or exercising in water because of viscosity. Water is more viscous than air, and resistance to limb movement through water is greater than resistance to the same movement through air molecules. Thus, it takes greater force to push through water molecules.[35,48]

Within-group improvement for both the groups could be explained on basis of the fact that vastus medialis obliquus could have been weak on day 0 because of proximal muscle changes associated with an ankle sprain,[36] so reach distance improved as the muscle strengthened during 4 weeks of training. Secondly, the changes in the dynamic balance due to the balance training protocol were seen.

In the anteromedial, medial, lateral, and posterolateral direction of SEBT, both the groups improved in a similar pattern over some time with the water group performing better at week 4. The within-group improvement with time can purely be explained by the facts stated before. The reasons for the water group performing better have been already explained above.

In the posteromedial and posterior directions of SEBT, there was a difference between the improvement patterns of the two groups with the water training group performing better at the end of training. This can be attributed to the fact that the tibialis anterior is the chief muscle when reaching out in the above two directions as concluded by Earl and Hertel.(47) The difference in tibialis anterior activity between the two groups can be explained by the fact that the tibialis anterior showed increased activity if an unstable ankle is provided with some sort of external support. (50) In water group buoyancy provides that external support can account for the difference between the two groups.

The reduced performance in pre-test scores can be accounted for by the inherent fear of falling when performing SEBT. Secondly, previous investigators demonstrated increased latencies for activation of peroneal and tibialis anterior muscles during a sudden ankle perturbation in subjects with CAI. (49) Lastly, studies(54) have demonstrated increased dorsiflexion to plantarflexion strength ratio with dorsiflexors being weak in subjects affected with a previous ankle sprain.

The posteromedial direction was reported to be highly representative of the performance of all 8 components of the test in limbs with and without chronic ankle instability.(8) The highest improvements were also registered in a posteromedial direction which can be related to the fact that it is the most representative direction of all the eight directions.

Anterolateral and lateral directions showed significant improvement from week 2 to week 4 on the land group. This improvement was greater when compared to other directions from week 2 to week 4. The specific reason for this couldn't be stated in the light of current literature available. In these directions also water group performed better owing to the facts stated before.

In total reach on SEBT, the total reach score for two groups was significant between the two groups at the end of 2 and 4 weeks of balance training, where the water group registered marginally better improvement than the land group. Total reach only provides a very gross picture so it has not been discussed in much detail. Secondly, no inference can be drawn based on the observation of the total reach score.

After the completion of training, there were statistically significant differences between the two groups at week 4. The water group performed marginally better in almost all directions (6 out of 8). So we can say water is a clinically better medium to train dynamic balance for subjects with functional ankle instability. The reasons for the water group performing better can be accounted to the reasons explained a prior.

On the one-leg stance test, static balance improved in both groups in a similar pattern with significant improvements in both groups. No differences existed between the two groups when measured on one leg stance test. The inability to maintain a quiet stance during single-leg standing has consistently been shown to be associated with ankle instability; however, the sensitivity of these assessments has been questioned in patients with chronic ankle instability. [8] Dynamic postural control tests such as excursion and functional reach tests are superior to basic single-leg stance (SLS) tests.[47]

Quiet standing in a single-leg stance might be a task that is too unconstrained, thus allowing subjects to use alternative motor strategies to adequately accomplish the task even in the presence of pathology.[51]

Greater improvements were registered in static balance scores when compared to SEBT scores. This can be counted as the reason that lesser demands are placed on lower extremity musculature when balancing on a single leg as compared to dynamic tasks. [32]

These improvements in balance ability appear to reflect improved neuromuscular ability along with enhanced functional joint stability.

One important observation of the study was that in general, no significant improvement occurred from day 0 to week 2 in the groups. This could be justified on the basis that probably two weeks of balance training is not sufficient for subjects with functional ankle instability. However significant improvement occurred from day 0 to week 4. These findings suggest that 4 weeks is sufficient time to promote reflex muscular activation patterns necessary for the maintenance of posture and balance. [49]One more reason can be attributed to the observed result that SEBT itself is composed of closed kinetic chain controlled motion and the ability to balance on one leg. It has been proved as an efficacious method of training balance in functional instability by Dootchai Chainichsiri et.al.[38]

The water group registered marginal though greater improvement (4.23%) as compared to the land group (3.76%) from day 0 to week 4 suggesting water was a better medium when training balance.

In our study, 86.67% of subjects suffered from functional ankle instability in their dominant leg. Ekstrand and Gillquist[52] found that the dominant leg sustained significantly more ankle injuries (92.3%) than the non-dominant side in male soccer players. Beynnon et al[53] found no influence of limb dominance on ankle sprains in the study of collegiate soccer, field hockey, and lacrosse athletes.

Lastly, maximum excursion distance was exhibited in the posteromedial direction when compared to other directions which were consistent with previous studies.[32] On the other hand, minimum reaching ability was observed in the lateral direction which was also by previous studies. [32]

Conclusion

The primary purpose of this study was to determine whether training medium (water versus land) has an effect when training balance for functional ankle instability. The overall results of the study show that both groups were equally effective when training balance for functional ankle instability.

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