International Journal of Engineering & Technology, 7 (4.42) (2018) 68-72

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Comparative Study of Water and Land Based Exercises Training Program on Stability and Range of Motion

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Abstract

Serious ankle injuries continue to be a strong concern to athletes of many sports. The frequency of ankle injuries in sport is paramount. The sports which involve the lower limbs usually will cause injuries around ankle and leading to ankle instability as a result recurrences are very common. Moreover, stability plays an important role in preventing ankle injury for an athlete. Thus, this study was aimed to identify the influence of exercises in different environments like water-based and land-based exercise over dynamic stability and range of motion (ROM) there by to prevent ankle injuries among collegiate athletes. A total of 24 amateur athletes who had ankle sprain during their sporting activities were recruited for this study and randomly assigned in two groups; water-based (BMI 23.08±3.17 kg.m-2) and land-based (BMI 23.94±4.86 kg.m-2). The exercises session were carried out twice per week, 45 minutes to an hour for 8 weeks. Both groups underwent eight weeks of training for the aquatic and land exercises. The changes (by pre and post-test) in dynamic balance were measured for both groups via Star Excursion Balance Test (SEBT) for the injured legs. The results shows pre and post-test means differences of SEBT test of water and land-based exercises groups were -5.26 ± 1.5 and -3.77±1.94 cm, respectively. While there was statistically no significant differences in improvement of dynamic balance between the exercise given in both media (t=0.36; p=0.72); post-test results of both groups showed significant improvement in both groups p<0.00. There was only significant differences in ROM between water-based and land-based groups (t=5.37, p=0.000). This study was concluded that water and land-based exercises are useful to improve the stability and range of motion and thereby to prevent ankle injuries.

Keywords: *ankle injuries, water-based exercise, dynamic balance, range of motion, athletes*.

1. Introduction

Ankle injuries are the most common injuries in athletics as well in non-athletics [1, 2] and people who involved in sports are at high risk to get ankle injuries [3]. Ankle injury usually occurs in sports involving running, cutting, jumping and landing, with higher possibility in contact sports [2]. It has been estimated that ankle injuries attributing upward of 45% of all athletic injuries to ankle sprains [4].

Further studies explained that 271 patients were classified as having bone injury and 1076 cases had sprain, muscle or soft tissue injury. It is assessed that between 10 and 30 percent of individuals who have had acute lateral ligament sprain continue to suffer chronic functional instability of the ankle [5]. In addition, athletes who suffer from ankle sprains are more likely to reinjure the same ankle which can result in disability and can lead to chronic pain or instability in 20% to 50% of these cases [6]. According to Oliveira et al., (2016) ankle sprain lesion can be classified as grade 1, 2, or 3, ranging from mild to severe (1 – 3) based on the extent of damage and number of ligaments affected. The grade 1 sprain is characterized by the stretching of the anterior talofibular and calcaneofibular ligaments. In the grade 2 sprain, the anterior talofibular ligament partially tears, and the calcaneofibular ligament stretches. The grade 3 sprain is characterized by rupture of the anterior talofibular and calcaneofibular ligaments, with partial tearing of the posterior talofibular and tibiofibular ligaments [7]. Ankle sprain usually involves a lateral ankle ligament complex, which may be stretched or torn, as a result of landing on a plantar flexed and inverted position of the foot [8].

Nualon [8] further explained that a high recurrent rate of ankle sprain has also been reported in athletes who have residual symptoms such as pain, swelling, weakness and instability. These impairments could further deteriorate the ankle functional ability of athletes who have recurrent ankle sprains. While the most common injury in athletics is the lateral ankle sprain, and recurrence rates have been found to be as high as 80% [9], ankle sprains are more likely to reinjure the same ankle over and over for the injured athlete.

In addition, previous studies have stated there are two potential mechanisms that can cause chronic ankle instability. The first mechanism is mechanical instability from ligament laxity and excessive joint motion of the talocrural, subtalar and inferior tibiofibular joint because of structural damage of the supporting ligamentous tissue. The second mechanism is functional instability, a condition in which a patient has imbalance of the postural stability and recurrent sprains with or without a feeling of ankle giving away [8, 10]. These will directly lead to balance deficits and joint position sense deficits which mainly depends of afferent data which is used for delicate sensory-motor integration [11].

Meanwhile, good proprioception as an ability to integrate the sensory signals from various mechanoreceptors is important for promoting dynamic joint and functional stability in sports (standing, walking and running) [12]. While previous study discovered the ankle plays an integral role in maintaining balance [13, 14], based on clinical experience, the majority of physical therapy clinics and athletic training for ankle sprain incorporate both strengthening

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and proprioception exercises [12]. Numerous studies have looked at the effects of strengthening exercises, proprioceptive exercises, or a combination of both on the return of a patient to functional activity. Moreover, Han et al., [15] stated that ankle proprioception can be altered by general and sports specific training, sports-related injuries and sports- induced fatigue, all of which may subsequently lead to altered balance ability. Balance ability of a group of athletes was significantly correlated with their agility performance [15]. This suggested that balance control is fundamental to sports performance and similarly, ankle proprioception and sport performance are related.

Besides that the static balance, dynamic balance also very crucial for an athlete. This is due to the movement presence in the sporting activity such as jumping, running, landing, hopping and more. These movements require pivot action of these ankle joint where the ankle at least need inverted, everted, or flexed up to certain degree of range of motion (ROM).When the pivot action beyond the normal level its causes injury to the ankle joint [16, 17]. To maintain good pivoting action, an athlete needs good dynamic balance to prevent ankle injury. Furthermore, ROM was evaluated as a predictor of ankle sprain. Dorsiflexion range strongly predicted risk of ankle sprain. Postural sway and possibly proprioception were also predictors [16]. However, the preliminary evidence suggests that people with reduced ankle dorsiflexion range may be at increased risk of ankle sprain. Thus, the study of dynamic balance is equally important as static balance and ROM to prevent ankle sprain. Theoretical and scientific bases declared that stability and proprioception are important ability for any athlete and it should be considered as part of any rehabilitation program [18, 19].

There is evidence indicating that land-based exercise can be more beneficial for people who suffering from ankle injuries by improving ankle stability and re-educate the muscle and ligament around the ankle join. Usually, land-based exercise is essential in the rehabilitation programs for neuromuscular function improvement in the acute and chronic phase of an ankle sprain [8]. Previous study done by Orna et al., (2011), on impact of plyometric exercises on land found that the body is exposed to high-impact loading which leads to compressions of the spine and lower extremities [20, 21]. Most of the sporting activities involve jumping and cutting activity on the land thus, pressure on the land is higher compared to water and the result shows that the loading impact on the joint is high on land based exercise.

Then, considering physical properties of water (buoyancy, viscosity, Hydrostatic pressure and temperature) [22] may be more efficient to improve stability and proprioception on a water-based program. Water exercise or also known as aquatic exercise have been widely used in physical therapy programs, especially when exercising under normal conditions of gravity is difficult and painful. Water buoyancy reduces the weight that joints, bones, and muscles have to bear [19]. The percentage of weight bearing decreases with greater immersion as an individual standing in water to the level of the xiphoid process will bear approximately 28% to 35% body weight depending on gender. The percentage of weight bearing will increase with activity walking and increasing speed of movement [20]. The warmth and pressure of the water also reduce swelling and increase blood circulation [19]. Consequently, an underwater environment allows early active mobilization and dynamic strengthening. In a study done by Nualon et al., [8], found that the hydrotherapy group and the land based therapy group had improved ankle functional ability as demonstrated by the single-limb hopping performance. Likewise Yalfani et al., (2015) observed better improvement in pain relief, performance, static and dynamic balance of people with chronic ankle sprain in water exercise, but there statistically was no significant difference with the land exercise group [21].

By way of applying and performing of physical properties of water, rehabilitation process for athlete presumably could optimize the effect of exercise. However, there is still a few studies on the effect of water-based exercise on improvement of ankle injuries particularly for athletes who should quickly return to their sports activities. Therefore, this study aimed to compare the effectiveness of 8 weeks rehabilitation exercise in water and land media on dynamic balance and range of motion (ROM) among athlete collegiate students who suffering from ankle sprain.

2. Methodology

2.1. Subjects

A total of 24 amateur athletes (10 males, 14 females), age ranging from 20 to 27 years from Sultan Idris Education University (UPSI) who had experienced ankle sprain during their sporting activities were recruited for this study. All the subjects were informed the procedures of the study and signed a consent form before enrolled in this study. The demography of subjects shows in Table I.

Table I: Demography of the subjects

Variables/ Group	Water based (n=12) % / (Mean ± SD)	Land based (n=12) % / (Mean ± SD)
Gender	M: 6 (50%)	M: 4(33%)
	F: 6 (50%)	F: 8 (67%)
Injured leg	L: 5 (41.7%)	L: 7 (58.3%)
	R: 7 (58.3%)	R: 5 (41.7%)
Age (yrs)	22.6±1.62	23.5±2.02
Height (cm)	166.1±9.19	165.17±6.89
Weight (kg)	63.91±8.87	65.35±12.86
BMI ($kg.m^{-2}$)	23.18±2.88	23.91±4.44
Sports involvement (yrs)	6.3 ±3.74	7.6 ±3.24

The athletes involved in the various sports with minimum three years sports involvement background. They had experienced at least one time ankle sprain (grade 1, 2 or 3) within the past six months with the residual symptoms of "giving way" or instability while walking or running in sports activities. The subjects were randomly placed into two groups: water-based (6 males, 6 females, with age: 22.6±1.62 years, height: 1.66.1±9.19cm, weight: 63.91± 8.87kg, BMI: 23.18±2.88 $kg.m^{-2}$, sports involvements background: 6.3±3.74years), and land-based (4 males, 8 females, with age: 23.5±2.02 years, height: 1.65.17±6.89cm, weight: 65.35±12.86kg, BMI: 23.91±4.44$kg.m^{-2}$, sports involvements background: 7.6 ±3.24years).

2.2. Instrumentation

A Goniometer (Baseline 12-inch Plastic 360-Degree ISOM/STFR) was used to measure range of motion (ROM) for Dorsi-flexion, Plantar-flexion; Inversion and Eversion movements. In addition, the subjects performed STAR EXCURSION BALANCE TEST (SEBT) to measure dynamic balance and highlight the loss of dynamic postural control [23]. SEBT test originally incorporated reaching in eight directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral) while standing on each foot, but factor analysis indicated that one reach direction in particular posteromedial was able to accurately identify individuals with chronic ankle instability as well as performing eight directions (Figure 1). All data were collected in two phases as pre-test and post-test. Pre-test was conducted before starting the exercise program and the post-test was performed on the same aspect one week after the training done.

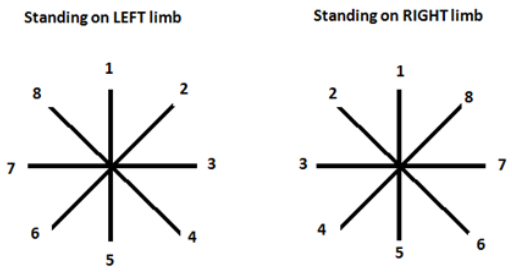

Figure 1: Star Excursion Balance Test Directions

2.3. Water and land based exercise protocol

All subjects were attended at the rehabilitation exercise class at gymnasium and swimming pool of Sultan Idris Education University (UPSI). Both programs were supervised by physiotherapist twice a week (45-60 minutes) in eight weeks' period. The subjects received same static stretching program of warming up and cooling down for ten minutes. After that, they participated either in water-based exercise session or land-based exercise session and progressed according to their assigned group for 40- 45 minutes. This main exercise section consisted of combination of water walking/jogging, forward lunges, side lunges, one leg balance, side stepping, marching, hip kickers, deep water bicycle, pool plank and wall push up, which similarly were performed for land-based group [8, 19, 21]. Between each repetition, 30 to 45 seconds break was considered.

The land-based exercise session was conducted in the exercise room, and the water-based exercise was conducted at UPSI outdoor swimming pool with 1.2 meters depth (shallow swimming pool) which the subjects nearly immersed to the xiphoid flow. The temperature of the pool was unable to maintain due to the weather changes. The intensity and frequency of the exercise were gradually increased followed by week [13, 24, 25]. The summary of water-based progressive exercise protocol showed in Table II.

Table II: A summary of eight weeks water-based exercise protocol

Exercise Protocol		**Intensity (week 1---> week 8)**	**Frequency (sets of repetition) (week 1--> week 8)**	**Time (mins)**
Warm-up: Static walk, jog in a place, step side to side, combination stretching		-	-	7-10
Main Exercise (dynamic balance & ROM)	Water walking/ jogging (steps)	20×4 ----->20×8 (forward and backward)	20 steps walking ---> jogging	40-45
	Forward lunges	10 steps of lunges	2 ----> 8	
	Side lunges	10 steps of lunges	0----> 8	
	One leg balance; Right & Left	Front (hold 3 counts), Side to side (hold 3 counts)	3----> 8	
	Side stepping; Right & Left	10--->15 steps	0-----> 8	
	Standing knee lift; Right & Left (marching)	10 steps	3 ----> 8	
	Hip kickers Right & Left	10 steps	3 ----> 8	
	Deep water bicycle	1 minute	3 ----> 8	
	Pool plank	30 second	4 ----> 8	
	Wall push up	10 push-ups	3 ----> 8	
Cool-down	Recreation, ball game ,combination Stretching, Joint relaxation and deep breathing			7-10

2.4. Statistical analysis

The mean and standard deviation for each parameter were analyzed using IBM SPSS software (version 23). Paired t-test for the comparison of the results was obtained from pre-test and post-test of the same group, which allows estimating if the effect of exercise protocol is significant. Independent t- test were used to compare the results by both groups (water-based and land-based) of subjects if the difference is significant. The significant level were statistically considered significant at $p<0.05$.

3. Results

According to descriptive data, both studied groups were statistically comparable. All subjects had a side ankle sprain experience (left or right). The demography of physical characteristics of the subjects based on exercise media (water/land-based) is showed in Table I. It should mention that no significant difference found in age, weight, height, and BMI and sports involvement background between both groups.

Analyzing of the depending variables; dynamic balance (SEBT) and ROM, illustrated significant differences between pre-test in water-based and land-based groups (p=0.000), while no significant difference found in pre-tests. The results of paired t-test revealed that eight weeks exercise could improve dynamic balance and ROM in both media which the changes showed in Table III. The results also revealed that no significant differences in dynamic balance between water-based and land-based groups (t=0.36; p=0.72). Although dynamic balance increased in poost-test for both groups, there was no significant difference between water and land-based exercise. There was only significant differences in ROM between water-based and land-based groups (t=5.37, p=0.000).

Table III: The effects of eight weeks exercise programs on dynamic balance (SEBT) and ROM of subjects in water and land media

Variables	**Media**	**Pre-test (Mean ±SD)**	**Post- test (Mean ±SD)**	**Mean diff**	**t (DV)**	**p**
Dynamic Balance (cm)	Water (n=12)	55.82±8.09	60.83±6.98	5.01±1.63	10.65	.000
	Land (n=12)	56.44±7.11	59.79±7.14	3.36±2.01	5.78	.000
t-test for independent variables	df=22	t = .201 p =.84	t = .36 p =.72			
ROM (°degree)	Water (n=12)	20.77º±1.39	27.72º±1.01	6.95° ± 1.27	18.98	.000
	Land (n=12)	21.66º±1.21	25.14°±1.32	3.52º ± .92	13.35	.000
t-test for independent variables	df=22	t= 1.6 p =.13	t=5.37 p=.000			

DV = Dependent variables

4. Discussions

This study investigated the comparison of eight weeks water and land-based exercise on improving dynamic balance and ROM of the athletes who experienced ankle sprain within the past six months. The findings revealed that the progressive intervention exercise was resulted in increasing dynamic balance and ROM in both media after eight weeks. Even though, the improvement of dynamic balance of land-based (+3.36±2.01cm) was smaller than water-based group (+5.01±1.63cm), there was statistically no significant differences between the exercise given in both media. While the findings of the study indicated increasing in ROM for water-based (+6.95º±1.27) and land-based (+3.52°±.92) group, for water-based group was significantly different with land-based group (t = 5.37, p = .000).

It is notable that although several studies have postulated the aquatic or water-based exercise for the therapeutic purpose, only limited studies presented to specifically support if water-based exercise is more effective in healing process for athletes with ankle sprain. While, in this study, there was no significant different in dynamic balance improvement as a result of eight weeks between land and water-based exercise groups, contrary findings by Rewald et al., (2015) revealed aqua-cycling is remarkably easy to incorporate in circuit training and provide an increase in dynamic postural stability scores compare to control group. They reported an improvement in self-reported pain relief after eight weeks training, even though the subjects (N=10) were non-athlete and 46-77 year old patients with knee osteoarthritis [26].

Similarly, these results support by Nualon et al., (2013) that reported hydrotherapy exercise could improve ankle functional performance among amateur athletes (N=24) with chronic ankle instability, alike a combining of ankle taping and land-based exercise (N=23). They recommended a combination of ankle taping, land-based exercise or hydrotherapy exercise can uses for clinical program in athletes with chronic ankle instability [8]. Likewise, Yelfani et al., (2015) have found that women (N=20), 20-30 years old, who suffering from chronic ankle sprain could improve pain relief, performance, static and dynamic stability in land and water-based exercises. They noted, while there was significant difference between the pre-test and post-test, no any significant difference detected in improvement of dynamic stability between land and water exercising groups [21].

An explanation for non-significant difference between land and water-based intervention programs was probably resulted due to minimal proprioceptive deficits in athletes who had chronic ankle instability [27]. Perhaps buoyancy of water and non-weight bearing provide a minimizing dynamic postural stability effected on the speed and direction of movements during exercise. Therefore, while the buoyancy acts in the opposite direction to the gravity, it gives the muscles, tendons and joint sense of feeling lighter in water media comparing to land [8, 19, 21, 22]. Another available evidence to support this arguments could be related to viscosity and resistance of water that resulted the slower motion, response and reaction time [28]. It could be more difficult to maintain stability in upright position, less joint flexion and increasing drag due to arm swing through the water [20]. Subsequently, the number of repetitions would be reduced in water-based group compare to the land-based.

Therefore, even though water-based exercise give the impression to be safer and very beneficial media of exercise than land-based exercise, a larger sample size and more focused studies among athletes needed since the primary goal of rehabilitation is to return the athlete to their sports participation as quickly as possible. It should mention that in all studies, the sample size of injured subjects (N≤25) could not be ignored for possibility of the non- significant results. However, more investigations are needed to answer the question of whether water-based exercise for ankle stability can be performed as a main injured athletes' rehabilitation or as a part of well-rounded exercise program.

Additionally, in this study, eight weeks water-based exercise caused a significant improvement on ROM compare to the similar land-based exercise. Earlier studies have declared the greater effectiveness of water-based exercise on flexibility and ROM among patients, older adults and individual with illness problems [29-31]. Poyhonen et al., (2002) showed ten weeks aquatic resistance training could change the knee extensors and flexors between 10 to 27% among healthy adult women [29].

Our findings in land-based exercise group and Zouita et al., (2006) studies had similarity in significant differences in postural sway after eight weeks proprioceptive exercise program among athletes with ankle sprain. They also reported a significant decrease in times of acceleration and deceleration at the level of plantar flexors, better stability and postural control of the injured leg [12].

These findings was consistent with a similar study by Wang et al., (2006) that reported approximately10% improvements in ROM of knee flexion, hip flexion and hip abduction in adults with osteoarthritis during 50 minutes aquatic exercise, three sessions for 12 weeks[30], although their subjects were not athlete. Nevertheless, it might be clarified by the fact of buoyancy of the water which made stretching easier to perform and optimal positions easier to maintain stretching[19].However, the duration of stretching can differ in a low intensity and duration of stretch (20-30 seconds) in water as a relaxing environment compare to land.

Recently, Welton et al., (2018) study's in a decade of patterns and trends of injury recurrence stated only 10.5% of all injuries resulted to reinjures which caused the athletes missing less than three weeks of their playing time[17].While athletes with ankle injuries temporarily should break their training or increasing risk of injury recurrence in this period of time, water-based exercise can provide a safe, non-painful and joyful opportunity to improve ROM, stability of ankle and reduce risk of re-injury.

Even though, there was no differences in baseline characteristics in both groups, all the subjects were athletes with ankle sprain within the past six months, the current study has limitation to control if the athletes participate in their sports training or having other daily activities. A further limitation associated with the severity of ankle sprain injury. It would be interesting to classify the similar groups with different grade of ankle sprain (1, 2 and 3) for further study to investigate the effect of this intervention treatment.

5. Conclusion

Though, water-based exercise program has shown a considerable enhancement on range of motion than dynamic balance, however the finding of this study has been reporting that the land-based exercise training group and the water-based training group had gradual increment in both balance and the range of motion (ROM) which could be effected in preventing ankle injuries. Including the subjects with different levels of severity of ankle sprain could be a potential reason for a lack of significant difference between programs in the current study.

Acknowledgement

The authors wish to thanks the participants for their voluntary involvement in this study. This study has been financially supported by University Research Grant code: 2016-0165-105-01 from Research Management and Innovation Centre, Sultan Idris Education University..

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