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Brief communication (Original)

The role of 6-week hydrotherapy and land-based therapy plus ankle taping in a preseason rehabilitation program for athletes with chronic ankle instability

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Background: Many athletes, especially at elite university level, suffer from chronic ankle instability (CAI). Chronic ankle instability usually occurs after simple ankle sprain from poor landing. The repetitive injury causes chronic ankle instability. This chronic ankle instability leads to poor performance and recurrent injury during training and competition. A proper rehabilitation program may improve performance and prevent further injury.
Objectives: We aimed to compare the effect of a 6-week functional rehabilitation program in athletes with chronic ankle instability between a hydrotherapy plus ankle taping group and a land-based plus ankle taping group on ankle functional ability, ankle joint position sense and the number of reinjuries.
Methods: Forty-seven university level athletes with chronic ankle instability and residual symptoms were randomized into a hydrotherapy group (24 participants) and a land-based group (23 participants). All participants were taped using a heel lock technique at the injured ankle during the training session. The rehabilitation program included stretching, aerobic exercise, balance exercise, strengthening exercise, and skill training using an aquatic or land-based environment according to the group for 6 weeks. A single-limb hopping test and ankle joint position sense were measured at baseline, 6 weeks, and 3 months. Recurrent ankle injuries were also recorded.
Results: In the hydrotherapy group, the time taken in the single-limb hopping test significantly decreased immediately after exercise and at the follow up compared with baseline ($p = 0.001$). In the land-based group, time taken in the single-limb hopping test significantly decreased at 3 months follow up compared with baseline ($p = 0.05$). No significant differences were detected between groups in ankle joint position sense and the number of recurrent ankle sprains. All participants returned to their athletic activity and competition.
Conclusion: The combined rehabilitation program of ankle taping, land-based exercise and/or hydrotherapy could be recommended for clinical uses in athletes with chronic ankle instability.

Keywords: Ankle taping, chronic ankle instability, hopping test, hydrotherapy, joint positional sense, land-based exercise

Ankle injury is one of the most common injuries during sports activities [1-4]. Ankle injury usually occurs in sports involving running, cutting, and jumping and landing, with higher possibility in contact sports. Ankle sprain usually involves a lateral ankle ligament complex, which may be stretched or torn, as a result of landing on a plantarflexed and inverted position of the foot [5, 6]. Firstly, the anterior talofibular ligament (ATFL) is injured, followed by injury to the calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL) [7-9]. A high recurrent rate of ankle sprain has also been reported in athletes who have residual symptoms such as pain, swelling, weakness, and instability [10-11]. These impairments could further deteriorate the ankle functional ability of athletes who have recurrent ankle sprains [12]. Chronic ankle instability (CAI) has been defined as the occurrence of multiple episodes of ankle sprains and instability [13]. There are two potential mechanisms that cause CAI. The first mechanism is mechanical instability (MI) from ligament laxity and excessive joint motion of the talocrural, subtalar and inferior tibiofibular joint because of structural damage

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of the supporting ligamentous tissue [14]. The second mechanism is functional instability (FI), a condition in which a patient has recurrent sprains with or without a feeling of ankle giving way [15].

The application of a specific functional exercise may be recommended in the athletes with chronic ankle instability and residual symptoms, particularly during the late phase or functional phase of ankle sprain recovery [10, 16]. Usually, land-based exercise is essential in the rehabilitation program for neuromuscular function improvement in the acute and chronic phase of ankle sprains [16-19]. Hydrotherapy or aquatic exercise is also indicated in the acute and chronic phases of sports rehabilitation programs in athletes [19, 22]. Utilization of water as a therapeutic modality based on its properties of buoyancy, viscosity, physiology of immersion and water temperature, hydrotherapy is preferable for rehabilitation of the injured ankle joints [20-22]. Ankle taping is also important to improve recovery of sprained ankles. The effectiveness of ankle taping has been studied as a mechanical support of the ankle and improved ankle proprioception [23-25]. A 6-week home program exercise supervised by a physical therapist showed clinical efficacy in the sprained ankle [19, 26]. However, only few studies on the effectiveness of a combined rehabilitation program on chronic ankle instability have been reported [19, 27]. The objective of this study was to compare the effect of a rehabilitation program combining ankle taping and land-based exercise with and without a hydrotherapy program in university athletes with chronic ankle instability and residual symptoms in the preseason period. The outcome measures are ankle functional ability, ankle joint position sense, and the number of reinjuries in the athletes.

Materials and methods

This study was reviewed and approved by the Research Ethics Committee of Thammasat University. All participants were informed the procedures of the study by the researcher. Written informed consent was obtained voluntarily from each participant before they enrolled in the study. Randomized allocation of participants was performed with a simple random sampling technique into either the hydrotherapy group or the land-based exercise group. This study was registered with the Clinical Trials Registry, No. NCT01298856).

University amateur athletes who have unilateral ankle inversion sprain during their sporting activities were recruited. Inclusion criteria were (1) recurrent unilateral inversion sprain at least one time within the past one year, (2) the residual symptoms of "giving way" or instability while walking or running in sports activities. Athletes were excluded if they had either a fracture or neurological disorders of the lower extremity, or allergy to zinc oxide compound.

All participants were asked to attend a rehabilitation and exercise class at the Physical Therapy and Hydrotherapy Clinic, Faculty of Allied Health Science, Thammasat University. Both programs were supervised by physical therapist twice a week (1 h/time) in a 6-week period. Participants were taped using heel lock technique on the injured ankle by the same physical therapist. All participants received the same static stretching program of warming up and cooling down for 10 minutes. After that, they participated either in the hydrotherapy session or land-based exercise session and progressed according to their assigned group for 45 minutes (**Table 1**). The land-based exercise session was conducted in the exercise room, and the hydrotherapy session was conducted in an indoor hydrotherapy pool with an adjustable platform. The temperature of the pool was maintained at 33°C to 34°C. All participants also underwent a home-based exercise program twice a week (15 min/time) for 6 weeks. The home program consisted of toe raise, heel walking, isometric ankle eversion, and one-leg standing on a towel with slightly flexed knee [17-19, 23].

The outcome measure consisted of ankle functional ability, active ankle joint position sense, and the number of reinjuries. Ankle functional ability was measured using a Single limb hopping test. Participants were asked to quick jump with their injured leg across the 8 uneven surfaces aiming to land on each area once without leaving the course. The test result was quantified by the time (in seconds) taken to complete the course [12, 28-30]. Joint position sense was actively quantified using a Biodex System 3 dynamometer at the target position of 30° ankle plantar flexion and 15° ankle inversion. The absolute error (AE) was determined from the difference between the target position and the response position (in degrees) without considering undershoot or overshoot. After 6 weeks of each rehabilitation program, participants were given a record form to note the number of reinjury ankle sprains during the following 3-months.

Table 1. Description of rehabilitation programs in this study

Program	Hydrotherapy		Land-based	
	Exercise	**Progression**	**Exercise**	**Progression**
Aerobic training (15 min)	1. Slow running with belt	1. The speed: low to moderate and carrying the resistance foam	1. Cycling on stationary bike	1. Intensity 80%–95% HRmax
Balance exercise (10 min)	1. Static: single-leg stance with the knee flexed 2. Dynamic: single-leg stance with the knee flexed and throw/catch a ball	1. Water level: chest deep to waist deep 2. Eyes open to eyes closed 3. Held position: 30 s, 60 s	1. Static: single leg stance with the knee flexed 2. Dynamic: single leg stance with the knee flexed andthrow/catch a ball	1. Uneven surface: foam pad, mini trampoline, wobble board 2. Eyes open to eyes closed 3. Held position: 30 s, 60 s
Strengthening exercise (10 min)	1. Double-leg squat 2. Single-leg squat 3. Toes raise walking 6 m 4. Heel touch walking 6 m 5. Deep water running with belt	1. Water level: chest deep to waist deep 2. Held position: 30 s, 60 s 3. Wall jet: high resistance	1. Leg press (50% 1 RM) 2. Leg curl (50% 1 RM) 3. Rubber band exercise Inversion/ eversion Plantar flexion/ dorsiflexion	1. Increased number of rep 2. increased weight resistance 3. Rubber band color Week 1–2 : blue Week 3–4 : silver Week 5–6 : gold
Functional skills (10 min)	1. Stepping forward/ backward and throw/ catch a ball 2. Stepping to the left/ right and throw/ catch a ball 3. Jumping: double-beg, single-leg and throw/ catch a ball	1. Water level: chest deep to waist deep 2. The speed: slow to fast 3. The ball weight: light to heavy	1. Jumping and throw/ catch a ball 2. Stepping with a ball 3. Sprinting	1. Uneven surface: foam pad, mini trampoline, wobble board

rep = repetition, HR_{max} = maximum heart rate, RM = repetitive maximum

Data analysis

Independent *t* tests and Chi-square tests were used to analyze continuous variables and categorical variables, respectively. Effects of interventions on ankle functional ability and ankle joint position sense were analyzed using a mixed design two-factor [treatment group (2) × time point (3)] analysis of variance. Independent *t* test procedures were also adopted for post hoc comparisons with a Bonferroni correction applied ($\alpha = 0.05$). Fisher's exact test was used to determine the recurrent ankle sprain data at 3 months follow-up. A probability level of less than 0.05 was adopted throughout.

Results

Fifty participants were recruited into this study. Twenty-five participants (23 men, 2 women) were randomly assigned into the hydrotherapy group, and another 25 participants (23 men, 2 women) into the land-based group. In the hydrotherapy group, 24 participants (96%) completed the protocol. One participant dropped out because of inability to commit to the intervention schedule. In the land-based group, 23 participants (92%) completed the program with 2 dropouts at 6-weeks and 3 months because of the transportation inconvenience. Forty-seven participants completed all training sessions and pretest, post-test, and follow-up test, and their performance data were included into analysis. There were no adverse events reported throughout this study.

Demographic information is presented in **Table 2**. No significant differences were found between groups for age, gender, height, weight, BMI, experience of playing sports, and side of injury. All participants were university athletes, preparing for university games. They played different kinds of sports (**Table 3**). A chi-square test for kinds of sports showed no significant difference between the

hydrotherapy group and the land-based group. The majority of participants in both groups were athletes in contact sports.

Ankle functional ability represented by the single-limb hopping test is shown in **Table 4**. In the hydrotherapy group, there was a significant difference between pretest and post-test ($p < 0.001$) and pretest and follow up test ($p < 0.001$). In the land-based group, there was a significant difference only between pretest and follow up test ($p = 0.05$). There was no statistical difference between groups. Time taken in the single-limb hopping test decreased after participating in either hydrotherapy group or land-based group. However, there was no statistical significant difference between groups. No statistical significant difference in active joint position sense the represented with absolute error (AE) between group.

A total of 12 participants (26%) suffered from recurrent ankle sprain while participating in sports activities over a 3-month period (**Table 5**). Four out of 24 participants in the hydrotherapy group (16.7%) and 8 out of 23 participants in land-based group (34.8%) experienced a reinjury episode. The percentage of participants suffered from the reinjury in the hydrotherapy group was lower than that in the land-based group. However, this difference was not significant. For 4 participants in the hydrotherapy group who experienced reinjury, 2 were rugby players, 1 was a basketball player, and 1 was a volleyball player. For 8 participants in the land-based group who experienced reinjury, there were 2 rugby players, 4 basketball players, and 2 football players. All reinjuries occurred during games or practice.

Table 2. Characteristics of 47 participants

Characteristics	Hydrotherapy (n = 24)	Land-based therapy (n = 23)
Age (years)	20.79 ± 1.89	20.04 ± 1.22
Sex (male/ female)	22/ 2	21/ 2
Height (cm)	172.69 ± 5.6	173.87 ± 7.49
Weight (kg)	171.25 ± 9.14	77.37 ± 16.03
% BMI (kg/m^2)	23.73 ± 2.89	25.65 ± 4.54
Experience of playing sports (years)	8.50 ± 4.30	7.39 ± 3.65
Injury side (left/ right)	7/ 17	9/ 14

Table 3. Kind of sports and number of participants

Kind of sport	Hydrotherapy group (n = 24) Number (%)	Land-based therapy group (n = 23) Number (%)
Rugby	12 (50)	11 (47.8)
Football	7 (29.2)	4 (17.4)
Basketball	3 (12.5)	5 (21.7)
Others*	2 (8.4)	3 (13)

*Others included taekwondo, softball, volleyball, and swimming

Table 4. Comparison of the single-limb hopping test and active ankle joint position sense between the hydrotherapy group (n = 24) and the land-based group (n = 23) at pretest, post-test, and follow-up test

Variables	Groups	Pretest	Posttest	Follow up test	*p* within group	*p* between group
Single-limb hopping test (seconds)	A	7.3 ± 1.4	6.1 ± 0.9	5.9 ± 0.8	<0.001**a, b	0.173
	B	7.4 ± 1.6	6.8 ± 1.3	6.5 ± 0.9	0.05*c	
Active JPS IV 15° AE (degrees)	A	3.6 ± 1.5	3.1 ± 1.7	2.7 ± 1.6	0.184	0.385
	B	3.7 ± 1.9	2.6 ± 1.7	2.3 ± 1.0	0. 072	
Active JPS PF 30° AE (degrees)	A	3.0 ± 1.8	2.1 ± 1.2	2.2 ± 1.2	0.059	0.056
	B	2.4 ± 1.2	1.8 ± 0.8	1.9 ± 1.2	0.173	

Mean ± SD using two-way mixed ANOVA, Post hoc analysis (Bonferroni), Significant differences *$p < 0.05$, **$p < 0.001$, [a] significant difference between pretest and posttest, [b] significant difference between pretest and follow up test, [c] significant difference between posttest and follow up test, JPS = joint position sense, IV = inversion, PF = plantar flexion, AE = absolute error, A = hydrotherapy group, B = land-based group

Table 5. Number of participants and reinjury data at 3-month follow up

Reinjury	Hydrotherapy Number (%)	Land-based Number (%)	Total Number (%)
Yes	4 (17)	8 (35)	12 (26)
No	20 (83)	15 (65)	35 (75)
Total	24 (100)	23 (100)	47 (100)

Fisher's exact test ($p = 0.193$)

Discussion

Forty-seven amateur athletes participated in this study and the compliance was as good as 96% for the hydrotherapy group and 92% for the land-based group. All participants had a subjective symptom of "giving way" while walking or running, and other residual symptoms of the chronic ankle instability such as pain, swelling, and muscle weakness. However, all of them were physically active, college-aged and still playing sports in their teams. Most participants involved in high contact sports in accordance to previous reports of athletes with ankle instability in rugby, football, and basketball [1-5, 9, 11, 31].

In our results, participants in both the hydrotherapy group and the land-based therapy group had improved ankle functional ability as demonstrated by the single-limb hopping performance. This improvement occurred within group immediately after participating in the 6-week rehabilitation program and at the 3 month follow up, whereas no differences were detected between groups ($p = 0.173$). The single-limb hopping test is a very complex task that involves multiple joints and structures [31]. Potential reasons for a lack of significant difference between programs in the current study may be the result of minimal proprioceptive deficits in athletes with chronic ankle instability as reported in previous studies [33]. Alternatively, these deficits may be were pronounced, but participants may use a compensatory strategy by using sensory input from other joints and structures in performing the single-limb hopping test.

The absolute error (AE) of the angle was calculated to express a total magnitude of error [36]. In the present study a trend of decreasing the absolute error angle both at inversion 15° and plantar flexion 30° after 6-week training in both groups. The rehabilitation program implemented in this study could improve the precision of active ankle repositioning of participants who have residual symptoms of chronic ankle instability and physically active athletes. The heel lock taping technique was expected to provide dual effects of improved ankle mechanical stability and increased stimulation of cutaneous receptors while training in both functional rehabilitation programs. Variations in exercise contents between the programs included using physical properties of the water and

floatation devices to change the speed and direction of the movement, as well as number of repetitions [35]. In deep water running, only the upright position is similar to walking and running on land, but nonweightbearing exercise in warm water is an advantage for relieving pain and swelling for participants in the hydrotherapy group. The buoyancy is in the opposite direction to the gravity, and therefore gives the body the sense of feeling lighter in the water than on dry land [20, 35].

Twelve participants reported one recurrent ankle sprain during the 3-month follow up. The result revealed no significant difference in reinjury between the hydrotherapy group (16.7%) and the land-based therapy group (34.8%). All subjects were participating in high contact sports and this could contribute to the occurrence of reinjury. The difference in rehabilitation protocols used between studies could be accounted for different results [17]. In the 3-month follow up period, participants in the current study could still participate in their teams, which might lead to a higher risk of reinjury ankle sprain. High recurrent episodes of ankle sprain usually occurred in the high level of activity [34]. Participants in the current study in both groups were classified as having vigorous activity, which includes jumping, pivoting, hard cutting (rugby, football, basketball) and it seems reasonable to encounter a high number of recurrent ankle sprain in both groups in the current study.

Our study has limitations including the lack of a control group (without exercise) to compare with the two exercise groups. Moreover, the participants in both groups are athletes with chronic ankle instability who have no differences in baseline characteristics between the 2 groups. They might have the same performance level comparable to healthy athletes in their team. This could be a reason for the finding of no significant difference between the single-limb hopping test, active joint position sense, and the number of recurrent ankle sprains between the hydrotherapy group and land-based therapy group. However, the new protocol of functional rehabilitation program in our study can improve the ankle functional ability immediately after 6-weeks and 3-month follow up within group exercise both in the hydrotherapy group and land-based therapy group.

In conclusion, amateur athletes with chronic ankle instability could be recommended for sports rehabilitation programs combining ankle taping and land-based exercise or hydrotherapy to improve ankle functional performance.

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