ผลของโปรแกรมฟื้นฟูนักกีฬาในน้ำและบนบกร่วมกับการพันผ้าเทปต่อความสามารถ
ในการทำงานของข้อเท้าและจำนวนการบาดเจ็บซ้ำในนักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรัง

นางสาวปุญญาณัฐ นวลอ่อน

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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THE EFFECT OF HYDROTHERAPY AND LAND-BASED REHABILITATION PROGRAM COMBINED WITH ANKLE TAPING ON ANKLE FUNCTIONAL ABILITY AND THE NUMBER OF RE-INJURY IN ATHLETES WITH CHRONIC ANKLE INSTABILITY

Miss Poonyanat Nualon

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Thesis Title	The effect of hydrotherapy and land-based rehabilitation program combined with ankle taping on ankle functional ability and the number of re-injury in athletes with chronic ankle instability
By	Miss Poonyanat Nualon
Field of Study	Biomedical Sciences
Thesis Advisor	Associate Professor Pongsak Yuktanandana, M.D., M.S.
Thesis Co-advisor	Pagamas Piriyaprasarth, Ph.D.

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Doctoral Degree

.... Dean of the Graduate School

(Associate Professor Pornpote Piumsomboon, Ph.D.)

THESIS COMMITTEE

.... Chairman

(Associate Professor Prawit Janwantankul, Ph.D.)

.... Thesis Advisor

(Associate Professor Pongsak Yuktanandana, M.D., M.S.)

.... Thesis Co-advisor

(Pagamas Piriyaprasarth, Ph.D.)

.... Examiner

(Assistant Professor Praneet Pensri, Ph.D)

.... Examiner

(Associate Professor Sompol Sa-Nguanrungsirikul, M.D., M.S.)

.... External Examiner

(Assistant Professor Kanda Chaipinyo, Ph.D.)

ปุญญาณัฐ นวลอ่อน : ผลของโปรแกรมฟื้นฟูนักกีฬาในน้ำและบนบกร่วมกับการพันผ้าเทปต่อความสามารถในการทำงานของข้อเท้าและจำนวนการบาดเจ็บซ้ำในนักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรัง. (The effect of hydrotherapy and land-based rehabilitation program combined with ankle taping on ankle functional ability and the number of re-injury in athletes with chronic ankle instability) อ. ที่ปรึกษาวิทยานิพนธ์หลัก: รศ.นพ.พงศ์ศักดิ์ ยุกตะนันทน์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร.ผกามาศ พิริยะประสาธน์, 99 หน้า.

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลของโปรแกรมฟื้นฟู 6 สัปดาห์ในนักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรัง ต่อความสามารถในการทำงานของข้อเท้า จำนวนการเกิดการบาดเจ็บข้อเท้าซ้ำ การทรงตัว การรับรู้ตำแหน่งของข้อเท้าและสภาวะสุขภาพทั่วไป นักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรังจำนวน 50 คนถูกสุ่มเลือกเพื่อเข้าโปรแกรมฟื้นฟูข้อเท้าในน้ำหรือบนบก การเก็บข้อมูลจะเก็บในช่วงก่อนฝึก หลังฝึกและติดตามผลภายหลังการฝึกเป็นเวลา 3 เดือน เมื่อสิ้นสุดการศึกษามีผู้เข้าร่วมงานวิจัยทั้งสิ้น 47 คน

ผลการศึกษาพบความแตกต่างระหว่างกลุ่ม เฉพาะการรับรู้ตำแหน่งการถีบปลายเท้าลงที่มุม 30 องศา ในกลุ่มที่ฝึกด้วยโปรแกรมในน้ำพบว่าเวลาที่ใช้ในการกระโดดขาเดียวมีค่าลดลงภายหลังการฝึกทันทีและหลังฝึก 3 เดือนเมื่อเทียบกับก่อนฝึกอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) และคะแนนจากแบบสอบถามสุขภาพทั่วไป (SF-36) ในด้านความสามารถในการทำกิจกรรมต่างๆ และอาการปวดเมื่อยร่างกายมีค่าเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) ในช่วงติดตามผล ในกลุ่มที่ฝึกด้วยโปรแกรมบนบกพบว่าเวลาที่ใช้ในการกระโดดขาเดียว มีค่าลดลงภายหลังฝึก 3 เดือนเมื่อเทียบกับก่อนฝึกอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) และการรับรู้ตำแหน่งของข้อเท้าดีขึ้นที่มุม 15 องศาของการบิดเท้าเข้าด้านในและมุม 30 องศาของการถีบปลายเท้าลงอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) โปรแกรมการฟื้นฟูด้วยการพันผ้าเทปบริเวณข้อเท้าร่วมกับการฝึกบนบกและในน้ำสามารถแนะนำให้ใช้ในทางคลินิกในนักกีฬาที่มีภาวะความไม่มั่นคงของข้อเท้าเรื้อรัง

สาขาวิชา ชีวเวชศาสตร์ ลายมือชื่อนิสิต ....

ปีการศึกษา 2553 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก..............................

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....

4989679920 : MAJOR BIOMEDICAL SCIENCES
KEYWORDS : ANKLE FUNCTIONAL ABILITY/ ANKLE TAPING/ CHRONIC ANKLE INSTABILITY/ HYDROTHERAPY

POONYANAT NUALON: THE EFFECT OF HYDROTHERAPY AND LAND-BASED REHABILITATION PROGRAM COMBINED WITH ANKLE TAPING ON ANKLE FUNCTIONAL ABILITY AND THE NUMBER OF RE-INJURY IN ATHLETES WITH CHRONIC ANKLE INSTABILITY. ADVISOR: ASSOC. PROF. PONGSAK YUKTANANDANA, M.D., M.S., CO-ADVISOR: PAGAMAS PIRIYAPRASARTH, Ph.D., 99 pp.

The purpose of this study was to examine the effect of the 6 week functional rehabilitation program on ankle functional ability, the number of ankle re-injury, postural sway, ankle joint position sense and health status. Fifty athletes with chronic ankle instability and residual symptoms were randomized into the hydrotherapy or land-based group. Data were collected at baseline, posttest and 3-month follow up. There were 47 participants who completed the protocol.

Results indicated differences between groups only in ankle joint position sense at 30 degrees of plantar flexion. In the hydrotherapy group, time taken in the single-limb hopping test significantly decreased immediately after exercise and at the follow up compared to baseline ($p<0.05$). The SF-36 questionnaire also improved in physical functioning and bodily pain scale at the follow up ($p<0.05$). In the land-based group, time taken in the single-limb hopping test significantly decreased at 3-month follow up compared to baseline ($p<0.05$). Ankle joint position sense also improved at 15 degrees of inversion and 30 degrees of plantar flexion ($p<0.05$). The rehabilitation program of ankle taping, land-based exercise and hydrotherapy could be recommended for clinical use in athletes with chronic ankle instability.

Field of Study : Biomedical sciences Student's Signature Poonyanat Nualon
Academic Year : 2010 Advisor's Signature
Co-advisor's Signature Pagamas Pi

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LIST OF ABBREVIATIONS

AE	=	absolute error
AP	=	anteroposterior
ATFL	=	anterior talofibular ligament
BMI	=	body mass index
CAI	=	chronic ankle instability
CFL	=	calcaneofibular ligament
CI	=	confidence interval
cm	=	centimeter(s)
CoP	=	center of pressure
FI	=	functional instability
HR_{max}	=	maximum heart rate
ICC	=	intraclass correlation coefficient
MI	=	mechanical instability
ML	=	mediolateral
mm	=	millimeter(s)
PTFL	=	posterior talofibular ligament
RE	=	relative error
rep	=	repetition
SD	=	standard deviation
sec	=	second(s)
SF	=	short form
VE	=	variable error

CHAPTER I

INTRODUCTION

1.1 Background and rationale

Ankle sprain, especially those involving the lateral ligament complex, has been reported as the most common injuries in sports players. It has been suggested that such injuries are usually sustained in sports involving running, cutting, jumping, landing, and contacting with other players (McKay, Goldie, Payne, and Oakes, 2001; Kofotolis and Kellis, 2007; Cumps, Verhagen, and Meeusen, 2007). The high recurrent rate of ankle sprain has also been reported in athletes who had residual symptoms (including pain, swelling, weakness and instability) for at least two years after their injuries (Braun, 1999; Pijnenburg, van Dijk, Bossuyt, and Marti, 2000; Anandacoomarasamy, and Barnsley, 2005).

The bony articulation along with surrounding ligaments of the ankle represented complex mechanical structures. Intact ligaments are essential for normal biomechanics of the ankle joint (Mangwani, Hakmi, and Smith 2001; Puffer 2002; O'Brien and Freund 2002; Williams III 2007). Each of the ligaments has a role in stabilizing the ankle joint. The lateral ankle ligamentous complex may be stretched or torn, known as 'sprains' which usually occur as a result of landing on a plantarflexed and inverted foot (Giza, Fuller, Junge and Dvorak, 2003; Beynnon, Vacek, Murphy, Alosa, and Paler 2005; Mangwani et al, 2001; Puffer 2002; O'Brien et al, 2002; Williams III 2007). These sprains may occur more often in contact injuries than in noncontact injuries when jump landing, running on uneven terrain, stepping in a hole, or landing on another athlete's foot (Kofotolis, Kellis, and Vlachopoulos, 2007; Cumps et al, 2007; McKay et al, 2001; Starkey, 2000). For the lateral ankle sprain, the anterior talofibular ligament (ATFL) is injured first, followed by injury to the calcaneofibular ligament (CFL) and posterior talofibular ligament (PTFL), respectively (Kofotolis et al, 2007; Puffer, 2002). Since the anterior talofibular ligament is the weakest in the lateral ankle complex, it is the most common injured structure as a result of plantar flexion and inversion injuries (Mangwani et al, 2001; Puffer, 2002; O'Brien et al, 2002; Williams III, 2007).

Chronic ankle instability (CAI) denotes the occurrence of repetitive bouts of lateral ankle instability, resulting in numerous ankle sprains (Hertel, 2002). Traditionally, CAI has been attributed to 2 potential causes. The first is the mechanical instability (MI) which is defined as laxity and excessive joint motion of the talocrural, subtalar and/ or inferior tibiofibular joint due to structural damage of the supporting ligamentous tissue (Tropp, Odenrick, and Gillquist, 1985; Hertel, 2000). The second is the functional instability (FI), a condition in which a patient has "recurrent sprains and/ or a feeling of giving way of the ankle (Freeman, 1965). In 1990, Konradsen and Raun attributed the cause of functional instability to both mechanical and functional causes in stating that functional instability results from "damage to mechanoreceptors in the lateral ligaments or muscles/ tendons with subsequent partial de-afferentiation of the proprioceptive reflex".

Various mechanoreceptors are present in joint capsules, ligaments, muscles, and skin around the ankle (Schmitz, 2007; Shaffer and Harrison, 2007). Mechanoreceptors provide afferent impulses regarding joint movement and position as well as contributing to a complex reflex system, which acts to maintain a state of body equilibrium. It has been suggested that damage to mechanoreceptors following ankle sprain could interrupt the flow of these afferent impulses to the central nervous system, thus leading to balance deficits (Isakov and Mizrahi, 1997; Akbari, Karimi, Farahini and FAghihzadeh 2006; Riemann, 2002; Trojian and McKeag, 2006; Emery, Cassidy, Klassen, Rosychuk and Rowe 2005; Hertel, 2007; Verhagen et al,2005), and contributing to the development of functional instability (Richie, 2001; Hertel, 2002). Residual symptoms such as giving way, pain, swelling, and muscle weakness of the ankle joint have been reported to be the problems that interrupted the functional activity of athletes who have recurrent sprains of the ankle (Giza et al 2003; Beynnon et al 2005; Braun, 1999; Anadacoomarasamy et al, 2005; Mangwani et al, 2001).

Understanding body's responses to an injury is paramount for designing a rehabilitation approach (Stacciolini, Meehan and d'Hemecourt, 2007; Williams III, 2007; Benani et al, 2008; Roebroeck, Dekker, Oostendorp and Bosveld, 1998; Holme, Magnusson, Becher, Bieler, Aagaard, and Kjaer 1999; Sekir, Yildiz, Hazneci, Ors, and Aydin, 2007; Monahan, Hartley, Hall and Smith, 2005; Subotnick, 2002; Kinch and Lambart, 2007; Hirth, 2007; Miller, Hunter and Prentice,2007). Ligament and soft tissue injury results in biomechanical changes similar to those seen after an injury. Injury results in bleeding and damage to tissue, which in turn produces pain. After the initial insult, the inflammatory response is initiated, followed by the proliferative phase and the maturation phase (Roebroeck et al, 1998; Benani et al, 2008; Kinch et al, 2007). The application of specific functional exercise is important to promote tissue healing. The specific adaptation to imposed demand (SAID) principle is helpful when designing a program for functional progression and the aim of this program is to adapt the demands of performance (Subotnick, 2002; Kinch et al, 2007).

More extensive rehabilitation, particularly during the late phase or functional phase of ankle sprain recovery, may be recommended for athletes at risk for residual symptoms (Braun, 1999; FitzGerald and Campion, 1996; Karlsson, 2007; Stacciolini et al, 2007; Subotnick, 2002; Miller, Hunter, and Prentice, 2007; Hunter and Prentice, 2004). Physical therapy exercise programs, including activities to enhance proprioceptive response and to strengthen the peroneous muscles may help in reducing the residual symptoms and may prevent re-injury (Braun, 1999; FitzGerald and Campion, 1996; Karlsson, 2007; Stacciolini et al, 2007; Subotnick, 2002; Miller et al, 2007; Hunter and Prentice, 2004).

Land-based exercises for improving neuromuscular functions are common in the acute and chronic phase of a rehabilitation program (Holme et al, 1999; Eils and Rosenbaum, 2001; Braun, 1999; Karlsson, 2007; Stacciolini et al, 2007; Subotnick, 2002; Mattacolar and Dwyer, 2002; Miller et al, 2007; Hunter and Prentice, 2004). Hydrotherapy is the utilization of water as a therapeutic modality based on the properties of buoyancy, viscosity, physiology of immersion and water temperature (Hoogenboom and Lomax 2007; Mattacolar and Dwyer, 2002; Brody, 2005; Kinch et al, 2007; Kim, Kim, Kang, Lee, and Childers, 2010). Hydrotherapy is indicated in the acute, and chronic phases of rehabilitation of sports injuries (Mattacolar et al, 2002; Kim et al, 2010). Lower extremity balance and proprioception are important for sports activity, and a well-designed water-based rehabilitation program. Any self-perturbation activity, such as hip flexion/ extension in waist-depth and chest-depth water while standing on the injured ankle, will challenge balance (Mattacolar et al, 2002; Kim et al, 2010). There is strong evidence that the use of ankle tape reduces the risk of ankle injury (Braun, 1999; Pijnenburg, et al 2000; Anandacoomarasamy, et al 2005; Simoneau, Degner, Kramper, and Kittleson; Burke and Bailey, 2002; Matsusaka, Yokoyama, Tsurusaki, Inokuchi, and Okita 2001). The effectiveness of ankle taping has been studied as a function of mechanical support of the ankle (Macdonald, 1994; Callaghan, 1997; Lohrer, Alt and Gollhofer, 1999; Burke et al, 2002; Wilkerson, 2002) and improvement in proprioception (Simoneau et al, 1997; Spanos, Brunswic and Billis, 2008) and postural control (Matsusaka et al, 2001).

Rehabilitation of athletic injuries requires the prescription of sport-specific exercise and activities that challenge recovering tendons, ligaments, bones, and muscle fibers without overstressing them. The goal of this rehabilitation is to return an athlete to the prior-injury level or higher level of competition as soon as possible (Braun, 1999; Karlsson, 2007; Stacciolini et al, 2007; Subotnick, 2002; Miller et al, 2007; Hunter et al, 2004; Mattacolar et al, 2002; Kim et al, 2010). The rehabilitation program integrating proprioception and muscle strengthening concepts is common in treating lower extremity injuries (Holme et al, 1999; Eils et al, 2001). Predictive factors for lateral ankle sprains included either intrinsic risk factors (balance, proprioception, muscle strength) or extrinsic risk factors (ankle taping, duration and intensity of competition) (Beynnon, Murphy and alosa, 2002; Murphy, Connolly and Beynnon, 2003). The previous studies has recommended not only training the ankle injury supervised by physical therapist in clinic settings, the home program exercise is also important for the sprained ankle (Mattacola and Dwyer, 2002; Emery, Cassidy, Klassen, Rosychuk, and Rowe, 2005; Bloch et al, 2007). However, only a few studies have been reported on the effectiveness of such a combined rehabilitation program for chronic ankle instability (Matsusaka et al, 2001; Mattacolar et al, 2002). Braun, (1999) reported in adult patient with ankle sprain 6 to 18 months after injury, there were 72.6% reported residual symptoms and factors associated with moderate to severe residual symptoms were re-injury of the ankle odds ratio; 7.21, 95%CI (4.14-12.68). These studied recommended more extensive rehabilitation during the subacute or later phases of ankle sprain may reduce the likelihood of significant residual symptoms and may prevent re-injury. Moreover, the six-weeks home-based balance training program is effective in improving static and dynamic balance and reducing sports related injuries among healthy adolescent (Emery, Cassidy, Klassen, Rosychuk and Rowe 2005).

Therefore, the aims of the study are to determine the effect of the 6-weeks ankle taping combined with hydrotherapy and land-based rehabilitation program on ankle functional ability, the number of re-injury, postural control, ankle joint position sense and health status in athletes with chronic ankle instability. This combined rehabilitation program would be useful for the athletes with chronic ankle instability who have residual symptoms.

1.2 Research Questions

Primary research questions

1. Does the combined ankle taping and land-based exercise with hydrotherapy improve ankle functional ability in athletes with chronic ankle instability better than the combined ankle taping and land-based exercise without hydrotherapy?
2. Is there any difference in the number of re-injury of ankle sprains in 3-month follow up after the rehabilitation program between the athletes with chronic ankle instability in the hydrotherapy group and the land-based group?

Secondary research questions

1. Can the combined ankle taping and land-based exercise with hydrotherapy improve ankle postural control in athletes with chronic ankle instability better than the combined ankle taping and land-based exercise without hydrotherapy?
2. Can the combined ankle taping and land-based exercise with hydrotherapy improve ankle joint position sense in athletes with chronic ankle instability better than the combined ankle taping and land-based exercise without hydrotherapy?

3. Is there any difference in the health status of the athletes with chronic ankle instability between the hydrotherapy group and the land-based group?

1.3 Objectives of the study

Major objectives

1. To compare the effect of combined ankle taping and land-based exercise program with and without hydrotherapy on ankle functional ability in the athletes with chronic ankle instability at pretest, posttest, and 3-month follow up test.
2. To determine the number of re-injury ankle sprain after 3-month follow up between the groups of combined ankle taping and land-based exercise with and without hydrotherapy.

Minor objectives

1. To compare the effect of combined ankle taping and land-based exercise with and without hydrotherapy on postural control in the athletes with chronic ankle instability at pretest, posttest, and 3-month follow up test.
2. To compare the effect of combined ankle taping and land-based exercise with and without hydrotherapy on ankle joint position sense in the athletes with chronic ankle instability at pretest, posttest, and 3-month follow up test.
3. To compare the effect of combined ankle taping and land-based exercise with and without hydrotherapy on health status of the athletes with chronic ankle instability at pretest, posttest, and 3-month follow up test.

1.4 Hypotheses of the study

Major hypotheses

1. There will be a difference in ankle functional ability between athletes with chronic ankle instability in the combined ankle taping and land-based exercise program with and without hydrotherapy at pretest, posttest, and 3-month follow up test.
2. There will be a difference in the number of re-injury of ankle sprain after 3- month follow up between athletes with chronic ankle instability in the combined ankle taping and land-based exercise program with and without hydrotherapy.

Minor hypotheses

1. There will be a difference in postural control between athletes with chronic ankle instability in the combined ankle taping and land-based exercise program with and without hydrotherapy at pretest, posttest, and 3-month follow up test.
2. There will be a difference in ankle joint position sense between athletes with chronic ankle instability in the combined ankle taping and land-based exercise program with and without hydrotherapy at pretest, posttest, and 3-month follow up test.
3. There will be a difference in the total score obtained from the SF-36 questionnaire between athletes with chronic ankle instability in the combined ankle taping and land-based exercise program with and without hydrotherapy at pretest, posttest, and 3-month follow up test.

1.5 Scope of the study

This study is a clinical trial that investigated the effect of the 6 weeks training of an ankle rehabilitation program in athletes with chronic ankle instability who had residual symptoms after injuries aged between 18 - 25 years. The intervention of this program is a combination of ankle taping, land-based exercise program with and without hydrotherapy, and home program exercise. The outcome measures consists of ankle functional ability, the number of re-injury, postural sway, ankle joint position sense and health status at pretest, posttest, and 3-month follow up test.

1.6 Conceptual framework

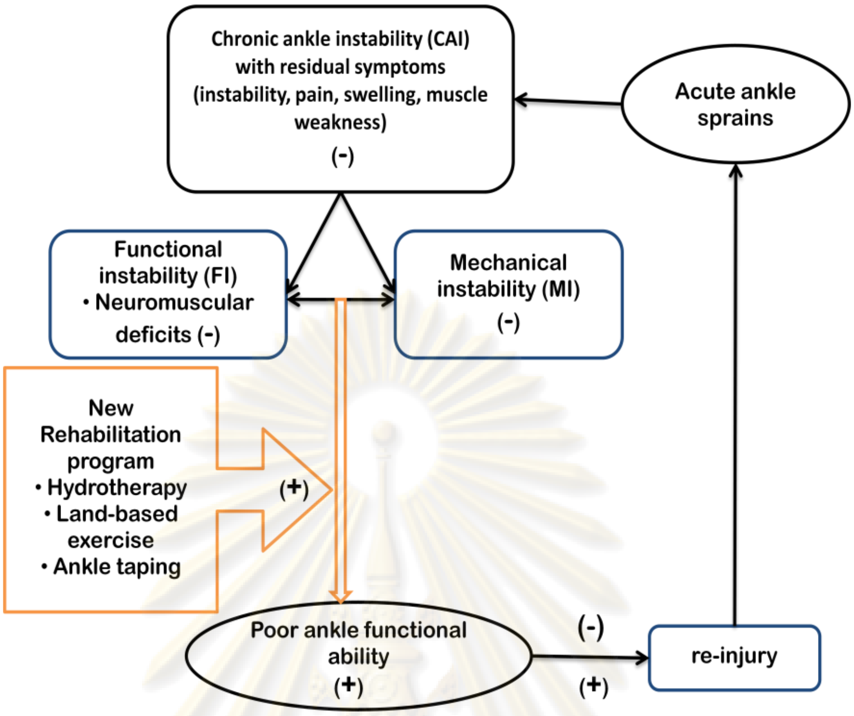


Figure 1.1 Conceptual framework

1.7 Benefits of the study

The findings of this study should demonstrate the effect of the rehabilitation program for athletes with chronic ankle instability whether it could improve ankle functional ability, static balance and the active ankle joint position sense, while reducing the number of re-injury of ankle.

CHAPTER II

LITERATURE REVIEW

2.1 Incidence of lateral ankle sprain and recurrent ankle sprain

Lateral ankle sprain is one of the most common injuries sustained in sports and exercise activities. Particularly, it can be found in sports in which participants frequently jump and land on one foot, or make sharp cutting maneuvers (Safran, Benedetti, Bartolozzi, and Mandelbaum, 1999). There are several studies on ankle injuries. In 2007, Kofotolis and Kellis reported ankle sprain injuries in female Greek professional basketball players. They found that the occurrence rate of ankle sprain was 1.12 per 1000 hours of exposure to injury. Players demonstrated a higher rate of ankle sprain from contact injuries during games than during practices. Their results also showed that the nonuse of external support was a predictor of ankle sprain ($p < 0.05$), with an odds ratio of 2.48 (95%CI= 1.10-5.60). Additionally, they found the high risk of ankle sprain in players who experienced a previous sprain. Accordingly, Cumps et al, (2007) reported that the incidence of acute ankle sprain was 1.5 per 1000 hours (95%CI= 1.0-2.0). Re-injuries occurred after one year was 52.9% of basketball players. The mechanisms of ankle sprains were explained as injuries after landing on an opponent's foot, jumping and suddenly changing direction. In addition, McKay et al (2001) studied injury rate and risk factors of ankle sprain in a group of basketball participation (n= 10,393). Their participants were largely recreational (77.9%) rather than elite (22.1%) players. The reported ankle injuries (n=40) occurred at a rate of 3.85 per 1000 participations. McKay et al identified three risk factors of ankle injury for this largely recreational basketball sample; 1) players with a history of ankle injury, 2) players wearing shoes with air cells in the heel and 3) players who did not stretch muscles before the game. Moreover, a retrospective study by Starkey (2000) provided the database of medical conditions experienced by athletes competing in the National Basketball Association (NBA) from the 1988-1998 season (n=9,904). The database (in frequency and percentage) showed that among all injuries the ankle was the most common site of musculoskeletal trauma

(1,062, 10.7%). Ankle sprains were also the most frequent occurred orthopedic injury (942, 9.4%) and involved the lateral ligaments (874, 92.8%) followed by patellofemoral inflammation (803, 8.1%), lumbar strains (491, 5.0%), and knee sprains (258, 2.3%).

In 2007, Kofotolis et al studied ankle injuries in 336 amateur soccer players. They reported ankle ligament sprains accounted for 66.8% of the total injuries sustained over two seasons which were significantly higher than the expected value ($p<0.05$). Overall, most players demonstrated the number of injuries at the anterior talofibular ligament (n= 87) was significantly higher compared with the expected value in relation to other regions ($p<0.05$), calcaneofibular ligament (n=5) and posterior talofibular ligament (n=5), respectively. Moreover, their results revealed that most injuries significantly occurred through contact injuries rather than noncontact injuries ($p<0.05$). Multivariate logistic regression analysis showed that the history of previous ankle sprain was found to be a significant predictor variable ($p<0.05$) and the odds ratio was 1.826 (95% CI= 1.46-2.29). Giza et al (2003) assessed the mechanisms of injuries of foot and ankle in soccer players through the video tape recording. Their result showed that foot and ankle injuries most often occurred during direct contact between the tackling and tackled players. The most tackle force occurred to the 37 lateral ankle and 31 medial ankle. In 2005, Beynnon et al studied the first-time ankle inversion sprain in 663 athletes in high school and 238 athletes in college between 1999 and 2003. They found that 43 athletes (4.8%) suffered a lateral ligament complex sprain, creating an overall incidence rate of 0.85 ankle sprain per 1,000 person-days of exposure to sport. Of these, there were 32 grade I sprains and 11 grade II sprains. Additionally, Woods et al (2003) studied the medical injury from the medical records of 91 football clubs in English football leagues for two seasons. They reported the most common type of ankle injuries was sprain and rupture (67%) and most often involved the lateral ligament complex (77%). One thirds of ankle sprain was sustained during training and two thirds during games. Contact injuries were accounted for 59% of injuries, and 39% were non-contact injuries. Tackling (36%) and being tackled (18%) were most common mechanisms of sustaining an ankle sprain. The non-contact sprains were caused during landing, twisting and turning, and running. The data also showed that 50% (n=336) of the players who sustained ankle sprains did not use external support whereas 25% (n=167) of the players were using ankle taping during injury episodes. The study by Braun (1999) assessed the 1-year outcome of standard medical care of acute ankle sprains in a general clinic-based population. The data showed that 72.6% of patients presented with residual symptoms after ankle sprain injury in 6 to 18 months. Of these, 40.4% reported at least one moderate to severe symptom. Most perceived ankle weakness; 40.3% were unable to walk 1 mile; and 43.3% were unable to jump or pivot on the ankle without symptoms. In addition, a retrospective case-control study by Anadacoomarasamy and Barnsley (2005) used the quality of life questionnaire (SF 36) to evaluate the long term outcomes of inversion ankle injuries sustained during sport activities between the acute ankle injury group (n=19) and the control group (n=19). Fourteen patients (74%) had at least one symptom at the time of follow up. Nine patients (47%) had pain, nine perceived instability, nine had muscle weakness, and seven (37%) had swelling. Moreover, 42% of subjects had a recurrent ankle sprain and the mean time to return to sports was 12.9 weeks (range of 2 weeks to 18 months). No significant differences in other SF 36 scales (physical functioning, role-physical, bodily pain, vitality, social functioning, role-emotional and mental health) were found between the acute ankle injury group and the control group.

Two literature reviews from Beynnon, Murphy and Alosa (2002) and Murphy, Connolly and Beynnon (2003) revealed similar conclusions of intrinsic (those from within the body) and extrinsic (those from the outside the body) risk factors of lateral ankle sprains. The most common intrinsic risk factors of lateral ankle sprain is the history of at least one previous ankle sprain (McKey 2001; Anandacoomarasamy 2005; Braun 1999) and impairment by persistent ankle symptoms which may lead to long term instability of the ankle (Braun 1999; Pijnenburg et al 2000; Anandacoomarasamy 2005). Extrinsic risk factors that have been investigated through prospective studies include ankle bracing and taping (McKay et al 2001; Pijnenburg et al 2000), the duration and intensity of competition, and player position (Kofotolis 2007).

2.2 Structures of lateral ligament complex

The lateral ligament complex of the ankle attaches the lateral malleolus to the talus and the calcaneus. The lateral ligament complex consists of 3 ligaments: the anterior talofibular ligament, the calcaneofibular ligament, and the posterior talofibular ligament (Rundle, 1995; Monahan, Hartley, Hall, and Smith, 2005; O'Brien and Freund, 2002) (Figure 2.1).

The anterior talofibular ligament (ATFL) is 15-20 mm long, 6-8 mm wide and 2 mm thick. It extends from the anterior border and the tip of the lateral malleolus and runs obliquely forward to insert at the neck of the talus. This ligament is the primary stabilizer against inversion and plantar flexion (Mangwani et al, 2001; Puffer, 2002; O'Brien et al, 2002). The ATFL is the most common injured structure in lateral ankle sprains (Starkey, 2002; Kofotolis, 2007).

The calcaneofibular ligament (CFL) is 20-30 mm long, 4-8 mm wide and 3-5 mm thick. It extends medially, posteriorly and inferiorly from the lateral malleolus to a tubercle on the lateral surface of the calcaneus. It is lining deeply to the peroneal tendons. This ligament is the primary stabilizer against inversion and dorsiflexion (Mangwani et al 2001; Hertel, 2002; O'Brien et al, 2002). The CFL is the second most common injured structure in lateral ankle sprains (Starkey, 2002; Kofotolis, 2007).

The posterior talofibular ligament (PTFL) is 30 mm long, 5 mm wide and 5-8 mm thick. This ligament is short, thick, and the strongest of the three lateral ligaments (Mangwani et al, 2001; Puffer, 2002). It extends from the medial surface of the lateral malleolus and runs medially in a horizontal manner to the posterior aspect of the talus. The PTFL is tensed only in extreme dorsiflexion (Mangwani, et al, 2001; Puffer, 2002; O'Brien et al, 2002). Because of these characteristics, this ligament is the least injured structure (Mangwani, et al, 2001; Puffer, 2002).

Each of the lateral ligaments has a role in stabilizing the ankle or subtalar joint, depending on the position of the foot. When the foot is in dorsiflexion, the posterior talofibular ligament is maximally stressed and the anterior fibers of the calcaneofibular ligament are taut, while the anterior talofibular ligament is laxity. Conversely, when the foot is in plantar flexion, the calcaneofibular ligament is loosened and the anterior talofibular ligament is taut (O'Brien et al, 2002; Puffer, 2002).

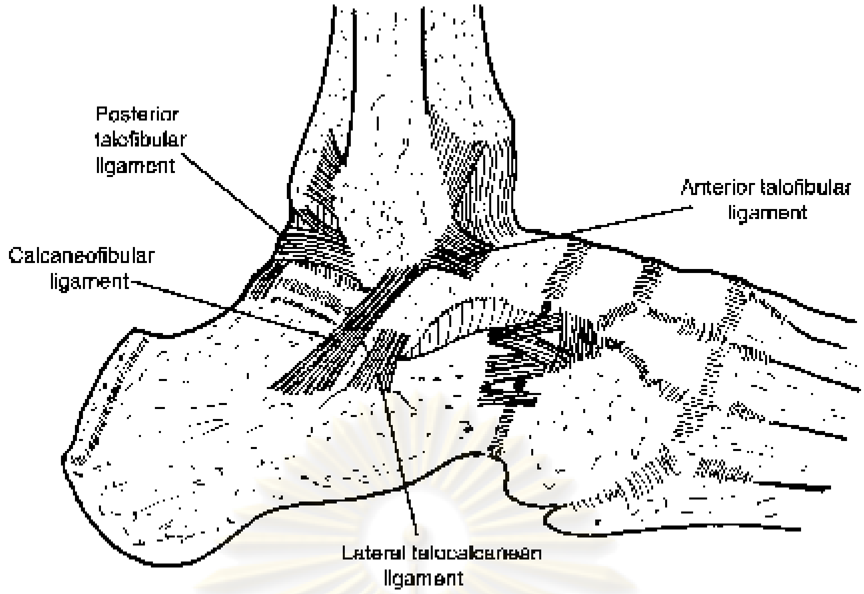


Figure 2.1 Lateral ligament complex of right foot and ankle (O'Brien and Freund, 2002)

2.3 Biomechanics of the ankle joint stability

The subtalar joint is formed by the talus and calcaneus. The subtalar joint is one of the most importants joint for the conversion of the rotatory forces of the lower limb. The stance limb is positioned and the supportive area is situated under the center of gravity (COG) while the body's center of gravity moves forward during walking and running (Tropp, 2002). Biomechanically, the reaction force from the ground acts on the foot to create moment acting on the subtalar joint. The position of the foot in relation to the COG affects the ground-reaction force acting through the center of pressure (CoP). Rotation around the CoP at the subtalar joint is the primary movement to correct the posture at the ankle joint. The postural corrections occur at the ankle or called ankle synergy, is the primariy occur through corrective motions of inversion and eversion to maintain the stability of the foot beneath the COG. If only pure ankle synergy takes place, no shear forces are produced, and any forces on the foot are counteracted by forces acting through the COG (Tropp, 2002). The coordinations of the muscles around the ankle and the axes of the subtalar and talocrural joints usually define the ability of the joint to counteract external loads (torques) on the ankle. The external load typically everts and dorsiflexes the ankle. This torque is counteracted by the strong plantar-flexor and inverter muscles (Tropp, 2002). Moreover, a global coordination system of the ankle has been used to demonstrate a three-dimensional motion analysis around the ankle joint or called triplanar movement of the ankle. Inversion and eversion were defined as a rotation around the anterior-posterior axis (Y-axis), dorsiflexion and plantar flexion were defined as a rotation around the medial-lateral axis (X-axis), and external rotation and internal rotation were defined as a rotation around the proximal-distal axis (Z-axis) (Figure 2.2) (Siegler, Lapoints and Nobilini, 1996; Omori, Kawakami, Sakamoto, Hara and Koga, 2004).

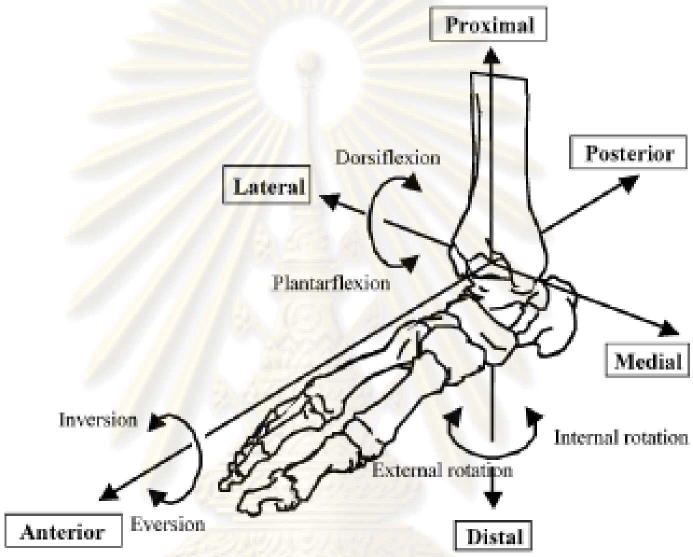


Figure 2.2 A global coordination system of the ankle joint (Omori et al, 2004)

2.4 Mechanisms of lateral ankle sprains

Lateral ankle sprains usually occur as a result of landing on a plantarflexed and inverted foot (Kofotolis et al, 2007; Giza et al, 2003). This may occur while running on uneven terrain, stepping in a hole, or landing on another athlete's foot (Woods et al, 2003; Cumps et al, 2007). The weakest anterior talofibular ligament is injured first and if the force is strong enough the calcaneofibular ligament and the posterior talofibular ligament can be injured as well (Kofotolis et al, 2007; Mangwani et al, 2001; Puffer, 2002; O'Brien et al, 2002).

The common tests for ankle instability are the anterior drawer test and the talar tilt test (Mangwani et al, 2001; Puffer, 2002; O'Brien et al, 2002). Anterior drawer test is used to assess the anterior talofibular ligament and to measure anterior translation of the talus within the mortise. The test is performed by stabilizing the lower extremity with one hand while pulling the foot forward with the other hand behind the heel in a relaxed the patient's sitting or lying supine position. Normally, the talus may translate 2-9 mm anteriorly, so it is important to compare the injured ankle with its noninjured counterpart to determine whether there is a difference. A positive test is determined by a 4 mm difference in anterior translation between the injured and the uninjured ankle (Mangwani, 2001; Puffer, 2002). Talar tilt test is used to assess the calcaneofibular ligament. The widely variability exists in the degree to the normal ankle may be inverted, with normal values ranging from 5-23 degrees. Excessive inversion of the ankle could indicate laxity of the calcaneofibular ligament. A positive test is defined as a 6 degree difference between the injured and uninjured side (Mangwani, 2001; Puffer, 2002).

The severity of the ankle sprain can be graded after the physical examination. Grading the ankle sprain guides treatment and rehabilitation and also provides useful information in accordance to the expected time of disability. Table 2.1 presents The West Point Ankle Sprain Grading System provide a useful criteria for classifying injury. On average, Grade 1 injuries will result in 7 to 14 days lost from activity, while Grade 2 sprains may result in a loss from 2 to 6 weeks of activity. Grade 3 sprains may result in a loss of 4 weeks to 26 weeks from athletic competition (Puffer, 2002).

Table 2.1 The West Point Ankle Sprain Grading System (Puffer, 2002)

Criterion	Grade1	Grade 2	Grade 3
Location of tenderness	ATFL	ATFL, CFL	ATFL, CFL, PTFL
Swelling and ecchymosis	Slight local	Moderate local	Significant diffuse
Weight-bearing ability	Full or partial	Difficult without crutches	Impossible without pain
Ligament damage	Stretched	Partial tear	Complete tear
Instability	None	None or slight	Definite

ATFL = anterior talofibular ligament, CFL = calcaneofibular ligament, PTFL = posterior talofibular ligament

2.5 Ligament healing process

Healing of the ligament is the result of successive and overlapping three stages (Figure 2.3) lasting from some days to several months or years (Oakes 1995; Benani et al 2008). The first stage is called the inflammatory phase, and last some days to up to some weeks. The gap between the interrupted and retracted collagen bundles is invaded by inflammatory cells, especially polymorphonuclear leukocytes which remove the debris of the injured part of the ligament. In addition, the released cytokines promote the capillary growth in the scar tissue, which helps the next repair stage. This phase lasts some weeks to months when fibroblasts and endothelial cells migrating from the epiligament proliferate and fill in the gap. The scar tissue is characterized by a high cell density in comparison to ligament, collagen fibers randomly oriented, and numerous capillaries. The last long lasting stage (from months to years) is called the remodeling phase. It is characterized by the reduction of cell density, disappearance of capillaries, and synthesis of high proportion of type I collagen instead of the type II collagen which was laid down during the previous proliferating phase (Oakes 1995; Benani et al 2008).

These events are sequential, but each phase of healing overlaps another. Optimal healing occurs when the introduction of exercise and functional activity is appropriate in each phase. Controlled stress promotes healing and results in stronger repair. Nevertheless, excessive loading can interrupt healing and prolong the inflammatory process. The time needed for healing depends on the grade of injury, and clinical decisions should be based on signs, symptoms and functional assessments (Safran, et al,1999; Benani et al 2008).

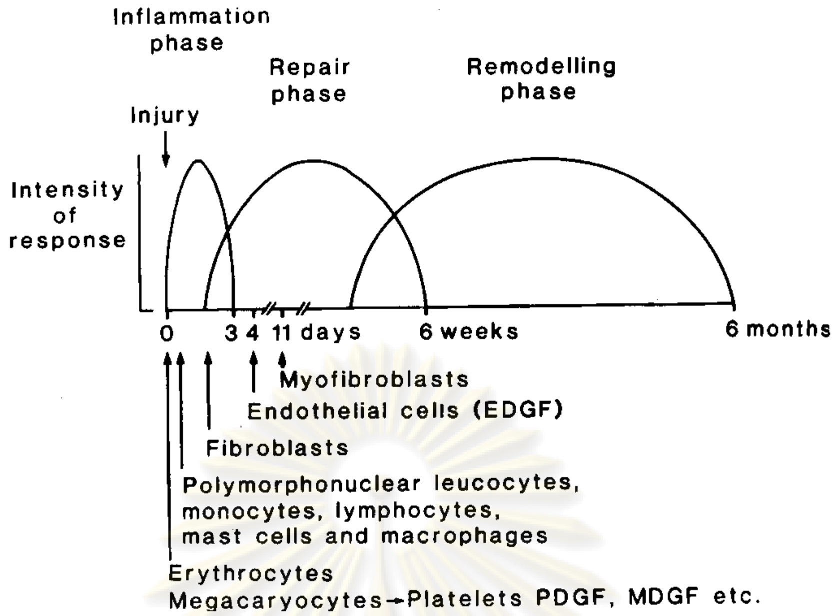


Figure 2.3 The three phases of ligament/ tendon healing and the cells involved (Oakes, 1995)

2.6 Pathomechanics of chronic ankle instability

Chronic ankle instability (CAI) is a subjectively reported feeling of the ankle “giving way” after an initial ankle sprain and repetitive bouts of instability resulting in numerous ankle sprains (Demeritt, Shultz, Docherty, Gansneder, and Perrin 2002; McKeon, Ingersoll, Kerrigan, Saliba, Bennett and Hertel 2008). Chronic ankle instability (CAI) is a clinical problem and has been attributed to 2 potential causes: mechanical instability (MI) and functional instability (FI) (Tropp, Odenrick, and Gillquist 1985; Hertel, 2000; Hertel, 2002; Richie 2001).

Mechanical instability (MI) of the ankle complex occurs as a result of anatomical changes after initial ankle sprain, which leads to insufficiencies that predispose the ankle to further episodes of instability. These changes include pathologic laxity, impaired arthrokinematics, synovial changes, and the development of degenerative joint disease, which may occur in combination or isolation (Tropp et al 1985; Hertel, 2002). Extensive mechanoreceptors are found in the lateral ligaments and joint capsule of the talocrural and subtalar joints (Hertel, 2000). In 1995, Michelson and Hutchins studied mechanoreceptors in human ankle ligaments from five cadavers. They found more abundant of type-II and type-III mechanoreceptors than type-I mechanoreceptors in ATFL, CFL and PTFL. The presence of type-II receptors, which sense the initiation of joint movement, in ligaments implies that the initiation of motion of the human ankle involves stress transmission through these ligaments. Type-III receptors are also abundant and active at the extreme of joint movement. They probably act to alert the CNS of imminent danger to the joint (Michelson, 1995). Mechanoreceptors sense increased tension in ligaments and send an afferent message through afferent pathway to the spinal cord. In response, an efferent response is sent to the target muscle which can slow or reverse the direction of joint movement (Hertel, 2000). A disruption of sensory receptors within the lateral ligamentous structure is believed to result in a decreased ability to sense changes in joint position (Hertel, 2000). Mechanoreceptors are located in the joint capsule, ligaments, muscles, tendons, and the skin (Aydin, Yildiz, Yildiz, Atesalp, and Kalyon 2000).

In 1965, Freeman, Dean, and Hanham first described the concept of ankle functional instability (FI). They attributed CAI to proprioceptive deficits after ligament injury. Over the past 2 decades, functional insufficiencies among individuals with either acute ankle sprains or chronic ankle instability have been demonstrated by quantifying deficits in ankle proprioception, neuromuscular response times, postural control, and strength (Hertel, 2002). Chronic ankle instability may be caused by mechanical instability, functional stability, or a combination of these entities (Hertel, 2002).

2.7 Proprioception deficits with chronic ankle instability

Proprioception is the sensory awareness allows for the sensation of body movement and position (Hertel, 2008). The receptors of proprioception are located in joint structures, participating muscles, ligaments, tendons, and the cutaneous (Figure 2.4) (Reer and Jerosch, 2002).

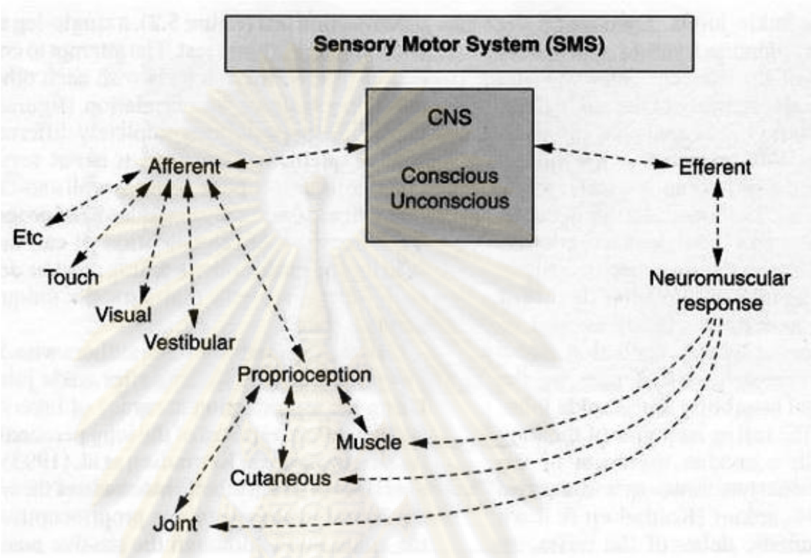


Figure 2.4 The sensorimotor system (Reer and Jerosch, 2002)

Freeman (1965) and Freeman et al (1965) hypothesized that the tensile strength of the mechanoreceptors is less than the connective tissue within which they are embedded. These mechanoreceptors must be disrupted when ankle ligaments and capsules are torn or stretched. In addition, the disruption of these mechanoreceptors results in decreased sensory input to the CNS which may in turn to depositioning and diminished reflex responses.

Proprioceptive deficits after ankle injury are thought to result from damage to mechanoreceptors in ligaments, muscles, and skin, contributing to subsequent feelings of instability (Lentell, Baas, Lopez, McGuire, Sarrels, and Snyder, 1995; Riemann, and Lephart, 2002; Demeritt et al, 2002). Proprioception plays an important role in the prevention and rehabilitation of ankle injuries (Braun, 1999; Lephart, Pincivero and Rozzi, 1999; Riemann, 2002; Mencher, 2002; Subotnick, 2002; Hunter, and Prentice, 2004; Verhagen et al, 2005; Kinch et al, 2007; Hirth, 2007; Miller et al, 2007). Joint position sense is mediated by joint and muscle receptors as well as visual, vestibular and cutaneous input (Reer et al, 2002). It can be measured by active or passive positioning of the limbs. In 1987, Gross studied the effect of recurrent lateral ankle sprains on active and passive ankle joint position sense in 14 subjects (age between 18 and 35 years) who sustained a recurrent unilateral ankle sprain involving lateral ligaments and 7 healthy control. All of them were tested active and passive ankle joint position sense six trials for each ankle using the Cybex® II isokenetic dynamometer at the speed of 5 degrees/ second. There was no significant main effect to indicate differences between the chronic ankle instability and control group in active joint position sense. He suggested that joint receptors play a dominant role in joint angle detection, while muscle receptors are the most importance in the perception of joint movement.

Loss of balance or postural control can be measured objectively with stabilometry, involving the calculation of center of pressure on a force platform. While stabilometry evaluating, subjects are required to stand on one leg with arm folded across the chest. The force platform detects anteroposterior and medial lateral shifts in the center of mass as it is maintained over the supportive foot (Richie 2001). Postural control is commonly measured as postural sway, the degree or amplitude that a person sways away from his or her center of balance (Riemann, 2002; Emery, Cassidy, Klassen, Rosychuk, and Rowe, 2005; Akbari, Karimi, Farahini, and Faghihzadeh, 2006; Trojian, and McKeag, 2006; Delahunt, 2007). After injury, a patient must be able to maintain posture against gravity before progressing to more complicated functional activities. Therefore, it is essential that evaluation and rehabilitation for deficits in postural sway be performed more frequently after musculoskeletal injuries. 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 joint capsules, ligaments, muscles, tendons and skin (Lentell, 1995; Hertel, 2002; Konradsen, 2002; Delahunt, 2007).

2.8 Ankle functional ability

Ankle functional ability is the ability to perform sport skill, multidirectional and coordinated movements over a measurable period of time. A variety of functional performance tasks have been developed to simulate, in a controlled environment, actions and forces imposed on the ankle joint during normal athletic performance (Demeritt et al, 2002). Clinicians use the functional ability test during the last stages of rehabilitation as a criterion of returning to sports activity (Munn, Beard, Refshauge and Lee, 2002; Kinch and Lambart, A 2007). Recent studies examined the functional ability using various tests including the single-limb hopping (Aydin et al, 2000; Christakou, Zervas and Lavallee, 2007; Sekir et al,2007; de Noronha, Refshauge, Kilbreath and Crosbie, 2007; Buchanan et al, 2008; Yildiz et al, 2009), single-limb hurdle test (Buchanan et al, 2008), the one-legged hop for distance (Christakou et al, 2006; Sekir et al,2007; Yildiz et al, 2009), the triple-legged hop for distance (Yildiz et al, 2009), the six-meter and cross 6-m hop for time (Sekir et al,2007). In 2009, Yildiz et al studied the reliability of 5 different functional ability tests in 20 healthy males. The intraclass correlation coefficient (ICC) for ankle functional showed good to high reliability. The ICC in the single limb hopping test is 0.91 and standard error of measurement (SEM) is ±0.88 seconds. This test is especially useful to document the function of the ankle on an uneven surface. Aydin et al (2000) studied proprioceptive functions of the ankle between female teenage gymnasts and healthy nongymnasts. They found highly significant differences in time taken in the single limb hopping test in the trained gymnastic group were 33.4% faster than the control group. This result indicated that gymnasts had a faster reaction time than normal untrained people because the exercise could improve joint proprioception, balance and coordination of the ankle. Recently, Sekir et al (2007) investigated the effects of isokinetic strengthening exercise in 24 male recreational athletes with unilateral functional ankle instability. The result for the single-limb hopping test showed significantly shortened hopping time in the injured side of the ankle group compared to the uninjured side of the ankle group ($p=0.03$). Similarly, the hopping time was shortened after training compared to pretest in the injured ankle group ($p<0.05$). These significant changes were not found in the uninjured ankle group.

Differently, Buchanan et al (2008) examined the functional performance in 40 active collegiate University who had a history of residual episodes of ankle giving way or instability using the single limb hopping test. The result revealed no difference in the single-limb hopping performance between the functional ankle instability (n=20) and the control group (n=20), who had no history of ankle sprains. Previous studies suggested that the single limb hopping test, the dynamic sports-specific condition, could be an appropriate test to determine functional improvements after rehabilitation in participants with functional ankle instability (Reer and Jerosch, 2002; Buchanan et al, 2008).

2.9 Health status measurement (SF-36 questionnaire)

SF-36 is one of the self-reported questionnaires. The "SF" stands for "short form", and the "36" refers to the fact that this form consists of 36 questions. SF-36 is the best known questionnaire amongst experts in measuring health status. The SF-36 consists of 8 health concept subscales and 2 component summary scores. Subscales included in the physical component summary are physical functioning, role-physical, bodily pain, and general health. Subscales included in the mental component summary are vitality, social functioning, role emotional, and mental health (Binkley, Stratford, Lott, and Riddle, 1999; Marsh, 2009).

The SF-36 has been translated and used in many countries. In 2007, Songsakon, Silpakit and Udomsubpayakul reported the Thailand normative data of the SF-36 health survey. The result showed that the scores of Bangkok people are lower than their US counterparts in all domains. Songsakon and colleagues (2007) suggested these data will be useful for assessing the health status of the general population and patient populations, and the effect of interventions on health-related quality of life.

2.10 Rehabilitation program of ankle instability

Rehabilitation of athletic injuries requires the prescription of sport-specific exercise and activities that challenge recovering tendons, ligaments, bones, and muscle fibers without overstressing them. Freeman et al (1965) stated that the danger to ligaments and their associated mechanoreceptors has been shown to result in deficient proprioception after injuries of the ankle. Therefore, rehabilitation for such injuries must be taken into account not only the structural abnormality, but also the loss of sensory feedback that resulted. Specific exercises for ankle rehabilitation have been developed to restore lost proprioception after ankle sprains, and it has been shown that these exercises give better functional results than rehabilitation without proprioceptive training (Freeman et al,1965).

Rehabilitation programs should be strategically designed in order to induce the appropriate amount of loading to ligament according to the stage and timing of repair (Michelson and Hutchins, 1995; Roebroech, 1998; Ng, 2007; Benani et al, 2008). In 1999, Holme et al investigated the effect of an early rehabilitation program in 92 subjects after acute ligament sprain. Subjects in the treatment group (n=29) were participated in a 6 week supervised group physical therapy rehabilitation (1 hour, twice weekly) which included comprehensive balance exercises on both legs, figure of eight running, standing on a balance board and catching a ball, standing on the outside-inside of the feet with eyes open and closed. The control group (n=42) only received the standard treatment of the emergency room, including strength training (standing on heels/ toes, hop on one foot), mobility (circular movements) and balance exercises (standing on one foot with eyes open and closed and standing on a balance board). After 6 weeks in the training group, there was a significant difference in strength between the injured and uninjured side for plantar flexion, eversion, and inversion, but not for dorsiflexion. Similarly, postural sway differed between the injured and uninjured side. In the control group, there was a significant difference in strength between the injured and uninjured side for plantar flexion, eversion, inversion, and dorsiflexion. Postural sway differed between the injured and uninjured side. Joint position sense was not found to be difference side to side after 6 weeks in training group. The re-injury data were shown that, a total of 19% of all subjects suffered a recurrent ankle sprain during the 12 month follow-up period. There was 11/ 38 subjects in the control group (29%) sustained a re-injury, while there was only 2/ 27 (7%) in the training group. The findings demonstrated that supervised rehabilitation might be substantially number of re-injuries lower than the control group, and therefore may play a role in injury prevention (Holme et al, 1999). Accordingly, Eils and Rosenbaum (2001) investigated the effects of 6 weeks multi-station, low-frequency exercise program in chronic ankle instability (CAI) participants. The exercise group (n=31) received the 6-week physiotherapeutic exercise program and the control group (n=17) only participated in the testing procedures before and after 6 week period. The 12 stations of exercise program consists of various proprioceptive training device (such as ankle disk, mini trampoline, Haramed® and Biodex® Balance System). A significant improvement in joint position sense and postural sway was found as well as significant changes in muscle reaction time. This advantageous program is considered relatively low training with the frequency of once a week. This exercise might be selected as a part of a land-based rehabilitation program athletes as functional rehabilitation or specific skill of sports for injured athletes (Kinch and Lambart, 2007; Stacciolini et al, 2007; Mencher , 2002; Hirth, 2007; Miller et al, 2007).

2.11 Physical properties of water and hydrotherapy in sports

Hydrotherapy is defined as a physical therapy treatment carries out in water by a physical therapist and involved the use of the medium in the treatment of sports injuries using the physical properties of water (Kent, 1998; Campaion et al and Hamer, 1995; Hoogenboom and Lomax 2007; Brody, 2005). The advantage of exercise in water for the injured athlete is appreciated as a mean of maintaining fitness as well as the treatment of specific injuries. Water has the property of buoyancy which reduces the stress on weight-bearing joint, particularly through the lower limb musculoskeletal system (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Buoyancy and gravity : Buoyancy and gravity are two generally opposing forces that act upon a body in water and play a major role in hydrotherapy. The use of buoyancy and gravity dominated depths depends upon the purpose for which an exercise is employed and the condition of the athlete being treated (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Viscosity : The viscosity of a fluid is its resistance to adjacent fluid layers sliding freely by one another. This friction causes a resistance to flow when moving through a liquid. The viscos quality of water allows it to be used effectively as a resistive medium because of its hydrodynamic properties. Turbulent flow is produced when the speed of movement reaches a critical velocity. Eddies are formed in the wake behind the moving object, creating drag that is greater in the unstreamlined object than in streamlined objects. In turbulent flow, resistance is proportional to the velocity squared, and increasing the speed of movement significantly increases the resistance (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Velocity of movement: Turbulence and resultant drag are created when movement reaches a critical velocity. Slow movement through the water produces little drag, and resistance is minimal. Buoyancy may be a more significant resistive or assistive property than viscosity during slow movement. However, when moving rapidly through the water, greater resistance can be encountered that is proportional to the speed of movement (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Hydrostatic pressure: The pressure exerted by the water at increasing depths accounts for the cardiovascular shifts seen with immersion and for the benefit of edema control Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). Pascal's law states that the pressure of a fluid is exerted on an object equally at a given depth (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Hydrodynamic exercises: These exercises are specifically related to changes of shape and based on the hydrodynamic principles of buoyancy, turbulence and metacenter (balance in water). When changes of shape are made an alteration in the balance of the body in water occurs due to the metacentric principle. When an object is immersed in water it is subjected to opposing forces gravity acting downwards and buoyancy acting upwards. When gravity or buoyancy are equal and opposite each other the body is balanced and in equilibrium (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Hydrotherapy in sports: Sports injuries are frequently treated by traditional land-based treatment. Water has the advantages of buoyancy which reduces the stress on weight-bearing joints. Where pain and muscle spasm are present, the affected part should be immersed in warm water so that the heating effects and supporting effects of the water will bring about relaxation (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). It is suggested that the warmth of the water may aid the circulation and assist the dispersal of hematoma and edema (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). Swelling may be further reduced by the pressure of water over the limb. Hydrostatic pressure increases with depth, suggesting that a swollen part should be exercised in a water depth level as possible (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007).

Deep water running: Deep water running or aquatic running consists of stimulated running in the deep end of the pool using a floating device (vest or belt) that maintains the head above water. The form of running in the water is patterned as closely as possible after the pattern used on land (Kinch et al, 2007).

Treating an athlete with ankle injury in the pool has a numerous advantages. Hydrostatic pressure may reduce swelling and a buoyancy dominated water depth allows exercise in standing on the affected leg to take place (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). Turbulence around the athlete requires their balance control and having the athlete standing on one leg can induce this more critical. A hydrodynamic exercise for the ankle would be that of sitting with the hips, knees and ankles at the right angle and the arms forward, the heels and toes rise (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). The warmth of the water plays a part in the physiological effects of immersion. The temperature of hydrotherapy pools should be maintained at 35°C. However, a range between 32°C and 34°C caters for many different conditions treated in the pool and is suitable during rehabilitation of sports injuries (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). Hydrotherapy had been widely used in physical therapy programs, especially when exercising on land with normal conditions of gravity is difficult and painful (Tapani et al, 2001; Mattacolar et al, 2002). The recent study, Kim et al (2010) reported the effect of aquatic (n=11) versus land-based (n=11) exercises during early-phase recovery from acute lower extremity ligament injuries in 22 elite athletes. All data were collected at baseline and at the 2^{nd} and 4^{th} week using a visual analog scale (VAS) for pain, static stability (overall stability index [OSI] level 5 and 3), dynamic stability using the test completion time (TCT), and percentage single-limb support time (%SLST). The results showed that both groups had VAS, OSI 5 and 3, and TCT decreased, with a concomitant increase in %SLST at the 2^{nd} and 4^{th} week ($P < 0.05$). No significant differences were detected between the 2 groups in any of the outcome measures. Researchers also suggested that for elite athletes with acute ligament sprains in the lower limb, aquatic exercises may provide advantages over standard land-based therapy for rapid return to athletic activities. Consequently, aquatic exercise could be recommended for the initial phase of a rehabilitation program.

2.12 Ankle taping

There are several studies on the effect of ankle taping to improve proprioceptive awareness (Robbins et al 1995; Simoneau et al, 1997; Spanos et a, 2008; Matsusaka et al, 2001). This effect is thought to involve the modulation of the neuromuscular system via cutaneous stimulation, leading to enhancement of muscle activity around the ankle (Robbin et al 1995). In 2001, Matsusaka et al studied the combination of ankle disk training and non-adhesive tape applied on the skin around the lateral malleolus in University students with functional ankle instability. Postural sway in this group decreased significantly after four weeks training compared with the control group who had only training with the ankle disk. The taping technique used in their study was "checkrein". Another common technique of ankle taping called "closed basket weave with a double heel lock" was used in the study of Spanos et al (2008). In their study, participants were 20 amateur athletes who involved in high contact sports and suffered from grade I or grade II ankle inversion sprain during their sporting activities. The purpose of study by Spanos et al was to explore the effect of taping on proprioception of the sprained ankle. The results indicated that there were statistically significant differences between taped and untapped conditions at each target angle (plantar flexion 10 degrees: p=0.01, plantar flexion 30 degrees: p=0.03, inversion 5 degrees: p=0.01, and inversion 20 degrees: p=0.01). This study suggested the adhesive taping could improve the ankle position awareness. Moreover, ankle taping could improve the mechanical stability by limiting of ankle movement. Lohrer et al (1999) studied the effect of Leukotape group (n=19) and 3M-tape group (n=20). Ankle taping on active range of motion in all normal ankle participants, the taping technique was applied using the 6 crossed dorsoventral and mediolateral straps and a figure-of-8 strips or called “basket weave and heel lock”. The results of their study indicated the baseline value (untaped ankle) of active inversion was 22 degrees (at 100%) for the Leukotape group and 23 degrees (at 100%) for the 3M-tape group. After applying the tape immediately, the active inversion movement of the ankle joint was reduced to 11 degrees (50%) in the Leukotape group and 11 degrees (48%) in the 3M-tape group. Comparing with the baseline (untaped), taping materials could induce changes of active inversion ($p<0.05$). The baseline values of active plantar flexion was 52 degrees (at 100%) for the Leukotape group and 53 degrees (at 100%) for the 3M-tape group. After applying the tape immediately, the active plantar flexion movement of the ankle joint was reduced to 33 degrees (63%) in the Leukotape group and 33 degrees (62%) in the 3M-tape group. After 20 minutes of exercise, inversion movement increased to 14 degrees (64%) in the Leukotape group and 15 degrees (65%) in the 3M-tape group. Plantar flexion movement increased to 50 degrees (96%) in the Leukotape group and 46 degrees (87%) in the 3M-tape group. The reduction in range of motion of plantar flexion was significant only immediately after taping ($p<0.001$). No statistically significant differences were detected between the two tape materials. In addition, no imparement of eversion movement when compared with baseline. Their study revealed that the ankle taping technique provides the limitation of functional motion, both in inversion and plantar flexion component.

CHAPTER III

MATERIALS AND METHODS

3.1 Research design

This study is a clinical trial investigating the effect of the six-week training program of ankle rehabilitation. The study was conducted in athletes with chronic ankle instability who had residual symptom after injuries aged between 18-25 years. The outcome measurements consisted of ankle functional ability, postural sway, ankle joint position sense, health status and the number of re-injury at baseline, immediately post exercise, and at follow up 3 months after exercise (Figure 3.1).

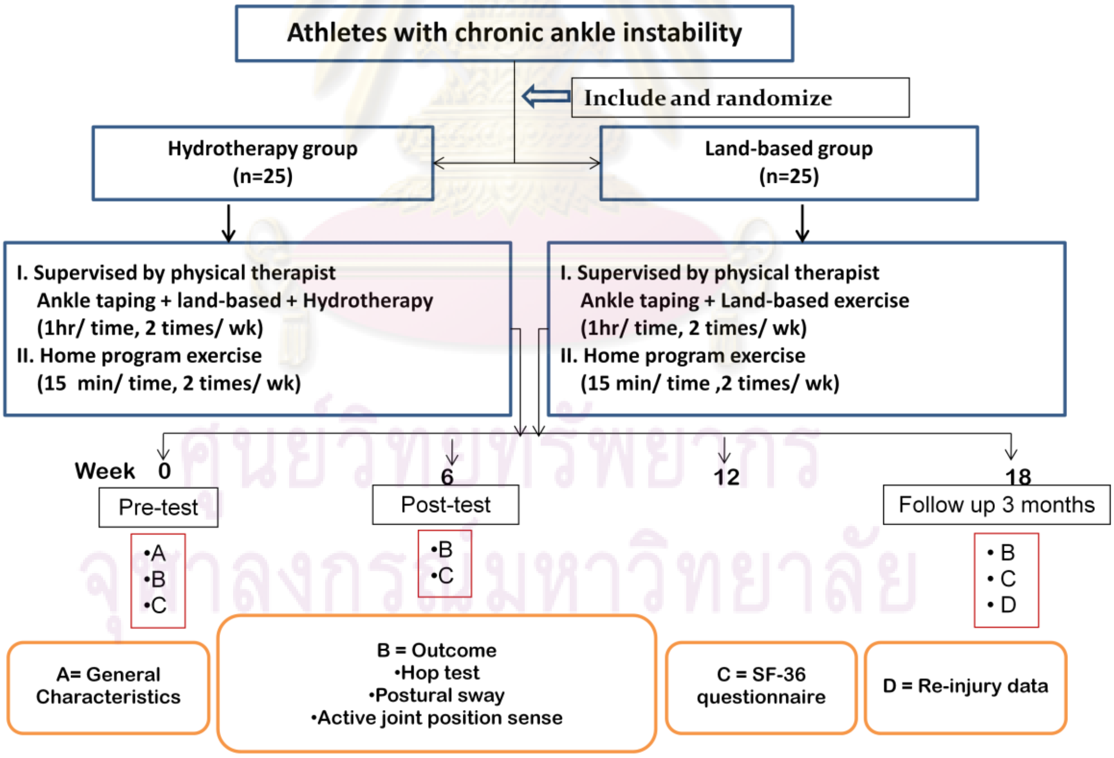


Figure 3.1 Experimental protocol

3.2 Participants

3.2.1 Sample size calculation

In 2008, Buchanan et al studied the functional performance test (single-limb hopping test) in participants with functional ankle instability (n=20) and in a healthy control group (n=20). Their results showed that average time taken in the single limb hopping test was 8.39±1.48 seconds and 6.82±1.25 seconds, respectively. The number of participants used in the study by Buchanan et al was chosen in calculating sample size in the current study.

α = 0.05 $Z_{\alpha/2} = Z_{0.05/2}$ = 1.96 (two tailed)

β = 0.10 $Z_{\beta} = Z_{0.01}$ = 1.28

n/group= $2(Z_{\alpha} + Z_{\beta})^2 \sigma^2/(X_1-X_2)^2$

X_1 = 8.39, X_2 = 6.82

σ^2 = pooled variance

$= (n_1-1)\, S_1^{\,2} + (n_2-1)\, S_2^{\,2} / n_1+n_2 - 2$

$= (10-1)\,(1.48)^2 + (10-1)\,(1.25)^2 / (10+10-2)$

= 1.876

n/group= $2(1.96+1.28)^2\,(1.876)/(8.39-6.82)^2$

= 15.98

= 16/group

To justification the drop-out in this study, 25 participants per group were recruited.

3.2.2 Participants and Randomization

Amateur athletes who had unilateral ankle inversion sprain during their sporting activities. They were recruited from various University sport clubs such as basketball, volleyball, soccer and rugby. In order for the participants to be included in this study, they had to meet the following criteria (Lentel et al, 1990; Konradsen et al, 2002; Demeritt et al, 2002; Buchanan et al, 2008) using a self-recording form (Appendix A);

1) have a recurrent unilateral inversion sprain at least one time within the past one year.

2) have the residual episodes of "giving way" or instability while walking/running in sports activities.

3) no report of either fracture or neurological disorders to the lower extremity.

4) no allergy to zinc oxide compound.

All participants were informed about the procedures of the study from the researcher and were required to sign in a written informed consent form (Appendix B). Participants had the right to interrupt their participation from the study at any time, and were informed that any publication of the results would be anonymous.

Randomized allocation of participants was performed with a simple random sampling technique. The twenty-five small pieces of white paper were written "hydrotherapy" and another 25 were written "land-based".

3.3 Instrumentation

1. A Kistler 2812-A13 force plate and BioWare® software analysis system (Kistler, Piezo-Messtechnik, NY, USA)
2. The Biodex system 3 Isokinetic dynamometer (Biodex Medical Systems Inc, Shirley, NY, USA)
3. The hopping course cover (ankle functional test)
4. Weight scale (Zepper, Qualified trading Co.,Ltd.)
5. Height scale
6. Rigid tape or non-elastic adhesive tape size 3.75 cm wide (Neosports tape, zinc oxide adhesive tape, Neoplast Co.,Ltd.)
7. Bandage scissors
8. Stop watch (Casio® module No. 2519, Casio computer Co.,Ltd. Japan)
9. Mini trampoline (FBT, Malaysia)
10. Foot ball (Adidas, Singapore)
11. Basketball (FBT, Thailand)
12. Volleyball (FBT, Thailand)
13. Medicine ball 4 kilograms
14. Foam pad (Thera-band, blue,)
15. Wobble board (BodyTrends; West Palm Beach, Florida)

16. Latex free exercise band (Thera-band ; Blue, Silver, Gold)
17. Bicycle ergometer (Marathon, Taiwan)

3.4 Outcome measurements

3.4.1 Independent variables

Two rehabilitation programs:

1) The new designed functional rehabilitation program which consists of ankle taping, land-based exercise, hydrotherapy, and home program exercise.

2) A rehabilitation program of combined with ankle taping, land-based exercise and home program exercise.

3.4.2 Dependent variables

1) Single-limb hopping time

2) The number of re-injury at 3 months follow up

3) Postural sway (static balance): CoP displancement, area of CoP

4) Active ankle joint position sense: RE, AE, VE

5) Health status (SF-36 questionnaire)

3.5 Measurements

3.5.1 Single-limb hopping test

The hopping course was constructed of hardwood and consists of eight squares (13-in x 13-in each square), four of which are even, one square has a 15 degrees increment, another square has a 15 degrees decrement, and two squares show a 15 degrees lateral inclination (Figure 3.2). The hopping course was placed on a rubber mat that was laid on a hard surface. The rubber mat prevented the course from moving while testing (Demeritt et al, 2002; Buchanan et al, 2008). Test-retest reliability of the single-limb hopping test was high (ICC=0.95, 95% CI (0.84-0.99)) (Appendix E).

Figure 3.2 Single-limb hopping course

The participants were asked to jump across this hopping course on one leg by touching each area once as quickly as possible without leaving the course. They were required to start in one direction, turn, complete the course in the opposite direction, and finish at the same starting point (Figure 3.3). The test result was quantified by the time (in seconds) taken to complete the course. Each failure adds an extra second to the time taken. All testing of hopping was performed with participants barefoot. Before testing, the researcher demonstrated the test and instructed the participant to practice it. Four practice trials were performed to familiarize themselves with the test. The single-limb hopping test was performed and repeated until five successful trials for each leg, with a rest of one minute between trials (de Noronha et al, 2006; Buchanan 2008; Yildiz et al, 2009).

Figure 3.3 Single-limb hopping test

3.5.2 Re-injury data measurement

After six weeks of the exercise program, participants were given a record form (Appendix D). They were requested to note a number of re-injury ankle sprains in the 3 months follow up phase post exercises. If there was any injury to individual participants, they were invited to visit the Physical Therapy Clinics and receive the standard treatment from the physical therapist.

3.5.3 Postural sway

The postural sway was measured using a Kistler force plate connected to a computer and using the BioWare® software analysis. The footplates contain electronic pressure transducers and are adjustable to allow for testing during one leg stance (Rose, Lee, Williams, Thomson, and Forsyth 2000). The rectangular area, which consists of maximum amplitudes of the anteroposterior (Ay) and mediolateral (Ax) sway (Matsusaka et al, 2001) and the area of center of pressure (CoP) also indicate in standard deviation (SD) and range (mm^2), signals from the Kistler amplifier (type 2812-A13) were transformed through a multichannel analogue to digital converter at a sampling rate of 100 Hz over a period of 30 seconds (Figure 3.4). Test-retest reliability of the postural sway test was fair (ICC=0.78, 95% CI (0.38-0.94)) (Appendix E).

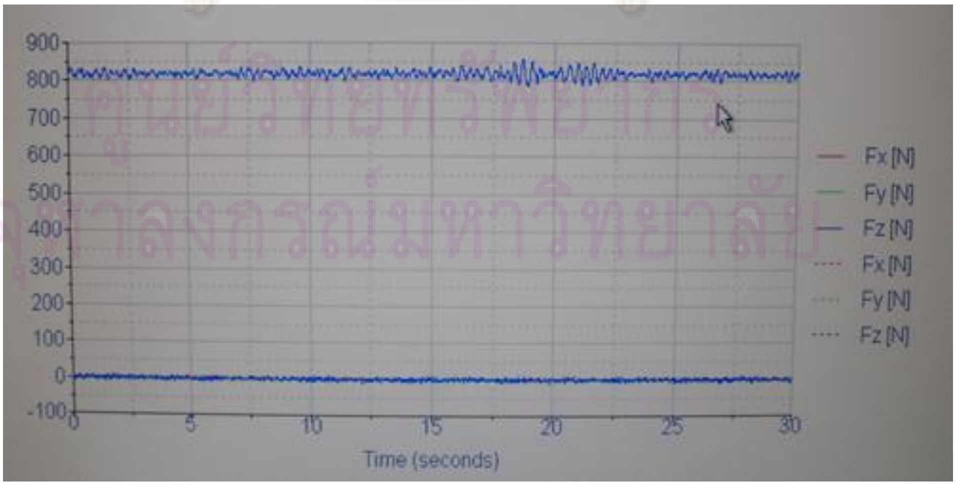


Figure 3.4 The BioWare® software analysis

In this test, the participants were asked to standing on one limb with their stance foot centered on the platform while their knees were slightly flexed (<10 degrees) with eyes open and arms folded across the chest for 30 seconds (Figure 3.5). They were instructed to lift the leg not being tested by bending the knee, and holding it in 90 degrees knee flexion. The test was performed three times at each examination period (week 0, week 6 and week 18). The best performance in which demonstrating the lowest variables of the center of pressure (CoP) in average displacement (mm), standard deviation (mm^2) and range (mm^2), was recorded for statistical analysis (Verhagen et al, 2005; Sefton et al, 2009).

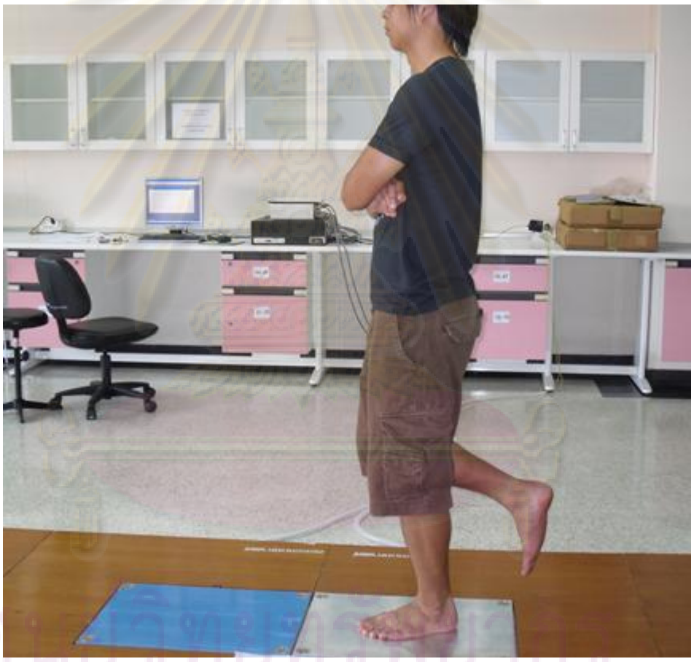
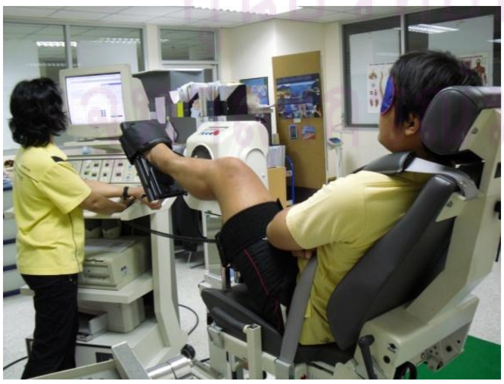


Figure 3.5 Postural sway test on left leg

3.5.4 Active ankle joint position sense testing

Testing was performed using the Biodex System 3 dynamometer at the position of 30 degrees ankle plantar flexion and 15 degrees ankle inversion. The barefoot being tested was placed in the mid plantar flexion – dorsiflexion position, and was secured with Velcro straps. The knee was placed at 90° flexion and the thigh was stabilized with a Velcro strap. Prior to the testing, the Biodex dynamometer was calibrated as a part of the regular equipment maintenance schedule for this testing device.

To initiate the test, the foot being tested was placed in the neutral (0 degrees) position. All participants were blindfolded in an effort to eliminate the contribution of visual cues to joint repositioning. To familiarize themselves with the testing device, participants were instructed to actively perform three repetitions of ankle movement ranging from maximal plantar flexion to maximal dorsiflexion. The test was started with the participants actively moving the ankle being tested at the velocity of 2 degrees/ second into the target position where the dynamometer was stopped at the 30 degrees ankle plantar flexion. Then they were required to concentrate on this position for 5 seconds with isometric hold. After that, the tested ankle was moved back to the opposite end range of motion at the velocity of 2 degrees/ second. The participants were then asked to actively reproduce the previous test angle of 30 degrees ankle plantar flexion (Figure 3.6 A). Six trials were performed. Following the first test, the similar testing protocol was used for the second test of active reproduction of active positioning at 15 degrees ankle inversion (Aydin et al, 2000; Beynnon et al, 2002) (Figure 3.6 B).


A


B

Figure 3.6 Active ankle joint position sense test at plantar flexion 30 degrees (A), and inversion 15 degrees (B)

The relative error (RE) was determined from the arithmetic difference between the target position and the response position, with positive errors representing overeshoot (a response with the ankle was in more extended position than the target position) and negative errors representing undershoot (a response with the ankle was in less extended position than the target position). The absolute error (AE) was determined as the difference between the target position and response position without reference to whether it constituted undershoot or overshoot. The variable error (VE) was determined the standard deviation from the mean of each set of six relative errors (Baker, Bennell, Stillman, Cowan and Crossly, 2002).

Test-retest reliability of the active ankle joint position sense at plantar flexion 30 degrees was fair (ICC=0.77, 95% CI (0.35-0.94)) and at inversion 15 degrees was also in the fair range (ICC=0.79, 95% CI (0.38-0.94)) (Appendix E).

3.5.5 SF-36 questionnaire

The SF-36 is a multi-purpose, short-form health survey with 36 questions. It yields an 8 subscales profile of functional health and well-being scores as well as psychometrically-based physical and mental health summary measures and a preference-based health utility index (Songsakon and Silpakit, 2007). The 8 health concept subscales consist of physical functioning, role physical, bodily pain, general health, vitality, social functioning, role-emotional and mental health. Score in each subscale can vary from 0 to 100, with higher scores representing more desirable health states (Binkley et al, 1999) (Appendix C).

3.6 Procedures

3.6.1 Preparation

The researcher gained clinical experience in applying several ankle taping techniques and rehabilitation programs for the injured athletes both in sports clinics and on field in various sport events.

The most important part in this study is the new functional rehabilitation program using hydrotherapy as a part of the intervention designed for athletes with CAI and residual symptoms. For this reason, the researcher has reviewed details of previous conservative treatments and rehabilitation programs of ankle sprain before designing the proper program. Each parameter outcome was standardized and the intra-tester reliability of single-limb hopping test, postural sway and ankle joint position sense measurements were conducted to ensure that all tests produce reliable results (Appendix E). The research proposal was submitted for research ethical approval from the Thammasat University Ethics committee (014/52, Appendix F).

3.6.2 Data collection

Prior to testing, participants were informed of the scope of the test. They were asked to avoid medication, coffee and any vigorous activity on the day of testing as well as the day before. The researcher contacted potential athlete participants from the University sports clubs. The athletes were approached and invited to participate in this study. Those who did not meet the inclusion criterion were excluded. The remaining athletes were recruited into the study. The simple random sampling technique was used to randomize the athletes into two groups which were hydrotherapy group and the land-based group.

The participants in the hydrotherapy group received ankle taping, land-based and hydrotherapy exercise supervised by a physiotherapist 2 times/ week, for 6 weeks. The participants in the land-based group received the same program with the hydrotherapy group, however, without hydrotherapy exercise. Both groups received the manual guidelines of home program exercise in which they were required to take 2 times/ week, for six weeks (Appendix H). This study was conducted at the Physical

Therapy and Hydrotherapy Clinic of the Faculty of Allied Health Sciences, Thammasat University (Rangsit Center).

Each participant was asked to attend the laboratory room, where the study was performed (Room 305, 307 at the Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University (Rangsit center) at pretest, immediately posttest and at the three months follow up. After the participants gave their consent (Appendix B), they were randomized into three testing conditions (single-limb hopping test, postural sway and ankle joint position sense). For the ankle joint position sense tests, the tests were randomized into two angles test (inversion 15 degrees degrees and plantar flexion 30) before performed the tests. The randomization was performed to reduce the bias.

3.6.3 Follow up

The follow up was at 3 months after the 6 weeks exercise program. Participants were informed to record the number of the re-injury ankle sprains episodes on a self-recording form (Appendix D) and brought it to the researcher on the day of follow up test. This form was given to participants on the day of posttest (week6).

3.7 Intervention

The intervention in this study consists of two concurrent exercise programs in 6 weeks.

Exercise I: supervised by the physical therapist 2 times/ week (1hr/ time) for 12 times in 6 weeks. All participants were asked to attend the Physical therapy and hydrotherapy clinic at the Ratchasuda building, Faculty of Allied Health Sciences, Thammasat University (Rangsit Center). Participants were taped with the heel lock technique on the injured ankle by the same physical therapist. After that, they were participated in the hydrotherapy group or land-based group according to their assigned group (Appendix G).

Exercise II: home program exercise 2 times/ week (15 min/ time) for 12 times in 6 weeks. Participants were given the manual guidelines of self ankle exercise (Appendix H).

3.7.1 Ankle taping

The taping procedure chosen in this study was the heel lock technique, using the tape applied directly to the skin. The precise instructions of Karlsson (2007) and Macdonald (1994) for the selected taping application technique were applied to all participants. Additionally, for consistency, the same physical therapist performed ankle taping.

Heel lock technique (Macdonald, 1994)

Indication: ankle inversion sprain.

Function: to support lateral ligaments without limiting motion unnecessarily.

Position: sitting on bed with foot and ankle over edge. Injured foot was set in the neutral position.

Materials: 2 strips of nonelastic tape size 3.75 cm (1.5 inch) wide, adhesive spray, and bandage scissors.

Protocol: To perform the lateral heel lock, the first strip of nonelastic tape is started proximally to the lateral malleolus. It should be angled downward towards the posterior aspect of calcaneous and then pulled tautly upwards, covering calcaneous laterally. It continues angled inferiorly across the medial longitudinal arch, then diagonally and posteriorly across the lateral aspect of the heel. Then, continued taping medially over the back of the Achilles tendon, angled upwards, and finishes the tape parallel to the starting point. The second strip is started the same technique but move the starting point laterally to the first strip.

Check function: Is it supportive or not too tight? Asking this question while the participant walking on the floor (Figure 3.7).

Figure 3.7 Ankle taping (heel lock technique) on the left leg

3.7.2 Lower extremity stretching

All participants received the same land-based program for warm up and cool down static muscle stretching for 10 minutes consisting of lower back muscles, gluteus muscles, hip flexor muscles (Figure 3.8 A), hamstring muscles, and calf muscles (Figure 3.8 B) (hold 10 seconds/ time, 10 times/ position).

A

B

Figure 3.8 Lower extremity stretching, hip flexors (A), and calf muscles (B)

3.7.3 Hydrotherapy exercise program

Hydrotherapy exercise session was performed in the indoor hydrotherapy pool (size 6 m x 10 m) and the water depth was separated into two levels:

1) stable platform (depth 0.80 m)

2) movable platform (depth 1.70 m)

The temperature of the pool was maintained at 33º C - 34º C (Figure 3.9) at all time.

Figure 3.9 Indoor hydrotherapy pool (size 6 m x 10 m)

In the hydrotherapy exercise program, viscosity, buoyancy, turbulence and participant's own body weight provided resistance, as did the adjunct use of different aqua equipment, such as belt, aqua noodle and foam dumbbell. The program exercise consists of 1) Warm up; lower extremity stretching, 2) Aerobic exercise, 3) Balance training, 4) Strengthening exercise, 5) Functional skills and 6) Warm down; lower extremity stretching (Figure 3.10) (Appendix G).

Figure 3.10 Hydrotherapy exercise program: static balance training (A), dynamic balance training (B), functional skills and throw/ catch a ball (C), jumping and throw/ catch a ball (D), stepping with a ball (E), and deep water running (F)

3.7.4 Land-based exercise program

In the land-based exercise program, the resistance was the participant's own body weight, a rubber band, or weight machine (leg press, leg curl). The program exercise consists of 1) Warm up; lower extremity stretching, 2) Aerobic exercise, 3) Balance training, 4) Strengthening exercise, 5) Functional skills and 6) Warm down; lower extremity stretching (Figure 3.11) (Appendix G).

Figure 3.11 Land-based exercise program: static balance training on foam (A), dynamic balance training on mini trampoline (B), stationary bicycling (C), rubber-band exercise (D), functional skills in rugby (E), and functional skills in basketball (F)

3.7.5 Home program exercise

In the home program exercise, the resistance was the participant's own body weight. The program exercise consists of 1) Toe raises/Heel walking, 2) Isometric ankle (Wrestling) and 3) One leg standing on the towel (uneven surface) with slightly flexed knee (Appendix H).

3.8 Statistical analysis

Baseline characteristics were compared using independent t tests for continuous variables and Chi-square tests for categorical variables. Effects of the 6 week interventions were performed utilizing a mixed design two–factor [treatment group (2) x time point (3)] analysis of variance to analyze the dependent variables related to single-limb hopping test, postural sway, ankle joint position sense and SF-36. Independent t-test procedures were also adopted for post hoc comparisons with a Bonferroni correction applied (alpha = 0.05). Where Mauchly's test was used to determine sphericity, the Greenhouse-Geisser epsilon was used to provide a conservative test of ANOVA main effects and interactions. Fisher's exact test was used to determine the re-injury data post training 3 months. All statistical procedures were performed using SPSS (version 17) and a probability level of <0.05 was adopted throughout.

CHAPTER IV

RESULTS

Fifty participants were recruited for the study participation. Twenty-five participants (23 male, 2 female) were randomly assigned into the hydrotherapy group, and 25 participants (23 male, 2 female) were randomly assigned into the land-based group. In the hydrotherapy group, 24 of the 25 participants (96%) completed the protocol. The only dropout was due to inability to make the time commitment needed for participation throughout the study. In the land-based group, 23 of the 25 participants (92%) completed the study, with 2 dropouts from initial of 6 weeks training to the end of 3 months follow up period because of transportation problems. Data off 47 participants completed all training sessions as well as pretest, posttest and follow up test were included in analysis. There were no adverse events reported during this study.

4.1 Characteristics of participants

The demographic information for each group is presented in Table 4.1. Independent t test revealed no significant difference among the demographic data between groups for age, gender, height, weight, %BMI, experience of playing sports and injury side.

The Chi-square test for the residual symptoms of the participants is presented in Table 4.2. There was no significant difference between the hydrotherapy group and the land-based group for instability, pain, weakness and swelling.

Table 4.1 Characteristics of participants

Characteristics	Hydrotherapy group (n=24)	Land-based group (n=23)
Age (yrs)	20.79±1.89	20.04±1.22
Gender (male/ female)	22/ 2	21/ 2
Height (cm)	172.69±5.61	173.87±7.49
Weight (kg)	71.25±9.14	77.37±16.03
% BMI (kg/m^2)	23.73±2.89	25.65±4.54
Experience of playing sports (yrs)	8.50±4.30	7.39±3.65
Injury side (Left/ Right)	7/ 17	9/ 14

Mean ± SD, significant difference * $p<0.05$

Table 4.2 Residual symptoms of participants

Residual	Hydrotherapy group (n=24)		Land-based group (n=23)	
symptoms	No. of participants	Percentage (%)	No. of participants	Percentage (%)
Instability	21	87.5	20	87
Pain	11	45.8	12	52.2
Weakness	5	20.8	2	8.7
Swelling	4	16.7	6	26.1

Data in the table are the number of participants and percentage (%)

The number of participants and percentage grouping along with the kind of sports activities are shown in Table 4.3. The contact sports consisted of rugby, football, basketball, taekwando and softball, while the non-contact sports consisted of volleyball and swimming. The Chi-square test for the kind of sports showed no significant difference between the hydrotherapy group and the land-based group. Both groups had the higher number of the athletes in contact sports than in non-contact sports.

Table 4.3 Kind of sports

Kind of sports	Hydrotherapy group (n=24)		Land-based group (n=23)	
	No. of participants	Percentage (%)	No. of participants	Percentage (%)
Rugby	12	50	11	47.8
Football	7	29.2	4	17.4
Basketball	3	12.5	5	21.7
Taekwando	-	-	2	8.7
Softball	-	-	1	4.3
Volleyball	1	4.2	-	-
Swimming	1	4.2	-	-

Data in the table are the number of participants and percentage (%)

4.2 Ankle functional ability

In hydrotherapy group, there was a significant difference in the single-limb hopping test between pretest and posttest ($p<0.001$) and pretest and follow up test ($p<0.001$) in Table 4.4. In land-based group, there was a significant difference only between pretest and follow up test ($p=0.05$). Time taken in the single-limb hopping test decreased after participating in either the hydrotherapy group or land-based group. However, there was no statistical significant difference between the hydrotherapy group and the land-based group.

Table 4.4 Comparison of the single-limb hopping test between the hydrotherapy group (A, n=24) and the land-based group (B, n=23) at pretest, posttest and follow up test

Parameters	Groups	Pretest	Posttest	Follow up test	P value within group	P value between group
Single-limb hopping test (seconds)	A	7.30±1.37	6.14±0.89	5.92±0.83	<0.001 ** a, b	0.173
	B	7.40±1.56	6.77±1.25	6.48±0.92	0.05 *b	

Mean ± SD, using 2 - way mixed ANOVA, Post hoc analysis (Bonferroni)

Significant differences from test * $p<0.05$, ** $p<0.001$

a = significant difference between pretest and posttest, $p<0.05$

b = significant difference between pretest and follow up test, $p<0.05$

c = significant difference between posttest and follow up test, $p<0.05$

4.3 The number of re-injury

The re-injury data of ankle sprain are shown in Table 4.5. A total of 25.5% of all participants suffered from recurrent ankle sprain while participating in sports activities during the 3-month follow up period. In the hydrotherapy group, 4 out of 24 participants (16.7%) sustained a re-injury. There were 8 out of 23 participants (34.8%) sustained a re-injury in the land-based group. The percentage of participants suffered from the re-injury in the hydrotherapy group was lower than that in the land-based group, but this difference was not significant.

Table 4.5 Re-injury data at 3 months after exercise

Re-injury	Hydrotherapy group (n=24)	Land-based group (n=23)	Total (n=47)
Yes	4 (16.7%)	8 (34.8%)	12 (25.5%)
No	20(83.3%)	15 (65.2%)	35 (74.5%)
Total	24 (100%)	23 (100%)	47 (100%)

Fisher's Exact Test (p=0.193)

The data analysis of re-injury in 12 participants who had re-injury ankle sprain in 3 months after exercise is shown in Table 4.6. For 4 participants in the hydrotherapy group who experienced re-injury, two were playing rugby, one played basketball, and one played volleyball. For 8 participants in the land-based group who experienced re-injury, two played rugby, four played basketball, and two played football. All re-injury occurred during games or practices.

Table 4.6 The detail of re-injury at 3 months after exercise

Data			Hydrotherapy group (n=4)		Land-based group (n=8)	
			No. of participants	Percentage (%)	No. of participants	Percentage (%)
1.	Resting day	Less than 7 days	4	100	7	87.5
		More than 7days	-	-	1	12.5
2.	Ankle re-injury	Games	3	75	4	50
		Practices	1	25	4	50
3.	Ankle support	With ankle support	-	-	3	37.5
		Without ankle support	4	100	5	62.5
4.	Treatment	Rest	2	50	4	50
		Ice compression	-	-	3	37.5
		PT clinic	2	50	1	12.5

Data in the table are the number of participants and percentage (%)

PT = physical therapy

4.4 Postural sway

The results of all variables of the center of pressure (CoP) are shown in Table 4.7. Increase in the displacement and area of CoP represents a less stable stance. There was no statistically significantly difference in either the mediolateral (Ax) or anteroposterior (Ay) displacement between groups (the hydrotherapy group and the land-based group) and within group at pretest, posttest, and follow up test. The data analysis of the standard deviation (SD) of the total area of CoP and range of CoP did not show a statistical significant difference comparing between group exercises and within group at pretest, posttest, and follow up test.

Table 4.7 Comparison of postural sway between the hydrotherapy group (A, n=24) and the land-based group (B, n=23) at pretest, posttest and follow up test

Parameters	Groups	Pretest	Posttest	Follow up test	P value within group	P value between group
CoP displacement (ML) (mm)	A	-0.38±2.08	-0.25±2.01	0.81±4.41	0.338	0.698
	B	-0.25±2.02	0.17±2.22	0.19±2.27	0.218	
CoP Displacement (AP) (mm)	A	-1.28±3.98	0.39±2.70	-0.72±4.36	0.291	0.742
	B	-0.70±3.59	-0.23±2.74	-1.27±4.87	0.655	
CoP area SD (mm^2)	A	7.19±1.38	7.74±2.39	7.53±2.21	0.641	0.201
	B	8.39±2.64	8.08±1.95	7.82±1.85	0.677	
CoP area Range (mm^2)	A	39.95±8.20	44.16±10.94	41.26±11.49	0.357	0.092
	B	48.32±18.28	45.51±10.94	44.31±12.13	0.634	

Mean ± SD, using 2 - way mixed ANOVA, Post hoc analysis (Bonferroni)

ML = mediolateral displacement (Ax), + value is medial, - value is lateral

AP = anteroposterior displacement (Ay), + value is anterior, - value is posterior

CoP = center of pressure, SD = standard deviation

4.5 Active ankle joint position sense

The data of angle of error obtained from active joint position sense tests are presented in Table 4.8. Comparing between the hydrotherapy group and the land-based group, there were only statistical significant differences in the relative error (RE) and the variable error (VE) at plantar flexion 30 degrees (p=0.018 and p=0.023, respectively).

Table 4.8 Comparison of active ankle joint position sense between the hydrotherapy group (A, n=24) and the land-based group (B, n=23) at pretest, posttest and follow up test

Parameters	Groups	Pretest	Posttest	Follow up test	P value within group	P value between group
IV 15° RE (degrees)	A	1.81±2.59	1.77±2.11	1.36±1.93	0.741	0.894
	B	2.01±2.84	1.59±1.91	1.51±1.39	0.704	
IV 15° AE (degrees)	A	3.56±1.48	3.12±1.66	2.71±1.61	0.184	0.385
	B	3.66±1.91	2.59±1.71	2.34±1.04	0.072	
IV 15° VE (degrees)	A	3.46±1.17	2.71±1.34	2.88±1.46	0.135	0.806
	B	3.66±1.64	2.61±2.03	2.56±1.66	0.002 *b	
PF 30° RE (degrees)	A	-0.20±2.15	-0.42±1.27	0.06±1.56	0.623	0.018 †
	B	0.28±1.91	0.58±1.28	0.88±1.68	0.467	
PF 30° AE (degrees)	A	3.02±1.78	2.13±1.16	2.22±1.15	0.059	0.056
	B	2.35±1.17	1.78±0.78	1.89±1.21	0.173	
PF 30° VE (degrees)	A	3.33±2.00	2.70±1.52	2.29±1.29	0.089	0.023 †
	B	2.83±1.56	2.05±0.95	1.63±0.82	0.002 * b	

Mean ± SD, using 2 - way mixed ANOVA, Post hoc analysis (Bonferroni)

Significant difference from group † p<0.05

Significant differences from test * p<0.05

a = significant difference between pretest and posttest, p<0.05

b = significant difference between pretest and follow up, p<0.05

c = significant difference between posttest and follow up, p<0.05

RE = relative error, AE = absolute error, VE = variable error

Within-group differences (time-effect) were compared among pretest, posttest and follow up test 3 months after exercise. There were only differences among tests in the land-based group: variable error (VE) of active ankle joint position sense at ankle inversion 15 degrees and ankle plantar flexion 30 degrees between pretest and follow up test (p=0.002 and p=0.002, respectively).

4.6 Health status

The data analysis of health status using the SF-36 questionnaire was shown in Table 4.9. There was no significant difference between the hydrotherapy group and the land-based group in all 8 items of the health status. However, within-group (time-effect) comparisons showed a significant difference in physical functioning between pretest and follow up test (p=0.039), and bodily pain between pretest and follow up test (p=0.009) in the hydrotherapy group.

Table 4.9 Comparison of the SF-36 questionnaire (8 items) between the hydrotherapy group (A, n=24) and the land-based group (B, n=23) at pretest, posttest and follow up test

Items	Groups	Pretest	Posttest	Follow up test	P value within group	P value between group
1.Physical functioning	A	78.08±22.55	87.50±10.00	86.96±9.86	0.039 ^{*b}	0.915
	B	81.74±14.11	87.17±10.64	86.59±59.93	0.211	
2.Role physical	A	65.29±34.37	72.04±36.88	79.17±31.85	0.382	0.626
	B	64.13±34.40	81.52±30.36	81.52±31.28	0.113	
3.Bodily pain	A	51.63±22.84	60.25±17.62	68.75±16.99	0.009 ^{*b}	0.697
	B	59.39±19.09	61.44±20.61	64.56±14.62	0.629	
4.General health	A	67.42±12.49	72.79±15.55	70.88±19.28	0.503	0.961
	B	68.48±14.35	69.70±14.11	73.43±15.58	0.495	
5.Vitality	A	57.88±10.45	63.33±14.19	62.92±16.15	0.319	0.456
	B	62.83±14.45	60.65±16.33	68.26±14.89	0.226	
6.Social functioning	A	67.06±22.32	76.56±19.96	75.00±19.15	0.235	0.522
	B	75.48±18.38	78.44±19.53	72.83±18.71	0.603	
7.Role emotional	A	56.94±43.38	63.89±36.67	75.00±34.40	0.265	0.415
	B	63.77±36.12	72.35±35.77	79.71±31.37	0.299	
8.Mental health	A	66.83±8.62	70.50±12.25	69.00±13.61	0.553	0.841
	B	68.52±15.22	68.96±16.40	70.78±14.14	0.868	

Mean ± SD, using 2 - way mixed ANOVA, Post hoc analysis (Bonferroni)

Significant differences from test * $p<0.05$

a = significant difference between pretest and posttest, $p<0.05$

b = significant difference between pretest and follow up, $p<0.05$

c = significant difference between posttest and follow up, $p<0.05$

CHAPTER V

DISCUSSION AND CONCLUSION

The purpose of this study was to determine the immediate and long term effect of combined ankle taping and land-based exercise with and without hydrotherapy on ankle functional ability, the number of re-injury ankle sprains, postural sway, active ankle joint position sense, and health status.

5.1 Characteristics of participants

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 muscles weakness. However, all of them were physically active, college-aged and still playing sports activities in their teams.

The demographic data have shown no significant difference between the hydrotherapy group and the land-based group for age (years), height (cm), weight (kg), body mass index (kg/ m^2), experience of playing sports (years) and residual symptoms. It could be implied that any significant difference of findings in this study may not be a result of characteristics of participants in both groups. Most participants involved in high contact sports in accordance to reports in previous studies of athletes with ankle instability in rugby (Gibbs, 1993; Anadacoomarasamy et al, 2005), football (Giza et al, 2003; Woods et al, 2003; Kofotolis et al, 2007), and basketball (Starkey, 2000; McKay et al, 2001; Cumps et al, 2007; Kofotolis et al, 2007).

5.2 Ankle functional ability

There was no significant difference of the single-limb hopping performance between the hydrotherapy group and the land-based group. These are in accordance with previous research findings either comparing between chronic ankle instability and the healthy control group (Demeritt et al, 2002; de Noronha et al, 2007) or comparing between the injured and uninjured side of participants with unilateral ankle instability (Munn, 2002; de Noronha et al, 2007). The single-limb hopping test, one of the functional performance tests, is a very complex task that allows multiple joints and structures to assist in such a movement (Demaritt, 2002). Potential reasons for a lack of significant difference in the current study may be that minimal proprioceptive deficits were present in people with chronic ankle instability (de Noronha 2007) or that these deficits were present but compensated by using feedback from other joints and structures while testing the single-limb hopping course. The functional rehabilitation program implemented in the current study consists of single-leg and double-leg jumping while throwing and catching the ball, and stepping and running as fast as possible in the functional skills performed both in the hydrotherapy group and the land-based group. The similarity in this part of training program could account for no significant difference of the single-limb hop test between the hydrotherapy group and the land-based group.

The finding in this study showed that participants had improved ankle functional ability as demonstrated by the single-limb hopping performance immediately after participating in the 6 weeks rehabilitation program and at 3-month follow up both in the hydrotherapy group and the land-based group. Similarly, Sekir et al (2007) determined the effect of 6 weeks isokinetic training in recreational athletes with functional ankle instability. Time taken in the single-limb hopping test in the injured side was significantly shortened following exercise at posttest (10.44±3.56 seconds) as compared to the pretest (13.27±6.27 seconds) ($p<0.001$). However, their study showed longer time taken in the test when comparing to the current study in both groups whereby mean time taken in the hydrotherapy group at pretest was 7.30±2.37 seconds and posttest was 6.14±0.89 seconds, the land-based group at pretest was 7.40±1.56 seconds and posttest was 6.77±1.25 seconds. The improvement of the ankle functional ability after 6 week exercise and at 3-month follow up both in the hydrotherapy program and land-based program might be due to two reasons. Firstly, time taken in the current study was performed by amateur athletes who was still playing sports activities which could be higher performance than recreational athletes in the study by Sekir et al (2007). Secondly, there are some differences in exercise protocols. While, the functional rehabilitation program used in the current study consisted of several exercises (hydrotherapy, land-based exercise and home program) combined with ankle taping, the previous study used only the isokinetic exercise at the angular velocity of 120 degrees/ second in inversion/ eversion concentric mode. Their exercise session was conducted 15 repetitions/ set, 3 sets/ time and repeated 3 times/ week for 6 weeks.

Accordingly, Buchanan et al (2008) compared functional performance test (single-limb hopping test and single-limb hurdle test) between physical active players (recreational level participating in sports at least twice a week) with functional ankle instability and the healthy control group. The single-limb hopping test was not found to be difference. However, when the functional ankle instability group was further stratified into those who reported instability (FAI-S) (8.39±1.48 seconds) and those who did not report instability (FAI-NS) (6.82±1.25 seconds) a significant difference was found between the FAI-S group and the others (p=0.01). Buchanan et al (2008) investigated further in the standard deviations (SDs) of hopping time and found that these values in the FAI-S and FAI-NS group were noticeably larger than those in the control group. The larger SDs of hopping time reflected the range of disability presented in participants with functional ankle instability (Buchanan, 2008). In the current study, the standard deviation of the single-limb hopping time at posttest and follow up test were noticeably lower than those at pretest, both in the hydrotherapy group and the land-based group exercise. This might be used to indicate ankle functional performance improved after participating in the functional rehabilitation implemented in the current study.

The functional rehabilitation program in the current study consists of general exercise and specific exercise combined with ankle taping, with (the hydrotherapy group) and without hydrotherapy (the land-based group) for athletes with chronic ankle instability who have residual symptoms. Both groups also had training on various uneven surface which may improve sensorimotor control in single-limb hopping tasks. In 2002, Riemann and Lephart reviewed the sensorimotor system related to functional joint stability. It is critical for effective motor control to have accurate sensory information concerning both the external and internal environment. The hopping test used in the current study was designed to measure single limb motor control on uneven surfaces, and has been shown to differentiate stable from unstable ankle (Aydin et al, 2000; de Noronha et al, 2007; Yildiz et al, 2009). The test involves the time taken to hop barefoot around a course of 4 levelled squares and the other 4 squares inclined 15 degree in different directions (2 in lateral slope, 1 incline and 1 decline). Participants were instructed to complete the course as fast and as accurately as possible, keeping the foot inside each square ankles (de Noronha, 2006; Buchanan, 2008). During goal-directed behavior, such as hopping course, provisions must be made to adapt the motor program for hopping to changes occuring in the external environment (uneven surface of square) and the internal environment (change in center of mass because of the additional load). These provisions are stimulated by sensory triggers occurring in both feedback (mechanoreceptor detection of altered support surface) and feedforward (anticipating center of mass change from previous experience) manners (Riemann, 2002).

The finding in the current study indicated that participants had improved ankle functional ability as demonstrated by the single-limb hopping test immediately and in long term 3 months after participating in the rehabilitation program either in the hydrotherapy group or the land-based group.

5.3 The number of re-injury

Twelve participants reported recurrent ankle sprain during 3-month follow up. All of them had one re-injury. The result revealed that no significant difference of re-injury between the hydrotherapy group (16.7%) and the land-based group (34.8%). The detail of re-injury at 3 months after exercise in 12 participants is presented in Table 4.6. All of them were participating in high contact sports. In the hydrotherapy group, all 4 participants had a rest less than 7 days before coming back to their sports teams. This could imply that all of them might have mild grade of ankle sprain. Three out of 4 had re-injury in games, while only one had re-injury during practices. All of them did not wear the ankle support while recurrent ankle sprain being occurred. For the treatment after re-injury ankle sprain, 2 out of 4 participants were only rest and the others visited the physical therapy clinic and received the standard treatment program for acute ankle sprain. In the land-based group, 7 out of 8 participants had a rest less than 7 days but one participant needed rest longer than 7 days. These data might be used to indicate mild to moderate severity of recurrent ankle sprain in these participants. Four participants had re-injury in games, and another four had re-injury in practices. Three out of 8 participants were having ankle support on while having the re-injury, but another 5 participants did not wear ankle support during re-injury episode. After re-injury, half of 8 participants only rested without any treatment. Only one used ice compression on injured ankle by himself and 3 out of 8 visited the physical therapy clinic and received the standard treatment program for acute ankle sprain.

The percentage of recurrent ankle sprain in the current study (16.7%) was higher than the training group(3%) of the study by Holme et al (1999). On the contrary, the percentage of recurrent ankle sprain in the current study was lower than the report of (42%) re-injury in the study by Anandacoomarasamy et al (2005). Nevertheless, there were differences of the characteristics of participants. In the current study, participants were having chronic ankle instability with residual episodes whereas participants in the study by Holme et al (1999) were recreational athletes who suffered from acute ankle sprain without prior complaints of ankle joint instability. Anandacoomarasamy et al (2005) also studied in participants with acute ankle inversion injuries. The difference in participants' characteristics led to inappropriateness to directly compare the percentage of re-injury ankle sprains.

The rehabilitation program implemented in the current study was also different from the program used by Holme et al (1999). In the current study, both groups received the combined program of land-based exercise and ankle taping with or without hydrotherapy as well as additional, home program exercise twice weekly for 6 weeks. In the study by Holme et al (1999), 24 participants in the treatment group participated in a supervised physical therapy program (1 hour, twice weekly), which included comprehensive various balance exercises with both legs on a balance board, figure of eight running, standing on the outside and inside of the feet with eyes open and eyes closed. Their 42 participants in the control group only received the standard emegency room informantion. The difference in rehabilitation program between studies could be accounted for different results. In the 3-month follow up period, participants in the current study could still participate in their teams which might lead to higher risk of re-injury ankle sprain. High recurrent episode of ankle sprain usually occurred in the high level of activity. In 2009, Haraguchi et al studied the influence of activity level on outcome of treatment of lateral ankle rupture. Their study was a 2-year prospective cohort study in patients who were suffering severe ankle sprain in the hospital. Four groups of participants were classified by pre-injury activity level: strenous, moderate, light, and sedentary activity. Their findings showed statistically significant higher percentage of reinjury ankle sprains in the group with strenous activtiy level (32.4%) than other activity level groups (p=0.003). Haraguchi et al (2009) also suggested that the treatment strategy for acute severe ankle injury should be determined according to the patient's pre-injury activity level. Functional treatment provided the quickest return to atheletic activity for patients with a high level of activity pre-injury. Findings from Haraguchi et al's study supported the finding of the current study. Participants in the current study in both groups were classified into strenous activitiy, which includes jumping, pivoting, hard cutting (rugby, football, basketball) according to the International Knee Documentation Committee (IKDC) standard (Hefti, Muller, Jakob, and Staubli, 1993) and it is reasonable to discover high number of re-current ankle sprain in both groups in the current study.

5.4 Postural sway

There was no significant difference of any outcomes indicating postural sway either between the hydrotherapy group and the land-based group or between time measures within the same group as presented in Table 4.7. Postural sway test during single limb stance has frequently been used to assess sensorimotor function in individuals who have chronic ankle instability (Hertel, 2008). The current study detailed the components of static balance training in water using the turbulence flow from wall jet to perturb static balance while single-legged standing with ankle taping. Similarly, static balance training on land was performed using uneven surface such as mini trampoline, foam and wobble boards to perturb static balance while single-legged standing with ankle taping. The training was performed with eyes open and eyes closed progressing from 30 seconds to 60 seconds in both groups. In the hydrotherapy group, the progression was also made by changing water level from chest depth to waist depth. The ability to maintain balance during standing on a single-leg depends on the integrity of the visual, vestibular, and somatosensory system (Brody and Dewane,2003). The similarity in this part of training program in both groups could attribute to no significant difference in all balance variables between the hydrotherapy group and the land-based group in the current study.

Shorter CoP displacement indicated better postural sway. Sefton et al (2009) compared the CoP displacement between the chronic ankle instability (CAI) participants (n=22) and healthy control participants (n=21). Their data presented ML displacement of CoP was -3.22±2.6 mm in the CAI group and 0.78±4.71 mm in the control group (p=0.002), AP displacement of CoP was 0.88±7.33 mm in the CAI group and -3.14±5.43 mm in the control group (p=0.056). Interestingly, the data of the healthy group in the study by Sefton et al was in the same range with the current study. The possible cause of this similarity could be due to unchanged postural control of participants in the current study given that they were training with their teams. However, afferent fibers of most joint mechanoreceptors have characteristics of group II and III nerve fiber types (Michelson and Hutchins, 1995) . Receptors of group II, III units are less sense to stretch than muscle spindles and the Golgi Tendon Organ (Michelson, 1995). They may still be able to respond despite damaged ligament.

5.5 Active ankle joint position sense

The current study found that the relative error (RE) and the variable error (VE) for active ankle joint position sense tests at plantar flexion 30 degrees were statistically significantly different between the hydrotherapy group and the land-based group as presented in Table 4.8. In the current study, the relative error at plantar flexion 30 degrees was in a negative value in pretest and posttest indicating participants' bias to undershoot the testing-position angle. This is in accordance with the finding of Willems et al (2002) which compared exact error and the absolute error of active joint position sense between the instability group (n=10) and the healthy group (n=53) of physical education students. Their results indicated that the exact error of maximal active inversion minus 5 degrees in the instability group and the control group was -2.96±2.96 degrees and -0.68±3.21 degrees, respectively ($p=0.012$), and the absolute error of maximal active inversion minus 5 degrees in the instability group and the control group was 3.89±2.07 degrees and 3.06±2.05 degrees, respectively ($p=0.161$). Measuring joint position sense requires a precise method with accurate registration of limb positioning and the elimination of input from other sources (Konradsen, 2002). Sekir et al (2007) determined the active ankle joint position sense after the 6 week-isokinetic strengthening program in 24 recreational athletes with functional ankle instability. Their results demonstrated absolute error of ankle inversion 10 degrees at pre-exercise and post-exercise was 2.35±1.16 degrees and 1.33±0.62 degrees, respectively ($p<0.001$) and of inversion 20 degrees at pre-exercise and post-exercise was 3.10±2.16 degrees and 2.19±0.98 degrees, respectively ($p<0.019$). The absolute error decreased after 6 weeks of the isokinetic strengthening program. The absolute error of angle replication was calculated to express a total magnitude of error while the relative error was used in order to elucidate a systematic tendency to overshoot or undershoot of angle error (Baker et al, 2002). Despite various studies, it was not clear for the cut off point of the error angle to indicate ankle proprioception deficits in athletes with chronic ankle instability. The absolute error found in this population have been reported to vary between 1 to 3 degrees (Konradsen et al, 2002; Willems et al, 2002; Sekir et al, 2007), in which the same range of absolute error was found in the current study at posttest. Howerver, these previous studies have some differences in protocols used in their studies for testing ankle joint position sense, and that may not be a perfect comparison of the error angle across studies. Despite indefinite cut-off error angle in this population, the functional rehabilitation programs implemented in the current study was effective enough to improve some joint position sense outcome measures.

In the current study, after the 6-week period of training the relative error was less than 2 degrees at inversion 15 degrees and plantar flexion 30 degrees, and the variable error was less than 3 degrees. There was a trend of all variables of error angle decreasing after 6 week training in both groups except the relative error of plantar flexion 30 degrees which was little greater than before starting the intervention program in all participants (pretest and posttest in the hydrotherapy group was -0.2 to -0.42 degrees, and in the land-based group was 0.28 to 0.58 degrees). The 2-way mixed analysis of variance in the current study showed the error angle to be significant difference between the hydrotherapy group and the land-based group for both the relative error and the variable error at plantar flexion 30 degrees. The current study also revealed that the land-based rehabilitation program could improve the precision of active ankle repositioning of participants who have residual symptoms of chronic ankle instability represented by the variable error angle both at inversion 15 degrees and plantar flexion 30 degrees as presented in Table 4.8.

The similarity in program component in both groups is injured ankle taping. Land-based training consisted of weightbearing exercise similar to closed kinetic chain exercise in all activities. On the other hand, program components in the hydrotherapy group consisted of both weightbearing and non-weightbearing exercise (deep water running) similar to closed kinetic chain and open kinetic chain exercise. Simoneau et al (1997) studied the effects of taping applied over the skin of the ankle (anterior and posterior part) on non-weightbearing joint position sense testing at plantar flexion 10 degrees. The average error angle in the non-weightbearing position with tape and without tape was 1.53±0.84 degrees and 2.31±1.22 degrees, respectively. Their results indicated that under the non-weightbearing condition, taping significantly improved ($p<0.05$) the ability of healthy participants to percieve ankle joint position. Their study also showed that increased cutaneous sensory feedback provided by strips of athletic tape applied directly to the skin would enhance joint position sense awareness, especially in the midrange of ankle plantar flexion. The current study applied ankle taping using the heel lock technique and not only strips of the tape because the researcher expected the dual effects of improved mechanical stability of the ankle joint and increased stimulation of cutaneous receptors while training in the functional rehabilitation program. This expectation was met as results revealed that the 6-week functional rehabilitation program could improve the joint position sense in both groups. Variations in exercises included application of physical properties of the water and floatation devices to change the speed and direction of the movement, as well as number of repetitions (Campaion et al, 1995). In deep water running, only upright position is similar to walking and running on land but non-weightbearing exercise in warm water is advantage for relieving pain and swelling for participants in the current study. The buoyancy force 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 (Campaion et al, 1995; Brody, 2005; Hoogenboom, 2007). Nevertheless, changes in ankle joint position sense in the current study are the result of combined effect of ankle taping and land-based or hydrotherapy program.

5.6 Health status (SF-36 questionnaire)

There was no significant difference between the hydrotherapy and land-based group in health status using all 8 items of the SF-36 questionnaire as presented in Table 4.9. However, within-group comparison showed a significant difference in physical functioning and bodily pain at 3-month follow up when comparing with before participation and this is found only in the hydrotherapy group exercise. It should be noted that all participants could participate in sports activities with their teams after finishing the rehabilitation program. Therefore, changes in scores of SF-36 at 3-month follow up might not be the result from only the training effect of the hydrotherapy program. It could also be the impact of the sports functional program of their teams. The high level of training program in their sports team might improve their physical function as well as the training effect of the hydrotherapy group. Accordingly, exercise in water could relieve pain as the buoyancy plays an important role in decreasing the gravitational forces in all weight bearing activities (Campaion et al et al, 1995). Anandacoomarasamy et al (2005) assessed the quality of life using the SF-36 questionnaire and revealed a difference in only the general health scale between the acute ankle injuries group and the control group who have no history of lower limb injuries. No significant differences in other SF-36 scales (physical functioning, role-physical, bodily pain, vitality, social functioning, role-emotional and mental health) were found between the groups. There were reasons for different results of the SF-36 between their study and the current study. Participants in the study by Anandacoomarasamy et al were patients with acute inversion ankle injury sustained during sports activity, and no age cut off in their study. On the other hand, in the current study, the participants were college-age amateur athletes who have chronic ankle instability with residual symptoms. The assessment using the SF-36 questionnaire in different groups of participants and various severities of ankle injuries could lead to different health status. The current study supported the use of the 6 week-combined functional rehabilitation program using ankle taping with hydrotherapy and land-based exercise in amateur athletes who have chronic ankle instability with residual symptoms. In addition, there is a trend within group toward a higher score immediately after training and at long term follow up comparing to before training in both groups.

The quality of life was evaluated using the health questionnaire SF-36, which was developed within the framework of the Medical Outcomes Study at the New England Medical Center (Jerosch and Schoppe, 2000). This questionnaire covers general health concepts that are important for people in various ages, disease, and treatment related groups (Jerosch and Schoppe, 2000). It is thus possible to record the participants' state of health from their own viewpoint by self-administering.

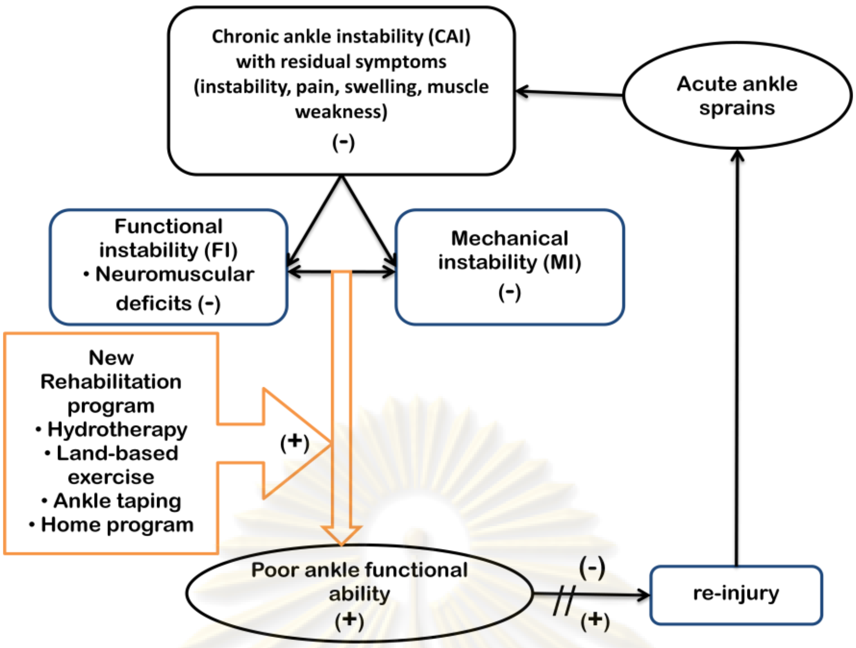


Figure 5.1 Revised conceptual framework

At the end of the current study, the conceptual framework in Chapter 1 was re-determined. The comparison between the new rehabilitation program consists of ankle taping combined with hydrotherapy, land-based exercise and home program (or the hydrotherapy group), and the land-based program consists of ankle taping combined with land-based exercise and home program. The results of this study showed that each program could improve ankle functional ability in chronic ankle instability athletes with the residual symptoms after 6 weeks of training. However, the current study could not indicate which program is better than another given that improvement of ankle functional ability between groups are not different. The number of re-injury ankle sprain after training in the functional rehabilitation program between the hydrotherapy group and the land-based group also did not show significant difference. Although participants had improvement in ankle functiona ability in individual groups, the number of ankle re-injury was not different. Therefore, the conceptual framework was minor revised as shown in Figure 5.1.

5.7 Limitations of the study

1. Participants in this study were amateur athletes who have been participating in sports activities in their teams. They might have the same performance level comparable to healthy athletes in their team. This could be a reason of no significantly different finding in the single-limb hopping test, the number of re-injury ankle sprains, postural sway and health status (SF-36) outcome measures between the hydrotherapy group and land-based group.

2. No blinded tester in the current study. The same researcher performed both testing and training for participants in both groups. Nevertheless, prior to testing, the researcher conducted a reliability study of all outcome measurements (single-limb hopping test, postural sway and active ankle joint position sense) as presented in Appendix E. Having the reliability study done with good measurement of time taken in the single-limb hopping test, and fair reliability both in postural sway and active ankle joint position sense, it was ensured that systematic error is reduced and all measurements are accurate. Although only one researcher performed all assessments and trainings, all outcome measures were tested based on participant's performance. In addition, the SF-36 questionnaire was self-administered by individual participants.

3. There is no control group in the current study. Participants in both groups were athletes with chronic ankle instability who participated in one of rehabilitation programs due to ethical reasons.

5.8 Recommendations for future studies

1. It is recommended by the investigator to study the effect of combined ankle taping and land-based training with and without hydrotherapy in acute or subacute ankle sprains or other lower extremity injuries.
2. Future studies could include various objective measures of ankle functional ability such as a single-limb hop for distance, triple leg hop for distance and agility hop test.

5.9 Clinical implications

The new protocol of functional rehabilitation program in the current study consists of ankle taping, hydrotherapy exercise and land-based exercise supervised by a physical therapist and home program exercise 2 times/ week for 6 weeks. This program is designed for athletes with chronic ankle instability who have residual symptoms such as instability, pain, swelling, and muscle weakness, and still have participation in their teams. In order to complete this protocol, a pool with adjustable water level is essential for varying the intensity of the workout by changing the water level as well as the speed of deep water running.

5.10 Conclusion

The results of the current study revealed that the functional rehabilitation program consists of hydrotherapy, land-based exercise combined with ankle taping, and home program exercise could be implemented to improve active ankle joint position sense at plantar flexion 30 degrees better than land-based exercise combined with ankle taping and home program exercise without hydrotherapy for chronic ankle instability athletes with residual symptoms. Moreover, both groups demonstrated significant improvement in the single-limb hopping test after the completing the program and at 3-month follow up. The SF-36 scale of the physical functioning and the bodily pain improved only in the hydrotherapy group at 3-month follow up. On the other hand, the precision of active ankle joint position sense both at inversion 15 degrees and plantar flexion 30 degrees improved only in the land-based group at 3-month follow up. The results also showed no significant difference in all variables of postural sway in mean scores between the hydrotherapy group and the land-based group.

The current study found no significant difference in the primary outcomes, neither ankle functional ability obtaining from the single-limb hopping test nor the number of re-injury between the hydrotherapy group and the land-based group.

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APPENDICES

APPENDIX A

DATA RECORDING FORM
แบบบันทึกข้อมูลนักกีฬา

รหัส..................................

วันที่............เดือน.........................พ.ศ. ....

1. ข้อมูลส่วนตัว

ชื่อ-นามสกุล (นาย / นาง/นางสาว)...

วัน/เดือน/ปีเกิด... อายุ..ปี

ขณะนี้ศึกษาในคณะ...ชั้นปีที่.........สถาบัน........................

ที่อยู่ปัจจุบัน..เบอร์โทรศัพท์...............................

ชนิดกีฬา/ตำแหน่งที่เล่น ....

ประสบการณ์ในการเล่นกีฬา...ปี

น้ำหนัก ....กิโลกรัม ส่วนสูง ....เซนติเมตร % BMI …………..kg/m^2

อัตราการเต้นหัวใจขณะพัก......................ครั้ง/นาที ความดันโลหิตขณะพัก.................มม.ปรอท

2. ข้อมูลเกี่ยวกับสุขภาพและการบาดเจ็บข้อเท้า

คำถามด้านสุขภาพและการบาดเจ็บ	เคย/มี/ เต็มที่	ไม่เคย/ไม่มี/ ไม่เต็มที่	ถ้ามี โปรดระบุ หรือ กา ☑
ท่านมีโรคประจำตัวหรือไม่			
ท่านเคยมีอาการข้อเท้าพลิก (ankle sprain) ขณะเล่นกีฬาหรือไม่			
ในช่วง 1 ปีที่ผ่านมา ข้อเท้าเคย<u>พลิกซ้ำข้างเดิม</u> อย่างน้อย 1 ครั้ง หรือไม่			❑ข้างซ้าย ❑ข้างขวา
ในช่วง 3 เดือนที่ผ่านมา ท่านเคยเข้ารับการรักษาข้อเท้าพลิกโดยวิธีทางกายภาพบำบัดหรือไม่			
ขณะนี้ท่านมีอาการปวด บริเวณข้อเท้าหรือไม่			❑ข้างซ้าย ❑ข้างขวา
ขณะนี้ท่านมีอาการข้อเท้าหลวมหรือรู้สึกข้อเท้าไม่มั่นคง หรืออาการเสียวในข้อเท้าขณะเดิน/วิ่ง ในการเล่นกีฬา หรือไม่			❑ข้างซ้าย ❑ข้างขวา

คำถามด้านสุขภาพและการบาดเจ็บ	เคย/มี/ เต็มที่	ไม่เคย/ไม่มี/ ไม่เต็มที่	ถ้ามี โปรดระบุ หรือ กา ☑
ขณะนี้ท่านมีความรู้สึกว่ากำลังกล้ามเนื้อขาอ่อนแรง หรือไม่			❑ข้างซ้าย ❑ข้างขวา
ขณะนี้ท่านเดินลงน้ำหนักที่เท้าสองข้างได้เต็มที่ หรือไม่			
ท่านเคยกระดูกหักบริเวณข้อเท้าหรือไม่			❑ข้างซ้าย ❑ข้างขวา
ขณะนี้ท่านมีปัญหาเรื่องการได้ยิน หรือไม่			
ขณะนี้ท่านมีปัญหาเรื่องการมองเห็น หรือไม่			
ท่านเคยมีผื่นแดง หรือผื่นคันตามผิวหนังบริเวณที่พันผ้าเทปแถบกาว หรือไม่			

APPENDIX B

CONSENT FORM
ใบยินยอมของอาสาสมัคร

โครงการวิจัยเรื่อง ผลของโปรแกรมฟื้นฟูนักกีฬาในน้ำและบนบกร่วมกับการพันผ้าเทปต่อความสามารถในการทำงานของข้อเท้าและจำนวนการบาดเจ็บซ้ำในนักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรัง

The effect of hydrotherapy and land-based rehabilitation program combined with ankle taping on ankle functional ability and the number of re-injury in athletes with chronic ankle instability

วันที่ให้คำยินยอม วันที่ ....เดือน ....พ.ศ...........................

ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตรายหรืออาการที่อาจเกิดขึ้นจากการวิจัยหรือจากยาที่ใช้ รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆ ที่ข้าพเจ้าสงสัยด้วยความเต็มใจ ไม่ปิดบัง ซ่อนเร้น จนข้าพเจ้าพอใจ

ข้าพเจ้ามีสิทธิ์ที่จะบอกเลิกการเข้าร่วมโครงการวิจัยนี้เมื่อใดก็ได้ และเข้าร่วมโครงการวิจัยนี้โดยสมัครใจและการบอกเลิกการเข้าร่วมการวิจัยนี้จะไม่เสียสิทธิในการรักษาพยาบาลที่ข้าพเจ้าพึงได้รับต่อไป

ผู้วิจัยรับรองว่าจะเก็บข้อมูล เฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับและจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้องกระทำได้เฉพาะกรณีจำเป็นด้วยเหตุผลทางวิชาการเท่านั้นและจะต้องได้รับคำยินยอมจากข้าพเจ้าเป็นลายลักษณ์อักษร

ผู้วิจัยรับรองว่าหากเกิดภาวะแทรกซ้อนใดๆ ที่มีสาเหตุจากการวิจัยดังกล่าว ข้าพเจ้าจะได้รับการรักษาพยาบาลโดยไม่คิดค่าใช้จ่าย และหรือจะมีการชดเชยค่าตอบแทน ตลอดจนเงินทดแทนความพิการที่อาจเกิดขึ้นตามความเหมาะสม

ข้าพเจ้ายินยอมให้ผู้กำกับดูแลการวิจัย ผู้ตรวจสอบ คณะกรรมการจริยธรรมการวิจัยในมนุษย์ และคณะกรรมการที่เกี่ยวข้องกับการควบคุมยา สามารถเข้าไปตรวจสอบบันทึกข้อมูล

ทางการแพทย์ของข้าพเจ้า เพื่อเป็นการยืนยันถึงขั้นตอนโครงการวิจัยทางคลินิก โดยไม่ล่วงละเมิดเอกสิทธิ์ ในการปิดบังข้อมูลของการสมัครตามกรอบที่กฎหมายและกฎระเบียบได้อนุญาตไว้

ข้าพเจ้าอ่านข้อความข้างต้นแล้ว มีความเข้าใจดีทุกประการและได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจข้าพเจ้าสามารถติดต่อได้ที่ ………………………………………………………….. ……………………………………………………………………………………………………..……

โดยบุคคลที่รับผิดชอบเรื่องนี้ คือ นางสาวปุญญาณัฐ นวลอ่อน ภาควิชากายภาพบำบัด คณะสหเวชศาสตร์ มหาวิทยาลัยธรรมศาสตร์ ในเวลาราชการโปรดติดต่อ เบอร์โทร 02-9869213 ต่อ 7208 นอกเวลาราชการโปรดติดต่อ 087-6964675

ลงนาม……………………………………………………..…ผู้ยินยอม

(...)

ลงนาม……………………………….………………..……..…พยาน

(...)

ลงนาม…………………………………………………...…………ผู้ทำวิจัย

(...)

ในกรณีที่ผู้เข้าร่วมโครงการวิจัยยังไม่บรรลุนิติภาวะ จะต้องได้รับการยินยอมจากผู้ปกครองหรือผู้อุปการะโดยชอบด้วยกฎหมาย ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว มีความเข้าใจในสิทธิและหน้าที่ของผู้เข้าร่วมโครงการวิจัยทุกประการและยินยอมให้ผู้เยาว์ และหรือบุคคลไร้ความสามารถเข้าร่วมการวิจัยได้ จึงลงลายมือชื่อไว้เป็นหลักฐาน

ลงนาม……………………………………………ผู้ปกครอง/ ผู้อุปการะโดยชอบด้วยกฎหมาย

(...)

ลงนาม……………………………….………………..……..…พยาน

(...)

ลงนาม…………………………………………………...…………ผู้ทำวิจัย

(...)

APPENDIX C

SF-36 QUESTIONNAIRE

แบบสำรวจสุขภาพ SF-36

แบบสอบถามนี้เป็นแบบสอบถามที่สำรวจความคิดเห็นของท่านที่มีต่อสุขภาพของท่านเอง ซึ่งจะเป็นคำถามเกี่ยวกับสุขภาพและความสามารถในการทำกิจกรรมโดยทั่วๆ ไป โปรดตอบคำถามทุกคำถาม โดยการวงกลมตัวเลือกในแต่ละข้อ ถ้าหากท่านไม่แนใจ ให้เลือกคำตอบที่ท่านคิดว่าใกล้เคียงที่สุด

1.โดยทั่วไปท่านคิดว่าสุขภาพของท่านเป็นอย่างไร ในขณะนี้

(วงกลมหนึ่งคำตอบ)

ดีเลิศ 1

ดีมาก 2

ดี 3

พอใช้ 4

ไม่ดี 5

2.เมื่อเทียบกับปีที่แล้ว ท่านคิดว่าสุขภาพของท่านเป็นอย่างไร

(วงกลมหนึ่งคำตอบ)

ดีกว่าเมื่อปีที่แล้วมาก 1

ค่อนข้างดีกว่าเมื่อปีที่แล้ว..2

เหมือนกับเมื่อปีที่แล้ว..3

ค่อนข้างแย่กว่าเมื่อปีที่แล้ว..4

แย่กว่าเมื่อปีที่แล้ว.......................................5

3. คำถามต่อไปนี้เป็นคำถามเกี่ยวกับกิจกรรมที่ท่านปฏิบัติในแต่ละวัน ท่านคิดว่า สุขภาพของท่านทำให้ท่านมีปัญหา ในการทำกิจกรรมเหล่านี้หรือไม่ ถ้ามี มีมากหรือน้อยเพียงใด

(วงกลมหนึ่งคำตอบในแต่ละบรรทัด)

ท่านมีปัญหาเวลาทำสิ่งเหล่านี้มากน้อยเพียงใด	มีปัญหามาก	มีปัญหาเล็กน้อย	ไม่มีปัญหาเลย
ก. กิจกรรมที่ต้องใช้แรงมาก เช่น วิ่งไกลๆ ทำงานที่ต้องออกแรงมากๆ ยกของหนัก ออกกำลังกายอย่างหนัก	1	2	3
ข. กิจกรรมที่ต้องใช้แรงปานกลาง เช่น เลื่อนโต๊ะ รดน้ำต้นไม้ ขี่จักรยาน 100 เมตร ซักเสื้อผ้าด้วยตนเอง 8-10 ชิ้น	1	2	3
ค. เดินยกหรือหิ้วของชำเต็มสองมือ	1	2	3
ง. เดินขึ้นบันไดหลายชั้นติดต่อกัน	1	2	3
จ. เดินขึ้นบันไดหนึ่งชั้น	1	2	3
ฉ. งอเข่า คุกเข่า โก้งโค้ง/โน้มตัวลง	1	2	3
ช. เดิน มากกว่าหนึ่งกิโลเมตร	1	2	3
ซ. เดิน ประมาณครึ่งกิโลเมตร	1	2	3
ฌ. เดิน ประมาณหนึ่งร้อยเมตร	1	2	3
ญ. อาบน้ำ แต่งตัว	1	2	3

4. ในระยะหนึ่งเดือนที่ผ่านมา สุขภาพกายของท่านทำให้ท่านมีปัญหา เวลาทำงานหรือกิจวัตรประจำวัน หรือไม่

(วงกลมหนึ่งคำตอบในแต่ละบรรทัด)

ท่านมีปัญหาเหล่านี้หรือไม่	มี	ไม่มี
ก. ทำงานหรือทำกิจกรรมต่างๆ ได้ ไม่นานเท่าเดิม	1	2
ข. ทำงานได้น้อยกว่าที่ต้องการ	1	2
ค. ไม่สามารถทำงานหรือกิจกรรมบางอย่างได้อย่างที่เคยทำ	1	2
ง. มีความยากลำบากในการทำงานหรือกิจกรรม (เช่น ต้องใช้ความพยายามมากเป็นพิเศษ)	1	2

5. ในระยะหนึ่งเดือนที่ผ่านมา อารมณ์ของท่าน (เช่น รู้สึกหดหู่ หรือวิตกกังวล) ทำให้ท่านมีปัญหาในการทำงานหรือกิจกรรมปกติประจำวัน หรือไม่

(วงกลมหนึ่งคำตอบในแต่ละบรรทัด)

ท่านมีปัญหาเหล่านี้หรือไม่	มี	ไม่มี
ก. ทำงานหรือทำกิจกรรมต่างๆ ได้ ไม่นานเท่าเดิม	1	2
ข. ทำงานได้น้อยกว่าที่ต้องการ	1	2
ค. มีความระมัดระวังในการทำงานหรือกิจวัตรประจำวันน้อยกว่าเดิม	1	2

6.ในระยะหนึ่งเดือนที่ผ่านมา สุขภาพทางร่างกายหรืออารมณ์ของท่านมีผลกระทบต่อการทำกิจกรรมทางสังคม เช่น การพบปะสังสรรค์กับครอบครัว ญาติสนิทมิตรสหาย หรือเพื่อนฝูงหรือเพื่อนบ้าน มากน้อยเพียงใด

(วงกลมหนึ่งคำตอบ)

ไม่มีผลเลยจนนิดเดียว 1
มีผลเล็กน้อย 2
มีผลปานกลาง 3
มีผลค่อนข้างมาก 4
มีผลมากที่สุด 5

7.ในระยะหนึ่งเดือนที่ผ่านมา ท่านมีอาการปวดเมื่อยร่างกาย เช่น ปวดหัว ปวดท้อง ปวดเข่า ปวดกล้ามเนื้อ รุนแรงเพียงใด

(วงกลมหนึ่งคำตอบ)

ไม่มีอาการเลย 1
มีอาการเล็กน้อยมาก 2
มีอาการเล็กน้อย 3
มีอาการปานกลาง 4
มีอาการมาก 5
มีอาการรุนแรงมาก 6

8.ในระยะหนึ่งเดือนที่ผ่านมา อาการปวดเมื่อยร่างกายของท่าน มีผลกระทบต่อการทำงาน ทั้งงานที่ทำงานและงานบ้าน (เช่น ทำความสะอาด ล้างจาน ทำครัว) มากน้อยแค่ไหน

(วงกลมหนึ่งคำตอบ)

ไม่มีผลเลย 1

มีผลเล็กน้อย 2

มีผลปานกลาง 3

มีผลค่อนข้างมาก 4

มีผลมากที่สุด 5

9.ในระยะหนึ่งเดือนที่ผ่านมา ท่านเคยมีความรู้สึกต่อไปนี้บ่อยเพียงใด

(วงกลมหนึ่งคำตอบในแต่ละบรรทัด)

	ตลอดเวลา	เกือบตลอดเวลา	บ่อยๆ	บางครั้ง	นานๆครั้ง	ไม่มีเลย
ก. ท่านรู้สึกมีชีวิตชีวา กระปรี้กระเปร่า	1	2	3	4	5	6
ข. ท่านรู้สึกวิตกกังวล	1	2	3	4	5	6
ค. ท่านรู้สึกหดหู่เศร้าซึม มากจน ไม่มีอะไรทำให้ท่านรู้สึกดีขึ้นได้	1	2	3	4	5	6
ง. ท่านรู้สึกอารมณ์เย็น และสงบ	1	2	3	4	5	6
จ. ท่านรู้สึกมีพละกำลัง มาก	1	2	3	4	5	6
ฉ. ท่านรู้สึกท้อแท้และหดหู่ใจ	1	2	3	4	5	6
ช. ท่านรู้สึกหมดเรี่ยวแรง	1	2	3	4	5	6
ซ. ท่านรู้สึกว่าตนเองเป็นคนที่มีความสุขคนหนึ่ง	1	2	3	4	5	6
ฌ. ท่านรู้สึกเหนื่อยล้า	1	2	3	4	5	6

10.ในระยะหนึ่งเดือนที่ผ่านมา สุขภาพทางร่างกายหรืออารมณ์ของท่านมีผลกระทบต่อการทำกิจกรรมทางสังคม เช่น การพบปะสังสรรค์กับครอบครัว ญาติสนิทมิตรสหาย หรือเพื่อนฝูง หรือเพื่อนบ้านบ่อยแค่ไหน

(วงกลมหนึ่งคำตอบ)

ตลอดเวลา 1
เกือบตลอดเวลา 2
บางครั้ง 3
นาน ๆ ครั้ง 4
ไม่มีเลย 5

11.ข้อความต่อไปนี้ เป็นจริงสำหรับท่านหรือไม่

(วงกลมหนึ่งคำตอบในแต่ละบรรทัด)

	จริงแท้แน่นอน	จริง	ไม่รู้	ไม่ค่อยจริง	ไม่จริงแม้แต่น้อย
ก. ฉันไม่สบายง่ายกว่าคนอื่น					
ข. ฉันมีสุขภาพดีเหมือนกับเพื่อนๆ					
ค. ฉันคิดว่าสุขภาพของฉันจะแย่ลง					
ง. ฉันคิดว่าสุขภาพของฉันแข็งแรงสมบูรณ์ดีเลิศ					

ขอขอบคุณที่ท่านให้ความร่วมมือในการตอบแบบสอบถามนี้

APPENDIX D

RE-INJURY DATA RECORDING FORM
แบบบันทึกอาการข้อเท้าพลิกในระยะเวลา 3 เดือน

ชื่อ-นามสกุล (นาย / นาง/ นางสาว)..

คำชี้แจง : โปรดบันทึกข้อมูลการบาดเจ็บบริเวณข้อเท้าที่เกิดขึ้นในช่วงเวลา 3 เดือน

: ในแต่ละคำถาม ท่านสามารถตอบได้มากกว่า 1 ข้อ โดยเติมตัวเลขหน้าข้อความที่เป็นคำตอบของท่าน

ข้อมูลการบาดเจ็บ ข้อเท้าพลิก (ankle sprain)	ครั้งที่ 1	ครั้งที่ 2	ครั้งที่ 3	ครั้งที่ 4
1. วัน/เดือน/ปี ที่เกิดการบาดเจ็บ ข้อเท้าพลิกซ้ำ				
2. ข้อเท้าที่ได้รับบาดเจ็บ ① ข้างซ้าย ② ข้างขวา				
3. ข้อเท้าพลิกในขณะ ① ซ้อมกีฬา ② แข่งกีฬา ③ อื่นๆ โปรดระบุ				
4. ภายหลังข้อเท้าพลิก ท่าน<u>ต้องหยุดซ้อมกีฬาหรือหยุดแข่งกีฬา</u>เป็นระยะเวลานานกี่วัน ① น้อยกว่า 7 วัน ② 7วันหรือมากกว่านั้น				
5. ขณะเกิดข้อเท้าพลิก ท่านมีอุปกรณ์ป้องกันบริเวณข้อเท้าหรือไม่ ① ไม่มี ② มี โปรดระบุ				
6. การรักษาที่ได้รับ เมื่อเกิดการบาดเจ็บ ① พัก ② ประคบน้ำแข็ง ③ ทำกายภาพบำบัด ④ พบแพทย์ ⑤ อื่นๆ โปรดระบุ				

APPENDIX E

RELIABILITY STUDY

The intraclass correlation coefficient (ICC) is a measure of the reliability of measurements or ratings (Portney and Watkins, 1993). In this study, the participants were the athletes who have no ankle sprain within one year. Ten men were volunteers to test (test 1 at day 1) and retest (test 2 at day 7) reliability in the single-limb hopping test, postural sway, and active ankle joint position sense.

Table E.1 Raw data of 10 participants

No.	Single-limb hopping test (second)		Postural sway CoP area (mm^2)		Absolute error (AE) of Active ankle joint position sense (degrees)			
					Inversion 15 (degrees)		Plantar flexion 30 (degrees)	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test2	Test 1	Test 2
1	9.95	10.08	9.00	10.00	0.33	0.17	0.83	0.33
2	5.69	5.33	8.91	8.99	1.00	0.83	1.50	1.00
3	7.39	6.88	8.77	9.11	0.50	0.83	0.83	0.33
4	7.31	6.52	7.99	7.12	0.67	1.00	1.00	0.33
5	7.82	7.66	7.42	7.22	1.00	0.83	0.17	0.00
6	5.60	5.52	7.70	8.09	0.17	0.33	0.83	0.50
7	6.76	6.15	7.12	7.97	0.50	2.50	0.67	0.17
8	5.31	4.92	7.74	7.93	0.50	2.83	0.33	0.50
9	6.20	5.75	7.17	7.00	0.67	0.33	0.33	0.83
10	5.69	5.20	6.41	7.36	0.50	2.83	0.00	0.33

Table E.2 Intraclass correlation coefficient (ICC)

Parameters	Intraclass Correlation	95% Confidence Interval		F Test with True Value 0	
		Lower Bound	Upper Bound	Value	Sig
1. Single-limb hopping test (second)	0.954	0.838	0.988	42.828	<0.001
2. Postural sway (mm^2)	0.784	0.372	0.941	8.256	0.001
Active ankle joint position sense (degrees)					
3. Inversion 15 (degrees)	0.788	0.382	0.942	8.446	0.001
4. Plantar flexion 30 (degrees)	0.774	0.351	0.938	7.868	0.002

One-way random effects model where people effects are random.

df 1 = 9, df 2 = 10

The ICCs were classified as follows (Currier, 1990)

0.90 - 0.99, high reliability

0.80 – 0.89, good reliability

0.70 – 0.79, fair reliability

< 0.69, poor reliability

APPENDIX F

THE DOCUMENT OF RESEARCH ETHICS APPROVAL

คณะอนุกรรมการจริยธรรมการวิจัยในคน มหาวิทยาลัยธรรมศาสตร์ ชุดที่ 2

....

รหัสโครงการ 014/52

ชื่อโครงการวิจัย ผลของโปรแกรมการฟื้นฟูนักกีฬาในน้ำและบนบกร่วมกับการพันผ้าเทปแถบกาวต่อความสามารถในการทำงานของข้อเท้าและอัตราการบาดเจ็บซ้ำในนักกีฬาที่มีความไม่มั่นคงของข้อเท้าเรื้อรัง

ชื่อผู้วิจัยหลัก อาจารย์ปุญญาณัฐ นวลอ่อน

หน่วยงานที่รับผิดชอบ คณะสหเวชศาสตร์ มหาวิทยาลัยธรรมศาสตร์

คณะอนุกรรมการจริยธรรมการวิจัยในคน มหาวิทยาลัยธรรมศาสตร์ ชุดที่ 2 ได้พิจารณาอนุมัติด้านจริยธรรมการวิจัยในคนให้ดำเนินการวิจัยตามโครงการวิจัยข้างต้นได้

ลงชื่อ	ลงชื่อ ....
(ผู้ช่วยศาสตราจารย์ พันเอก ดร. ถวัลย์ ฤกษ์งาม)	(อาจารย์ ดร. วีระชัย เอื้อสิทธิชัย)
ประธานอนุกรรมการ	อนุกรรมการและเลขานุการ

อนุมัติ ณ วันที่ 24 มิถุนายน พ.ศ. 2552

APPENDIX G

EXERCISE PRESCRIPTIONS IN THIS STUDY

Table G.1 The hydrotherapy exercise program

Aims	Exercise	Time	Progression
Aerobic training	Slow running with belt	15 min	The speed : low to moderate carrying the resistance foam while running
Balance exercise	1. Static : single-leg stance with the knee flexed 2. Dynamic: single-leg stance with the knee flexed and throw/ catch a ball while maintaining balance	5 rep/ side	1.Water level : chest deep to waist deep 2.Eyes open to eyes closed 3.Held position: 30 sec to 60 sec
Strengthening exercise	1. Double-leg squat 2. Single-leg squat 3. Toes raise walking 6 m 4. Heel touch walking 6 m	5 rep	1.Water level : chest deep to waist deep 2.Held position : 30 sec to 60 sec
	5. Deep water running with belt	5 min	Wall jet : high resistance 5 – 10 rep
Functional skills	1. Step forward/backward and throw/ catch a ball 2. Step to the left/ right and throw/ catch a ball 3.jumping : double-leg, single-leg and throw/ catching a ball	5 rep	Water level : chest deep to waist deep The speed : slow to fast The weight of a ball : light to heavy

rep = repetition, min = minute, sec = seconds,

Table G.2 The land-based exercise program

Aims	Exercise	Time	Progression
Aerobic training	Cycling on stationary bike	15 min	Intensity: 80 – 95 % HR_{max}
Balance exercise	1. Static : single-leg stance with the knee flexed 2. Dynamic : double-leg stance with knee flexed and throw/ catch a ball while maintaining balance	5 rep/ side	1. Uneven surface : foam, mini trampoline, wobble board 2.Eyes open to eyes closed Held position: 30 sec to 60 sec
Strengthening exercise	1.Leg press (50% of 1 RM) 2.Leg curl (50% of 1 RM)	5 rep/ side	Increased number of rep. Increased weight resistance
	Rubber band exercise 1. Inversion/ eversion 2. Plantar flexion/ dorsiflexion	15 rep/ side	Color : week 1-2 ; blue Week 3 – 4 ; silver Week 5-6 ; gold
Functional skills	1. Jumping and throw/ catch a ball	30 rep	Uneven surface : mini trampoline
	2. Stepping with a ball 3. Sprinting	5 min	The speed : slow to fast

rep = repetition, min = minute, sec = seconds,

HR_{max} = maximum heart rate (beat per minute)

APPENDIX H

MANUAL GUIDELINES OF HOME PROGRAM EXERCISE
คู่มือโปรแกรมการฝึกออกกำลังที่บ้าน

ชื่อ-นามสกุล (นาย / นาง/ นางสาว)..

คำชี้แจง :

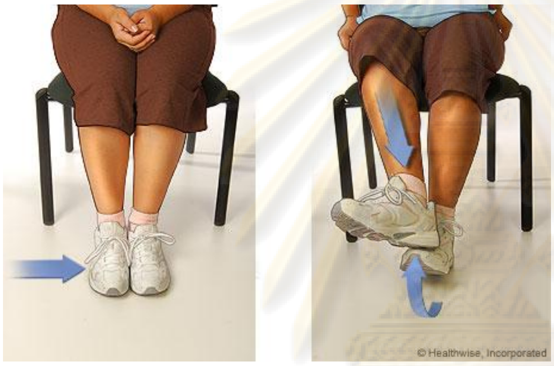
1. ให้ท่านฝึกการรับรู้ข้อต่อของข้อเท้าและความแข็งแรงของกล้ามเนื้อขา โดยปฏิบัติตามคู่มือนี้ทุกข้อ
2. ในขณะฝึกออกกำลังนี้ ท่านจะสวมรองเท้ากีฬา หรือฝึกด้วยเท้าเปล่าก็ได้
3. ใช้เวลาฝึก วันละ 15 นาที ฝึก 2 วันต่อสัปดาห์ รวมระยะเวลาฝึก 6 สัปดาห์
4. โปรดบันทึก วันที่ทำการฝึกโปรแกรมนี้ลงในตาราง

ท่าฝึกออกกำลัง ข้อเท้า	วิธีการฝึก	จำนวนครั้งที่ฝึก
ท่าที่ 1 เดินด้วยปลายเท้า	เดินลงน้ำหนักที่ปลายเท้าและยกส้นเท้าลอยพ้นพื้น เดินไป-กลับด้วยท่านี้เป็นระยะทาง 3-5 เมตร	เดินไป-กลับ นับเป็น 1 รอบ ฝึก 5-10 รอบ/ วัน
ท่าที่ 2 เดินด้วยส้นเท้า	เดินลงน้ำหนักที่ส้นเท้าและยกปลายเท้าให้พ้นพื้นเดินไป-กลับด้วยท่านี้เป็นระยะทาง 3-5 เมตร	เดินไป-กลับ นับเป็น 1 รอบ ฝึก 5-10 รอบ/ วัน

ท่าที่ 1

ท่าที่ 2

ท่าฝึกออกกำลัง ข้อเท้า	วิธีการฝึก	จำนวนครั้งที่ฝึก
ท่าที่ 3 ฝึกเกร็งกล้ามเนื้อในการเคลื่อนไหวข้อเท้า **ท่าเริ่มต้น**: นั่งเก้าอี้ หรือนั่งพื้น เหยียดขาตรงไปข้างหน้า **ข้างที่ฝึก**: ข้อเท้าข้างซ้าย	ไขว้เท้าขวาวางบนเท้าซ้ายเยื้องไปทางด้านนิ้วก้อย **เท้าซ้าย**: ให้ออกแรงสู้กับเท้าขวา โดยออกแรงต้านเท้าขวา ไม่ให้มีการเคลื่อนไหว เกร็งข้อเท้าค้างไว้ 10 วินาที/ ครั้ง	ฝึก 10 ครั้ง/ ชุด ฝึกข้างละ 4 ชุด/ วัน
ท่าที่ 4 ยืนด้วยขา 1 ข้าง บนผ้าเช็ดตัวหรือเบาะนุ่มๆ	ขาข้างที่มีอาการข้อเท้าพลิก ยืนบนผ้าเช็ดตัวหรือเบาะนุ่มๆในลักษณะงอเข่าเล็กน้อย ส่วนขาอีกข้างงอไปด้านหลัง 90° พยายามทรงตัวให้สมดุล	ฝึกยืนข้างละ 3 นาที/ วัน



ท่าที่ 3

ท่าที่ 4

ตารางบันทึกวันที่ทำการฝึก Home program

สัปดาห์ที่ 1	**สัปดาห์ที่** 2	**สัปดาห์ที่** 3	**สัปดาห์ที่** 4	**สัปดาห์ที่** 5	**สัปดาห์ที่** 6
วันที่	วันที่	วันที่	วันที่	วันที่	วันที่
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BIOGRAPHY

Miss Poonyanat Nualon was born on October 19th, 1975 in Buriram, Thailand. She graduated the Bachelor degree of Science (Physiotherapy) from Khonkaen University in 1998 and the Master degree of Science (Sports Medicine) from Chulalongkorn University in 2002. She has worked as an instructor at the Department of Physical therapy, Faculty of Allied Health Sciences, Thammasat University since 2002. She has studied for a Docterate degree in the Biomedical Sciences Program at Graduate School, Chulalongkorn University since 2006.