ผลของการฝึกระบบโพรพริโอเซ็พทีฟที่เกิดขึ้นในนักบาสเก็ตบอล ที่มีภาวะความไม่มั่นคงของข้อเท้า

นายธนาวุฒิ อาจกิจโกศล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาเวชศาสตร์การกีฬา
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THE EFFECT OF PROPRIOCEPTIVE TRAINING IN BASKETBALL PLAYERS WITH ANKLE INSTABILITY

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Sports Medicine
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Field of Study	Sports Medicine
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ธนาวุฒิ อาจกิจโกศล : ผลของการฝึกระบบโพรพริโอเซ็ฟทีฟที่เกิดขึ้นในนักบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้า. (THE EFFECT OF PROPRIOCEPTIVE TRAINING IN BASKETBALL PLAYERS WITH ANKLE INSTABILITY) อ.ที่ปรึกษา : รศ.นพ. พงศ์ศักดิ์ ยุกตะนันทน์, อ.ที่ปรึกษาร่วม : รศ. นพ. สมพล สงวนรังศิริกุล, 90 หน้า.

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อศึกษาการทำงานของระบบโพรพริโอเซ็ฟทีฟในนักกีฬาบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้าภายหลังจากได้รับการฝึกระบบโพรพริโอเซ็ฟทีฟเป็นเวลา 6 สัปดาห์ อาสาสมัครเป็นนักบาสเก็ตบอลชายไทยระดับสโมสรที่มีภาวะความไม่มั่นคงของข้อเท้าจำนวน 24 คน แบ่งออกเป็นกลุ่มควบคุมซึ่งจะได้รับการฝึกระบบโพรพริโอเซ็ฟทีฟแบบไม่ใช้อุปกรณ์ จำนวน 12 คน อายุ 23.58 ± 2.71 ปี กลุ่มทดลองซึ่งจะได้รับการฝึกระบบโพรพริโอเซ็ฟทีฟแบบใช้วับเบิลบอร์ดเป็นอุปกรณ์ จำนวน 12 คน อายุ 23.75 ± 1.22 ปี อาสาสมัครทั้ง 2 กลุ่มได้เข้ารับการทดสอบการรับรู้ตำแหน่งของข้อเท้า และแรงปฏิกิริยาที่เกิดจากการกระโดดทั้งก่อนและภายหลังการฝึกระบบโพรพริโอเซ็ฟทีฟ ผลที่ได้จะถูกนำมาทดสอบทางสถิติที่ระดับนัยสำคัญที่ 0.05 ผลการศึกษา เมื่อนำผลการทดสอบการรับรู้ตำแหน่งของข้อเท้าทั้งก่อนและหลังการฝึกระบบโพรพริโอเซ็ฟทีฟมาทดสอบทางสถิติพบว่า กลุ่มควบคุมและกลุ่มทดลองนั้นมีค่าความคลาดเคลื่อนในการรับรู้ตำแหน่งของข้อเท้าภายหลังการฝึกลดลงอย่างมีนัยสำคัญทางสถิติที่ 0.05 เมื่อเปรียบเทียบกับก่อนการฝึกในเกือบทุกองศาของการทดสอบ และเมื่อทำการทดสอบเปรียบเทียบค่าความคลาดเคลื่อนในการรับรู้ตำแหน่งข้อเท้าภายหลังการฝึกระบบโพรพริโอเซ็ฟทีฟระหว่างกลุ่มควบคุมและกลุ่มทดลอง พบว่ากลุ่มทดลองเกือบทั้งหมดมีค่าความคลาดเคลื่อนในการรับรู้ตำแหน่งของข้อเท้าน้อยกว่ากลุ่มควบคุม ซึ่งจะมีเพียงบางองศาในการทดสอบเท่านั้นที่กลุ่มทดลองมีค่าน้อยกว่ากลุ่มควบคุมอย่างมีนัยสำคัญที่ 0.05 ในส่วนของจุดศูนย์กลางแรงกดที่คำนวณจากแรงปฏิกิริยาที่เกิดจากการกระโดด จากผลการทดสอบพบว่า พื้นที่ของการส่ายจุดศูนย์กลางแรงกดที่เกิดจากการกระโดดภายหลังการฝึกระบบโพรพริโอเซ็ฟทีฟมีค่าลดลงเมื่อเทียบกับก่อนการฝึกระบบโพรพริโอเซ็ฟทีฟ ทั้งในกลุ่มควบคุมและกลุ่มทดลอง จากการศึกษานี้สรุปได้ว่าการฝึกระบบโพรพริโอเซ็ฟทีฟทั้งแบบที่ไม่ใช้อุปกรณ์และแบบใช้วับเบิลบอร์ดในการฝึกนั้น สามารถทำให้ระบบโพรพริโอเซ็ฟทีฟของข้อเท้าเพิ่มขึ้น ส่งผลให้ภาวะความไม่มั่นคงของข้อเท้าลดลง โดยที่โปรแกรมการฝึกระบบโพรพริโอเซ็ฟทีฟนี้สามารถนำไปใช้เป็นโปรแกรมการป้องกันและการฟื้นฟูในนักบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้าได้

สาขาวิชา..........เวชศาสตร์การกีฬา........ ลายมือชื่อนิสิต..............................

ปีการศึกษา...............2550.................ลายมือชื่ออาจารย์ที่ปรึกษา..............................

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม..............................

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KEY WORD: PROPRIOCEPTIVE TRAINING / BASKETBALL PLAYERS / ANKLE INSTABILITY

THANAVUD ARDKIJKOSOL : THE EFFECT OF PROPRIOCEPTIVE TRAINING IN BASKETBALL PLAYERS WITH ANKLE INSTABILITY. THESIS ADVISOR : ASSOC.PROF. PONGSAK YUKTANANDANA, M.D., MSc., THESIS COADVISOR : ASSOC.PROF. SOMPOL SANGUANRUNGSIRIKUL, M.D., MSc., 90 pp.

The purpose of this study was to investigate the effect of proprioceptive training in basketball players with ankle instability. Twenty four Thai basketball players who play in Thai association and have ankle joint-instability were proprioceptive training program. Twelve subjects in control group (age 23.58±2.71 years) received conservative Physical Therapy program. Twelve subjects in intervention group (age 23.75±1.22 years) received wobble board training program. Two groups received training program for 6 week. All received joint position sense test and ground reaction force measurement before and after training. An alpha level of 0.05 was used to determine statistical significant. **Result**: Post training, the control and the intervention groups showed significant decrease in the error of joint position sense ($p<0.05$) in most degree of testing. Post training, the intervention group showed a significant decrease in the error of joint position sense ($p<0.05$) in most degree of testing when compare with the control group. In the part of center of pressure data, the area sway of the post proprioceptive training in the control group and the intervention group decreased compared to the pre proprioceptive training. **Conclusion**: Based on the present results, proprioceptive training program, conservative and wobble board training can be increased proprioceptive sensation of the ankle joint. The proprioceptive training program can be recommended for prevention and rehabilitation in basketball player who have recurrent ankle sprain.

Field of study ....Sports Medicine.......Student's signature...Thanavud Ardkijkosol...
Academic year ....2007...............Advisor's signature.......................
Co-advisor's signature.......................

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CONTENTS

PAGE

PAGE

PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER I

INTRODUCTION

Ankle sprain is a common problem that occurs frequently daily accident in sports competition or exercise. Ankle injuries constituted 15-20% (**Boruta et al** 1990) of all sports-related injuries. Ankle sprain is usually recurrent after primary injury. One of all reasons in recurrent ankle sprain is a loss of proprioception or deficited of proprioception in ankle joint.

Proprioception is an awareness of position and movement of a part of body, like joints, with elimination of visual guidance (**Janwantanakul P** 2001). Proprioceptive signal, about awareness of position and movement of a part of body, comes from receptors called "mechanoreceptor".

Injury to a joint may cause direct or indirect to the alterations in sensory information provided by mechanoreceptors. Direct trauma may lead to ligament and capsule tearing, leading to rupture of the nerve fibers because nerve fiber has less tensile strength than collagen fiber. The consequent destruction of the messages from the joint receptors then causes "deafferentation" and proprioceptive loss (**Freeman et al** 1965, **Schutte et al** 1990, **Decarlo et al** 1986).

Recurrent ankle sprain may follow proprioceptive loss of the ankle joint and will lead to chronic ankle instability or functional instability.

The two hypothesized causes of chronic ankle instability consisted of mechanical instability and functional instability. Mechanical instability (MI) is defined as ankle movement beyond the physiologic limit of the ankle range of motion. The term "laxity" is often used synonymously with MI. Functional instability (FI) is defined as the subjective feeling of ankle instability or recurrent, symptomatic ankle sprains (or both) due to proprioceptive and neuromuscular deficits (**Tropp H** 2002).

Ankle sprain was found in all sports-related injuries with the incidence of 21% to 53% in basketball injuries and 17% to 29% in soccer injuries when compare with all injuries. The stability of ankle joint depended on the supporting ligamentous structures. The lateral ankle ligaments (**for detail see in Chapter II**) which were responsible for resistance against inversion and internal rotation stress, are the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL) and the posterior talofibular ligament (PTFL). The medial supporting ligaments are the superficial and deep deltoid ligaments, which are responsible for resistance to eversion and external rotation stress, which are less commonly injured. Clinically, the most commonly sprained ankle ligament is the ATFL, followed by the CFL. The PTFL is rarely injured. The selective part of ligamentous injury was determined by the mechanism of injury and relative ligamentous strength. The strength of the ankle ligaments from weakest to strongest is the ATFL, PTFL, CFL and deltoid ligament. The nature of both basketball and soccer has frequency jump landing. Then, ground reaction force across the ankle joint was happened during jump landing. The analysis of mediolateral ankle force found increase force on lateral side more than medial side in both healthy and ankle instability subjects. **In addition, ankle instability subjects have lateral force occurring earlier than healthy subjects because of deficiency or loss of proprioception (Hockenbury et al** 2001).

Proprioceptive training system utilizes the wobble board, which is the program recommended by **Konradsen** (2002). Due to the wobble board's training diminished the functional instability injured people rate. Moreover, it has more proprioceptive systems, balance control's and muscle reaction time's improvement (**Gordon et al** 2004, **Victoria et al** 2005).

Research question is studying proprioception system and ground reaction force from jump landing in basketball players who have ankle instability and receive proprioceptive training for 6 weeks. This knowledge can apply to treatment and prevention recurrent ankle sprain and ankle instability.

Goal of this study is verify the efficiency of proprioceptive training to improve ankle stability which will be measure by using multiple equipments.

Research question

Primary research question: Were the proprioceptive system different between the wobble board training for basketball players who had ankle joint instability and the conservative training.

Secondary research question: Had the basketball players, having the ankle joint instability, who had been trained in proprioceptive program, the ground reaction force from jump landing differently from those who had been post-trained in the same program.

Objective

1. To study the effect of proprioceptive training on joint position sense in ankle joint instability basketball players.

2. To study the effect of proprioceptive training to the ground reaction force in ankle joint instability basketball players.

Hypothesis

1. The ankle joint instability basketball players who had proprioceptive training had better proprioception. Which tested by joint position sense.

2. There was a different of ground reaction force from jump landing in ankle joint instability basketball players after proprioceptive training.

Conceptual Framework

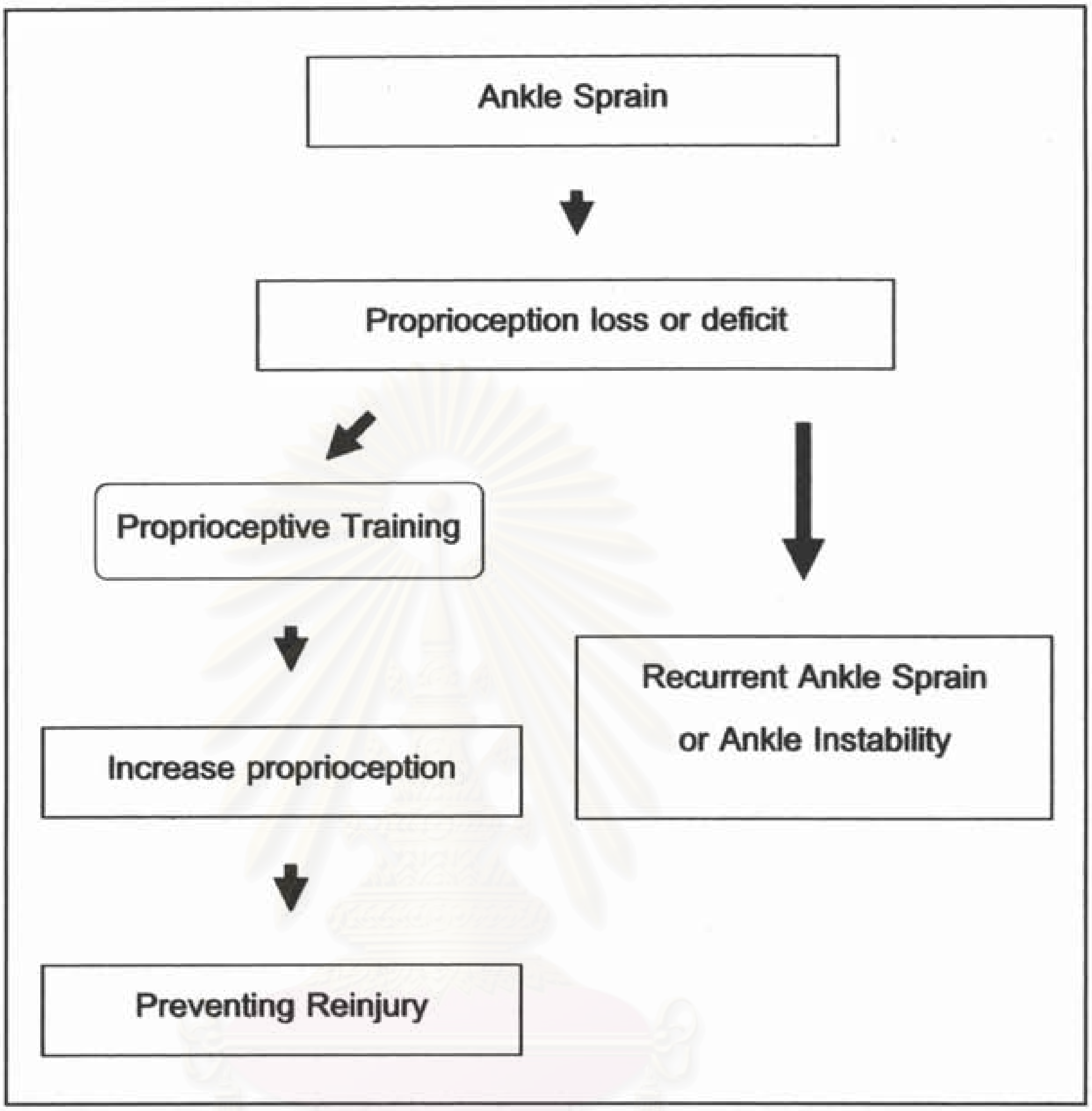

Figure 1.1 Conceptual Framework

Scope of research

1. This study is an experimental research designs which Thai male basketball players who have ankle joint instability.

2. The study approval was obtained from the University Ethics Committee. Written inform consent was obtained from each subject before the experimental started

Limitation

1. In this study, needs to work together among basketball players who will be recruited following the inclusion criteria.

2. In this study, needs to work together between departments, which have equipments for this study.

Key Words

Proprioception, Ground Reaction Force, Ankle Instability, Ankle sprain, **Wobble board, Joint position sense**

Operational Definition

Proprioception is an awareness of position and movement of a part of body with elimination of visual guidance (**For detail see in Chapter II** page 8).

Ground Reaction Force (GRF) is basically the reaction to the force the body exerts on the ground (**For detail see in Chapter II** page 28).

Ankle instability happened from development of recurrent ankle sprain. The 2 hypothesized causes of chronic ankle instability have been labeled a mechanical instability and functional instability. Mechanical instability (MI) is defined as ankle movement beyond the physiologic limit of the ankle's range of motion. The term "laxity" is often used synonymously with MI. Functional instability (FI) is defined as the subjective feeling of ankle instability or recurrent, symptomatic ankle sprains (or both) due to proprioceptive and neuromuscular deficits. In this case study, the subjects are functional instability. Therefore, they are capable to training program and basketball match.

Wobble board is a piece of training equipment used to develop physical balance. It is often used for rehabilitation purposes, although it can be very useful to improve balance and reflexes. The top side, on which the individual stands, is flat and usually features a non-slippery cover. The bottom side, which goes on the ground, has a hemisphere in the center. This allows the board 360 degrees of movement, usually with 10 to 20 degrees of axial tilt.

Joint position test has been previously demonstrated, termed the "repositioning test". The repositioning test is generally used to evaluate position sense at various joints, such as the shoulder, elbow, wrist, hip, knee and ankle joints (**For detail see in Chapter III** page 36).

Expected benefits and applications

1. Understanding the effect of proprioception from proprioceptive training by wobble board in basketball players with ankle instability.

2. Understanding ground reaction force from proprioceptive training by wobble board in basketball players with ankle instability.

3. Providing recommendation for rehabilitate basketball players with ankle instability.

4. Providing recommendation for prevent recurrent ankle sprain.

5. Providing the preliminary data for further research

CHAPTER II

Review of the Related Literatures

Ankle Sprains

Ankle sprains are due to an excessive inversion or eversion injury. Lateral ankle sprains are more common than medial, as the ligaments are weaker on the lateral side (**Boyd and Bogdan** 1993, **Hollis et al** 1995, **Shapiro et al** 1994). Ankle sprain can classified to I, II and III grades upon pathology, function and instability.

GRADE I: when the ligament is stretched but not torn and the anterior talofibular ligament is usually involved. The anterior draw test is negative.

GRADE II: is moderate sprains which usually result in partial tears of the ligaments, primarily the anterior talofibular and possibly the calcaneofibular ligament. Ligamentous laxity may be present and there is moderate swelling.

GRADE III: is classified as severe sprains and uncommon by occured. Grade III sprains have significant swelling, marked instability due to complete rupture of the ligament. The anterior draw test is positive and a fracture or rupture is likely to be present. Problems occur in the grade III classification as more than one ligament may be injured, or bony structures may be affected (**Davis and Trevino**1995).

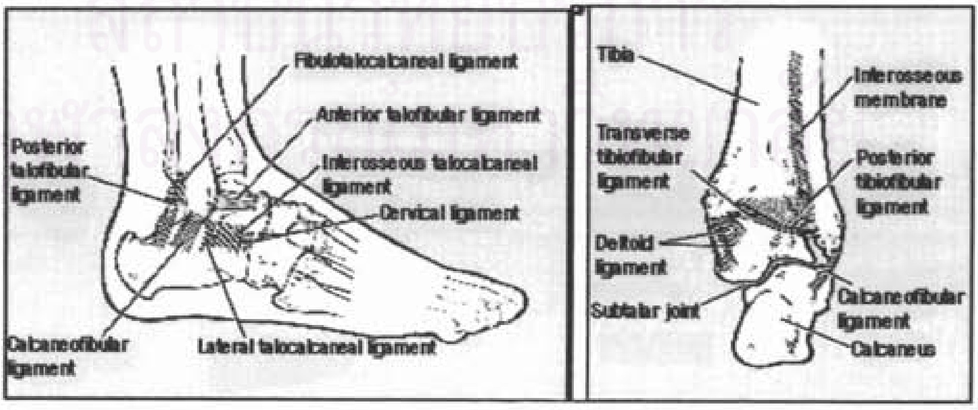

Figure 2.1 Lateral (A) and syndesmotic (B) ligaments of the ankle (**Hockenbury** and **Sammarco** 2001)

Definition of Proprioception sense

Proprioceptive sensation has been recognized since 1557, when Julius Caesar Scaliger described a "sensation of locomotion" (cited in **Cohen** 1957). In general, there are two distinguish types of proprioception: First, position sensation or static proprioception; the ability to detect the position of body parts. Second, movement sensation or dynamic proprioception; the ability to detect the actual movement of the limb which includes information about the velocity and direction of movement at which a limb changes its position (**Clark and Horch** 1986, **Hogervorst and Brand** 1998, **Lephart and Henry** 1996). However, some authers includes other sensory modalities as components of proprioception, for example; sensations related to muscle force including effort, tension, heaviness and stiffness as well as perception of timing of muscle action (**Clark and Horch** 1986, **Gandevia** 1996, **McCloskey** 1987, **Moberg** 1983, **Newton** 1982, **Schmidt** 1986).

According to Stedman's Medical Dictionary (2000), proprioception refers to the sense or perception of the position and movement of the body, especially its limbs, and is independent of vision whereas kinesthesia means the sense or perception of movement. Consequently, the term "proprioception" is suitable for the porpose of this study, used in order to refer the perception of joint position and movement (**Janwantanakul** 2001).

Anatomy of Mechanoreceptors

Mechanoreceptors are located in skeletal muscles, joint capsule, tendons, and ligaments and skin (**Grigg** 1994) (**Figure 2.1**) derives proprioceptive sensation peripherally. They are stimulated by mechanical deformation of the receptors themselves or of tissues adjacent to them. Then transform this mechanical deformation into neural signals.

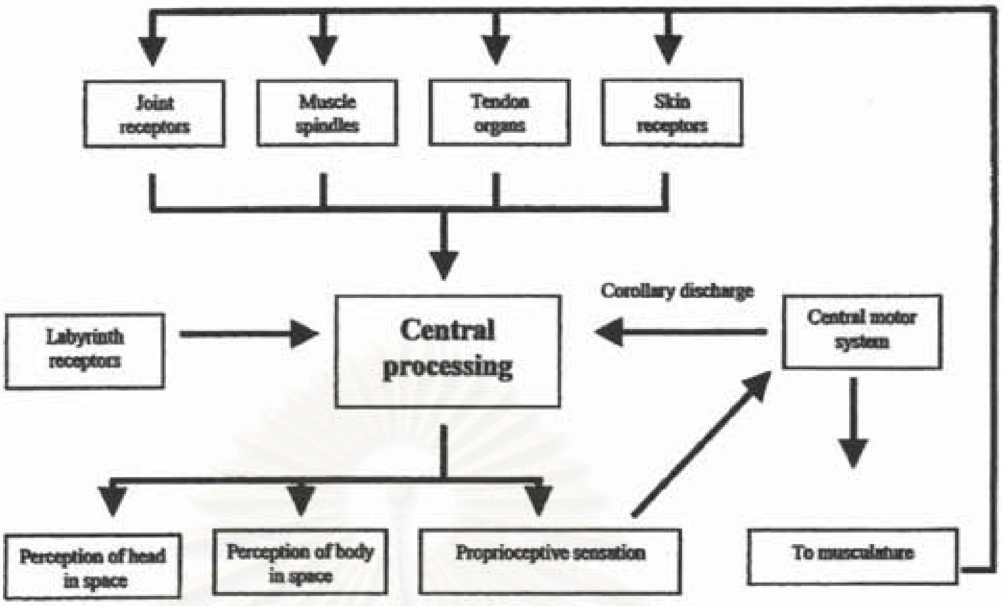

Figure 2.2 Diagram of the origin of proprioceptive sensation (modified from **Schmidt** 1986)

Proprioceptive information, also called "corollary discharge" (**Gandevia** 1996), is a part of the command signals, destined for the muscles and gives feedback into the perceptual regions in the brain (**Sperry** 1950).

Skeletal Muscle Mechanoreceptors

Voluntary muscles can be divided into two main kinds of muscle mechanoreceptors. First, the muscle spindles (**Figure 2.2**) are typically found in skeletal muscles (**Barker** 1974, **Carpenter** 1990). Second, Golgi Tendon Organs (GTOs) or neurotendinous spindles are mostly situated at the musculo-tendinous or musculo-aponeurotic junctions of extrafusal muscle fibres with the rest in the tendon itself (**Barker** 1974, **Moore** 1984). The number, density and location of the muscle spindles and GTOs vary extensively among and within muscles (**Devanandan et al** 1983, **Gandevia** 1996). Anatomical characteristics and actions of the muscle spindles and GTOs are summarized in **Table 2.1**.

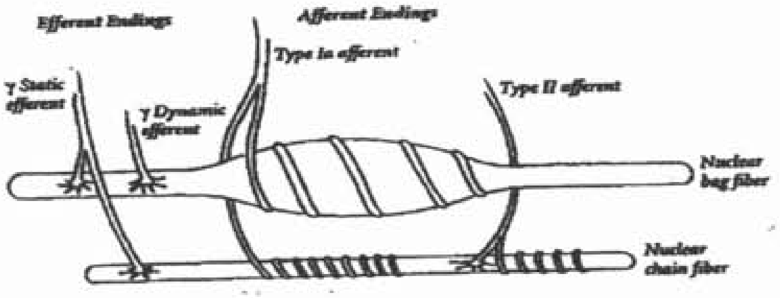

Figure 2.3 Muscle spindle showing details of nerve connection of the nuclear bag and nuclear chain fibres (**Mitz and Winstein** 1993)

	Muscle Spindle	**Golgi Tendon Organ**
Receptor Appearance	• fluid-filled capsule built around 3 to 12 intrafusal muscle fibres	• encapsulated sensory receptor
Location	• parallel to the extrafusal muscle fibre	• lies in series between extrafusal muscle fibres and tendons
Type of Intrafusal Fibre	• nuclear bag fibres divided into bag$_1$ and bag$_2$ fibres • nuclear chain	• none
Motor Innervation	• γ- and β-dynamic axons terminated on bag$_1$ fibres • γ- and β-static axons terminated on bag$_2$ and nuclear chain fibres	• none
Sensory Innervation	• primary ending (type Ia fibre): innervates the central portion of both the nuclear bag and nuclear chain fibres • secondary ending (type II fibre): innervates the peripheral portion of the nuclear chain fibres	• Ib
Ending Characteristics	• Ia: annulospiral ending • II: annulospiral and flower-spray endings	• none
Adapting Rate	• Ia: rapidly adapting • II: slowly adapting	• slowly adapting
Receptor Area	• central portion of the intrafusal muscle fibres	• tendon organ itself
Activation	• lengthening of the whole muscle • contraction of the end portions of the spindle's intrafusal fibres innervated by γ motor nerve fibres	• tension produced by contraction of extrafusal muscle fibres or by external force during passive movement

Table 2.1 Anatomical characteristics and actions of the muscle spindles and GTOs (**Carpenter** 1990, **Gregory and Proske** 1990, **Guyton and Halls** 1996)

As the GTOs are only slowly adapting receptors, the muscle spindles, on the other hand, consist of both slowly and rapidly adapting receptor components. Slowly adapting receptors generate impulses and transmit them to the CNS as long as at the time, they are stimulated. However, rapidly adapting receptors are the receptors that generate impulses during the movement, and then stop after approaching the new position cease within the first few seconds. Thus, slowly and rapidly adapting receptors are expected to signal joint position and movement, respectively (**Clark and Horch** 1986, **Lephart et al** 1998b). However, this classification of receptors is only a rough indicator that shows the type of proprioceptive information these receptors may provide. They can relay information about joint position. Evenwhen a brief subtle muscle contraction activates at an insufficient level to produce noticeable joint movement. Transient signals plus a good memory of joint position may serve well to provide information about position of a joint (**Clark and Horch** 1986).

Articular Mechanoreceptors

Mechanoreceptors located in the capsule of joint, ligament and any intra-articular structures also produce proprioceptive signals (**Schutte and Happel** 1990). Four types of articular mechanoreceptors are identified: Ruffini corpuscle, Pacinian corpuscle and GTO-like corpuscle are considered "true" articular mechanoreceptors while free nerve endings are considered "pain receptors" (**Newton** 1982). **Table 2.2** summarises the general anatomical characteristics and actions of each type of articular mechanoreceptors.

	Ruffini Corpuscle	**Pacinian Corpuscle**	**Golgi Tendon Organ-like Corpuscle**	**Free Nerve Ending**
Sensory Unit	• myelinated parent axon and 2-6 corpuscles	• myelinated parent axon and 1-5 corpuscles	• myelinated parent axon and 1 corpuscle	• thinly myelinated parent axon and terminal endings
Sensory Innervation	• group I and II	• group II	• group I	• group III and IV
Adapting Rate	• slowly adapting	• rapidly adapting	• slowly adapting	• slowly adapting
Threshold To Activation	• low	• low	• high	• high
Activation	• stretch	• compression	• transverse compression • stretch	• noxious stimuli • deep pressure

Table 2.2 The general anatomical characteristics and actions of each type of articular mechanoreceptors. (**Grigg and Hoffman** 1982, **Newton** 1982, **Schaible and Schmidt** 1983, **Zimny** 1988)

The slowly adapting receptors, which consist of Ruffini corpuscles and GTO like corpuscle; have the potential to convey information about joint position. The rapidly adapting receptors, signalling joint movement, are Pacinian corpuscles. Articular mechanoreceptors are presumed to be able to provide information about joint position and movement to the CNS. As a result, articular mechanoreceptors may play an important role in transmitting any stress on the capsule-ligament structures as a joint reaches its extremes of movement (**Guanche et al** 2000).

Cutaneous Mechanoreceptors

There are two types of skin mechanoreceptors, hairy skin and hairless one. The hair-follicle receptors, tactile disks, Ruffini endings and Pacinian corpuscles are identified in hairy skin (**Carpenter** 1990, **Schimdt** 1986). Their anatomical characteristics and actions are summarised in **Table 2.3**. Hairy skin where a few free nerve endings located mainly in, are sensitive to touch and pressure as well (**Hamann** 1995, **Schmidt** 1986).

	Hair-follicle Receptors	**Tactile Disks**	**Ruffini Ending**	**Pacinian Corpuscle**
Type	• rapidly adapting (FA) type I	• slowly adapting (SA) type I	• SA type II	• FA type II
Location	• in the papillae of the corium	• lie in small groups in the lowest layers of the epidermis	• in the corium of the skin	• in the fatty tissue of subcutaneous layers • in the dermis
Receptive Field	• large	• small	• large	• large
Sensory Innervation	• A-beta	• A-beta	• A-beta	• A-beta
Threshold To Activation	• low	• high	• high	• low
Activation	• movement of very light objects over the surface of the skin • low-frequency vibration	• movement of objects on the surface of the body • initial contact with the body • pressure	• stretching of the skin • pressure	• rapid movement of the skin • vibration • touch pressure

Table 2.3 Anatomical characteristics and actions of each type of cutaneous mechanoreceptors. (Guyton and Hall 1996, Schmidt 1986, Shepherd 1994)

In hairless or glabrous skin, four types of mechanoreceptors are identified, namely the Meissner's corpuscles, Merkel's disks, Ruffini ending and Pacinian corpuscles (Carpenter 1990, Schmidt 1986). The Meissner's corpuscles and Merkel's disks in hairless skin are similar to the hair-follicle receptors and tactile disks in hairy skin respectively (Schmidt 1986). The glabrous skin of the human hand has high density of mechanoreceptors. However, no information exists regarding the density of cutaneous mechanoreceptors in any other skin areas (Schmidt 1986). Cutaneous mechanoreceptors are both slowly and rapidly adapting receptors, which are capable of signaling information about joint position and movement.

Physiology of Mechanoreceptors

The contribution of muscle, articular and cutaneous mechanoreceptors on proprioception is explored. According to neurophysiological and psychophysical evidence, afferent signals from muscle, articular and cutaneous mechanoreceptors can reach the cortical centres. There are reports on the occurrence of cerebral potentials following the stimulation of muscle, articular and cutaneous mechanoreceptors (**Amassian and Berlin** 1958, **Faccini et al** 1990, **Gandevia and Burke** 1988, **Nakanishi et al** 1973, **Oscarsson and Rosen** 1963, **Phillips et al** 1971, **Pitman et al** 1992, **Restuccia et al** 1999, **Tibone et al** 1997). Nevertheless physiologists still discuss the role of muscle, articular and cutaneous mechanoreceptors in signaling position and movement sense is still a source of ongoing debate among physiologist. In 1900, **Sherrington** suggested sensation that involves the awareness of joint position and movement, coming mainly from muscle receptors and some contributions from joint and skin receptors. In the mid-twentieth century, According to an electrophysiological recording of articular receptors 'responses during movement imposed on joints, the concept of articular receptors as a main source signaling proprioceptive information was favoured (**Boyd and Roberts** 1953, **Gelfan and Carter** 1967, **Merton** 1964, **Provins** 1958, **Skoglund** 1956). In the early 1970s many neurophysiological experiments convincingly supported, the role of muscle receptors, as important contributors to proprioceptive sensation, especially the muscle spindles (**Clark et al** 1985, **Craske** 1977, **Goodwin et** al 1972, **Matthews and Simmons** 1974, **McCloskey et al** 1983). The current view is that, at most joint, mechanoreceptors from muscles, joint and skin are all considered to be candidates for providing the CNS with proprioceptive information (**Gandevia** 1996, **Grigg** 1994, **McCloskey** 1995). Nevertheless, how each types of mechanoreceptors contributes to each type of proprioception (position and movement sense) is still an unresolved issue (**Janwantanakul** 2001).

Contribution of Skeletal Muscle Mechanoreceptors

Muscle mechanoreceptors refer to the muscle spindles, which detect changes and the rate of change in length of a muscle, and GTOs, which detect degree and rate of change of tension in tendon (**Crow** 1997). The primary and secondary ending are stimulated then generate neural signals as the receptor site of muscle spindle is stretched. "Static response" of muscle spindles continues to transmit their impulses for as long as the receptors themselves remain stretched. Consequently, the number and frequency of discharges increase almost linearly in proportion to the degree of stretch of spindles at any moment (**Carpenter** 1990, **McCloskey** 1987, **Vallbo** 1974a). The primary endings in the muscle spindles are powerfully excited because they response to a rate of change in the spindle length. As long as the spindles length increases, the primary ending generates impulses at a high rate. When the rate of impulse discharge returns to the level of the static response, the lengthening ceases (**Carpenter** 1990, **Vallbo** 1974a). This effect is called the "dynamic response" of muscle spindles (**Carpenter** 1990, **Matthews** 1988). As a result of their neurophysiological properties, the muscle spindles are believed to be suitable candidates to signal both position and movement sense.

The GTOs also have both static and dynamic responses. When the tendon fibre tension suddenly increases the GTOs generate impulses. Their discharge settles down to a lower level as soon as the tendon fibre tension has stopped increasing (**Guyton and Hall** 1996). Increasing in the tension of tendon fibres during muscle contraction help the GTOs be stimulated more effectively then than slow passive stretching (**Gandevia** 1996, **Moore** 1984, **Stephens et al** 1975, **Stuart et al** 1970). In other word, the GTOs are sensitive to changes in contractile force (**Jami** 1992). Accordingly, the GTOs are believed to have a predominant role in signaling the sense of force or load, particularly that produced by contractile elements (**Clark and Horch** 1986, **Gandevia** 1996, **Matthews** 1988, **Proske et al** 2000, **Rymer and D'Almeida** 1980).

To summarize, there are several experiments that support the importance of muscle mechanoreceptors, especially the muscle spindles, in subserving proprioceptive information, both position and movement sense. First, stimulation of muscle mechanoreceptors by mechanical pull, vibration or electrical stimulation induced the illusion of joint position and movement. Second, proprioceptive acuity is reduced after the elimination of the contribution from muscles receptors by nerve block. Third, tightening the muscle acting on the joint improves proprioceptive acuity. Last but not least, the awareness of joint position and movement still remains after the elimination of inputs from articular and cutaneous mechanoreceptors. The CNS relies on proprioceptive information from the lengthening or antagonistic muscles in order to detect joint position and movement (**Janwantanakul** 2001).

Contribution of Articular Mechanoreceptors

Electrophysiological studies which observed discharges from articular mechanoreceptors during movement at various joints in animals as well as finger joints in human have showed that when a tested joint was moved towards the end ROM, articular mechanoreceptors were primarily activated (**Baxendale and Ferrell** 1983, **Burke et al** 1988, **Clark et al** 1989, **Ferrell et al** 1986, **Tracey** 1979). According to **Rossi and Grigg** (1982), the discharge of hip joint afferents in the cat's posterior articular nerve (PAN) and medial articular nerve (MAN). The record show slowly adapting receptors in the capsule of the hip joint only discharged when the joint was rotated into its limit of movement. However, few studies also reported activities of joint receptors in the intermediate ROM (**Baxendale and Ferrell** 1983, **Ferrell** 1980). In **Ferrell** (1980), the discharge of knee joint afferents in the cat's PAN noted that during movement of the knee joint at the intermediate ROM, a small number of slowly adapting joint receptors were activated tonically. As a result, discharges recorded at the intermediate ROM are considered likely to be derived from the muscle spindles.

In conclusion, articular mechanoreceptors, which are excited by tension created in the joint capsule and ligaments, have the potential to signal proprioceptive information when a joint approaches the limit of movement. Nonetheless, the contribution of joint mechanoreceptors to proprioception, both position and movement sense, is not entirely clear, largely due to the inability to isolate articular from cutaneous afferent inputs. However, it is shown the combination of articular and cutaneous afferent inputs can provide information about joint position, especially near the extremes of movement. In addition, there is evidence suggesting that articular afferent inputs alone can signal movement sense (**Janwantanakul** 2001).

Contribution of Cutaneous Mechanoreceptors

It has been long known that cutaneous mechanoreceptors have an exteroceptive role (touch, light touch, pressure-touch, pain and temperature). The skin is stretched on one side of the joint, and compressed or folded on the other, when a joint is moved. This may lead to stimulation of mechanoreceptors lying in cutaneous tissue (**Carpenter** 1990, **Clark and Horch** 1986, **Grigg** 1994, **Schmidt** 1986).

Electrophysiological studies demonstrated that the sensation of vibration, pressure and stress are induced by electrical stimulation of single cutaneous afferents from the glabrous skin of the hand (**Macefield et al** 1990, **Vallbo et al** 1984). During passive and active movements of the fingers, cutaneous mechanoreceptors of the human hand discharged (**Burke et al** 1988, **Edin** 1992, **Edin and Abbs** 1991, **Hulliger et al** 1979). This discharge response from cutaneous afferents during movement has also been reported to be sustained during static conditions. From **Hulliger et al** (1979) observation, when the finger joint was held in various physiological joint positions, discharges in cutaneous afferents from glabrous skin. Slowly adapting receptors sampled in the study derive these discharges predominantly. **Edin** (1992) discharges in cutaneous afferents from the back of the hand while the skin was stretched in a manner similar to the normally occurs during movements of the MPC joint of the index finger were observed. In **Edin** (1992), cutaneous mechanoreceptors, particularly Ruffini endings (slowly adapting receptors), responded prominently at first stretch, and then lowered their response to a sustained discharge level when the skin was held in the stretched position.

In summary, cutaneous mechanoreceptors play an important role in signaling proprioception. Based on electrophysiological studies, during movements some particularly slowly adapting receptors most cutaneous mechanoreceptors are activated and response to static joint positioning. Recently, the perception of joint position and movement are produce by electrical or mechanical stimulation of the skin around and over the finger joints. Proprioceptive acuity is improved by the application of type or brace, which is believed to be the result of enhanced cutaneous afferent inputs from an excessive skin stretching and/or compression (**Janwantanakul** 2001).

Factors Affecting Proprioception

Factors that may affect proprioceptive acuity at a test joint must be named and also controlled both when recruiting subjects and in the experiment. Failure to control factors potentially affecting proprioception may lead to a confounded outcome which, in turn, is a threat to the internal validity of the study (**Janwantanakul** 2001).

1. Joint Hypermobility

General ligamentous laxity resulting in an increased ROM is called "joint hypermobility" or "laxity" (**Mallik et al** 1994). Joint hypermobility is associated with hereditary connective tissue syndromes, for example Ehlers-Danlos Syndrome, Familial Articular Hypermobility Syndromes, Marfan's Syndrome, osteogenesis imperfecta, Larsen Syndrome, Desbuquois' Syndrome, skeletal dysplasia with predominant joint laxity, and dwarfing dysplasia with variable joint laxity (**Beighton et al** 1989). The Beighton scoring system is the most common scoring system, ROM, using in evaluating the joint hypermobility (**Beighton et al** 1973).

Joint hypermobility has been demonstrated to affect proprioception at various joints (**Barrack et al** 1983a, **Hall et al** 1995, **Mallik et al** 1994). Two hypotheses have been proposed for decreased proprioceptive acuity in a hypermobile joint. First, a hypermobile joint may possess defects in the capsule-ligamentous structures and a decrease in muscle tone leading to a disruption of proprioceptive signals into the CNS (**Allegrucci et al** 1995, **Hall et al** 1995, **Mallik et al** 1994). Second, in proprioceptive testing, hypermobile joints have more reduce tissue tension and, consequently, a decrease in proprioceptive signal than those of non-hypermobile joint at the end ROM (**Allegrucci et al** 1995, **Blasier et al** 1994, **Mallik et al** 1994).

2. Age

On proprioceptive acuity, they are two stages of the effect of age. To begin with, before reaching maturity, there is an ongoing development of the nervous system. Therefore, proprioceptive acuity, which is mediated through the nervous system, could be hypothesized to change with progressive development. **Ashton-Miller et al** (1992) investigated trunk proprioception in subjects with ages ranging from 7-18 years using the repositioning test. They found that with increasing age and were fully matured by age 15-16 years, trunk proprioception improved progressively. A similar result has been recently reported by **Visser and Geuze** (2000) has recently a similar result about upper limb proprioceptive acuity in boys aged between 5-14 years.

After reaching maturity, sensory impairment such as diminished vision, hearing, olfaction and taste occurs commonly with aging, which also affects the somatosensory system. Advancing age has the potential to affect the function of mechanoreceptors situated in neural tissues, muscles, skin and joint structures, thereby altering proprioceptive acuity. Indeed, a decline in proprioception with increasing age has been shown in various joints (**Attfield et al** 1996, **Ashton-Miller** 2000, **Barrack et al** 1983c, **Barrett et al** 1991, **Ferrell et al** 1992, **Hearn et al** 1989, **Hurley et al** 1998, **Kaplan et al** 1985, **Lord and Ward** 1994, **Pai et al** 1997, **Petrella et al** 1997, **Skinner et al** 1984).

There is a research supporting the effect of aging on proprioception, showed proprioceptive deterioration in osteoarthritic (OA) joints, a condition which occurs commonly in the elderly (**Barrack et al** 1983c, **Barrett et al** 1991, **Garsden and Bullock-Saxton** 1999, **Hurley et al** 1997, **Koralewicz and Engh** 2000, **Marks et al** 1993, **Sharma et al** 1997). To explain proprioceptive impairment in the OA joint, several hypotheses have been proposed. Proprioceptive deficit in the OA joint may be a result of destruction of articular receptors in joint structures (**Barrack et al** 1983c) or may be due to laxity of the joint capsule and ligaments caused by loss of cartilage and bone height (**Barrett et al** 1991). Another hypothesis has attributed proprioceptive impairment in the OA joint to a decline in muscle spindle sensitivity (**Hurley et al** 1997). This hypothesis proposes that abnormal sensory inputs to the CNS which, in turn, inhibit α- and γ-motoneurone activation may come from articular damage, which is result of muscle weakness and poor proprioceptive acuity. This phenomenon would result in muscle weakness and poor proprioceptive acuity, respectively. In summary, previous studies is that aging point out likely to have a significant effect on proprioception.

3. Hand Dominance

The right and left sides of the brain stem and spinal cord control physical asymmetry between the right and left hemispheres (**Koff et al** a986). The specialization between the right and left limb may come from asymmetry of the CNS. The right side of the body is controlled from the left hemisphere, which is superior of complex motor operation such as speech, fine temporo-sequential motor activities. The left side of body controlled from the right hemisphere, which is superior for the processing of visuo-spatial-perceptual information (**Bradshaw and Nettleton** 1983, **Tucker and Williamson** 1984). **Shimoyama et al** 1990, **Todor and Kyprie** 1980, **Van Emden** 1994 showed the example, performance of a simple motor task such as fast tapping is superior with the right limb than with the left limb.

No difference in proprioceptive acuity between the right and left limbs has been found in the previous studies.

4. Ethnicity

The transmission properties of the nervous system are not affected by difference in ethnic backgrounds. For example, there is no difference has been found in the nerve conduction velocity between black and white subjects (**Buschbacher and Koch** 1999). As a result, before a final conclusion regarding the effect of ethnicity, research involving a large sample size is required.

5. Gender

Some controversy remains whether gender affects proprioceptive acuity and evidence for the effect of gender on proprioceptive acuity is far from conclusive. No difference from several previous proprioceptive studies at the knee joint were reported in proprioception between males and females (**Barrack et al** 1984, **Barrett et al** 1991, **Friden et al** 1996, Hall et al 1995, **Jerosch et al** 1996a). Therefore, the effect of gender of proprioception still remains to be elucidated.

6. Exercise

A number of researchers in various groups of athletes have examined the effect of regular exercise on proprioception. Several studies have reported enhancement of knee proprioceptive acuity in athletes or following regular exercises (**Euzet and Gahery** 1995, **Lephart et al** 1996, **Petrella et al** 1997). In **Petrella et al** (1997), an improvement in knee proprioception, measured by the repositioning test, in active elderly subjects compared with sedentary controls has been found. Their findings of greater proprioceptive acuity following exercise to a number of factors have been attributed. First, competitive athletes with innate superior proprioception may be selected (**Allegrucci et al** 1995, **Euzet and Gahery** 1995, **Lephart et al** 1996). Second, exercise causes not only short-term adaptations of contraction muscles, which the muscle spindles and GTOs may be more excitable to stretching following exercise (**Hutton and Atwater** 1992), but also a long-term, which may allow the development (hypertrophy) of extrafusal as well as intrafusal muscle fibres (**Euzet and Gahery** 1995, **Maier et al** 1972). Last but not least, neuromuscular may be enchancement exercise. The neuromuscular control *via* both central and peripheral mechanisms may lead to improvement in neurosensory pathways (**Euzet and Gahery** 1995, **Lephart et al** 1996, **Petrella et al** 1997).

7. Muscle Fatigue

Muscle fatigue is a reduction of muscle force or power that occurs with exercise (**Taylor et al** 2000). A number of simultaneous mechanisms, causing fatigue include: the CNS drive to motor neurons, neuromuscular propagation, excitation-contraction coupling and the availability of metabolic substrates

There are investigations of the effect of muscle fatigue on at various joints. Deterioration of proprioceptive acuity following fatiguing contractions have been reported in a number of experiments (**Lattanzio et al** 1997, **Marks** 1994, **Skinner et al** 1986a, **Taimela et al** 1999), although some studies have not found such a change (**Marks and Quinney** 1993, **Sharpe and Miles** 1993). Variation in the findings may partly lead to the difference of proprioceptive tests used, fatigue protocol, joint tasted and sample size.

To explain the effect of muscle fatigue on proprioception, a number of hypotheses have been used forward in an attempt. Not only are the contractile elements of muscles but also intramuscular receptors that lie within the fatigued muscle possibly affected by muscle fatigue. Fatigue has been shown to cause a reduction in muscle spindle discharge and a decline in responsiveness to stretch of GTOs (**Hutton and Nelson** 1986, **Macefield et al** 1991).

Fatigue may cause the desensitization of intramuscular receptors to muscle tension is another hypothesis for a decrease in discharges from intramuscular receptors after fatigue. Consequently, intramuscular receptors may become less sensitive to the stimuli; this may lead to a decrease in discharges from intramuscular receptors (**Lattanzio et al** 1997, **Voight et al** 1996).

Fatigue, followed with proprioceptive impairment also may relate to increased joint laxity. Muscle fatigue has been shown to increase joint laxity (**Sakai et al** 1992, **Skinner et al** 1986b, **Weisman et al** 1980). "Central fatigue" or changes within the CNS are also caused by fatigue and defined as a failure of voluntary activation of muscle, thereby decreasing maximal voluntary force or power (**Gandevia et al** 1995). Changes within the CNS due to fatigue can occur at multiple levels in the motor pathway, including supraspinal and spinal levels.

8. Joint Pathology

8.1 Damage to mechanoreceptor sites

Both joint structures (capsule and ligaments) and muscles around the joint may be damaged by pathology to a joint. Afferent discharges from damaged structures may be altered and/or interrupted, possibly resulting in proprioceptive disturbance. It has been clearly demonstrated in previous works that at several joints pathologies were associated with proprioceptive deficits.

A relationship between joint instability and proprioceptive deficit has been proposed in the literature (**Figure** 2.3). Mechanical instability is the result of traumatic or repetitive injury to passive retrains (joint capsule and ligaments).

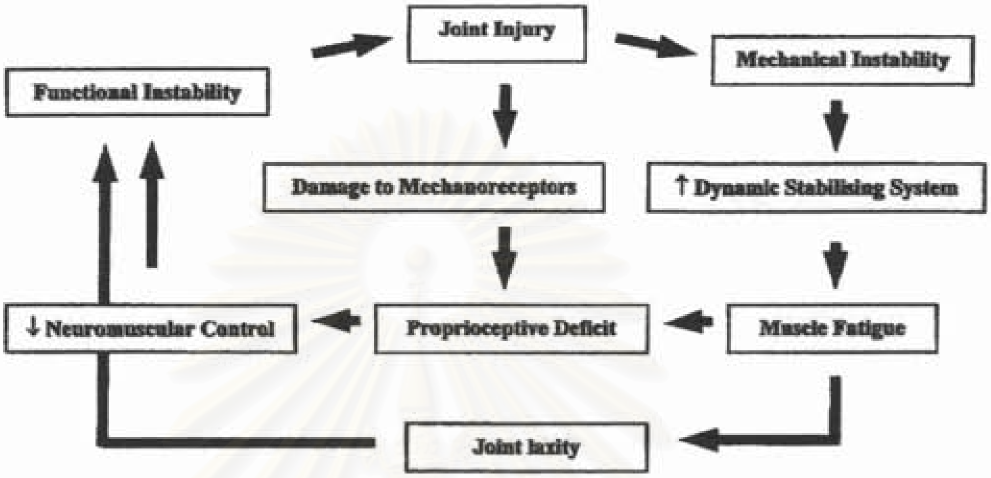

Figure 2.4 Paradigm depicting the relationship of instability and proprioceptive impairment (modifier from **Lephart** and **Henry** 1992)

8.2 Conditions associated with joint pathology

Joint pathology is commonly associated with pain, inflammation, effusion and joint immobilization, which may cause changes in the somatosensory system, both peripherally and centrally. A painful condition may lead to altered movement patterns which in turn may result in altered proprioceptive input into the CNS. In normal circumstances, inflammation often accompanies pain. It has been demonstrated that inflammation and pain cause changes in the proprioceptive system as well (**Mense and Skeppar** 1991, **Schaible and Schmidt** 1985, **Yamashita et al** 1993).

8.3 Changes in neural tissue

Joint pathology may also alter nerve conduction velocity. In **Nitz et al** (1985), a high incidence of peroneal and posterior tibial neurapraxia (causing local conduction block) in grade III ankle sprains was recorded. **Kleinrensink et al** (1994) also found that deep and superficial peroneal nerve conduction velocity was slower following grade II or III inversion ankle sprain at 4 to 8 days post-injury. Neural traction during injury and ankle effusion after injury were attributed in these findings. The outcome of the proprioceptive tests may be affected by alteration of nerve conduction velocity following pathology.

According to **Grigg** (1994), when the normal ankle joint is moved, its associated ligaments joint capsule, muscles, tendons and skin deform, thus activating populations of sensory neurons located in these tissues. Provided cortical pathways are intact, the ensuring sensory or proprioceptive input are implicated in mediating the cognitive experiences of ankle joint motion and/or joint position that influence joint function. The excitation of proprioceptors in the ankle joint tissues is also thought to evoke reflex responses at the brainstem and spinal cord levels, which protect the joint. Hence, an ankle injury, which may involve damage to one or more joint tissues and their sensory receptors, may not only have the potential for impairing the precision of joint motion and/or joint position sensibility, but also for influencing reflexly mediated protective neuron responses. **Boyle and Negus** (1998) studied proprioception in 25 subjects with recurrent ankle sprains compare to 67 uninjured subjects. Proprioception tested was using pedal goniometer. They were found greater errors passive repositional sense in the injured group, and active position sense at 30 percent position was also worse in injured groups. **Glencross and Thornton** (1981) studied 24 subjects (age<25 years old) with history ankle injury of at least 8 month duration, subject were devided to 3 groups on basis of severity, and compared to 9 healthy subjects. Goniometer measured proprioception in this study. There was a linear trend between the degree of injury error of repositional sense and range of motion. The injured group showed better positional sense compare to unaffected side. The error was greatest for the most severely injured group. **Gross** (1987) measured positional sense by cybex II isokinetic dynamometer in 14 subjects with unilateral ankle sprain were compared to subjects with "normal" ankle. He found no significant differences. 23 subjects, median aged 29 years (22-37 years), scheduled for ankle stabilizing operations studied and compared to none injured controls by **Konradsen and Magnusson** (2000). They measured by using torsion goniometer. The result showed that the absolute error was significantly greater for the affected ankle in the unstable group compared to the control group. But, numerically this difference was less than 1 degree. **Bullock and Saxton** (1995) found that the stance time on the injured leg was 5.7second less on the injured side than on the uninjured side in 20 men with unilateral ankle injuries compared to 11 healthy men. **Payne et al** (1997) studied 31 female and 11 male basketball players' ages 18-22 years with no ankle injury history. They used biodex isokinetic dynamometer for joint measurement. The result showed that ankle position sense deficits could predict ankle injury and right inversion proprioception was better in the injured than the uninjured subjects. **Am S. N. Fu et al** (2005) studied 20 healthy male basketball players and 19 male basketball players who had suffered bilateral ankle sprains within the past 2 years. They found ankle repositioning errors and postural sway in stance increased in basketball players with multiple ankle sprains. A positive relationship was found between these 2 variables. **Willems et al** (2002) studied proprioception loss in 87 patients who had ankle sprain (44 male and 43 female, median age 18 years). They measured proprioception by biodex isokinetic dynamometer. They found that ankle instability groups had decreased positional sense and eversion muscle groups had decreased strength when compared with control groups.

Ankle instability may caused by proprioceptive loss. Ankle instability occurred after recurrent ankle sprain and it affected to both systems of ankle joint, it has been considered to be the mechanical instability and functional instability.

Ryan (1994) found that functional instability (FI) of the ankle joint or a tendency for the foot to repeatedly sprain or give way, was as a late complication of between 10% and 30% of acute ankle sprains. **Caulfield** (2000) found the associated between disordered strength of ankle musculature, decreased proprioception, less of balance and ligamentous laxity. **Freeman et al** (1965) postulated that functional instability could result from delayed reflex responses to stress on ankle ligaments as a result of damage to ankle joint receptors at the time of the initial injury. **Konradsen et al** (1997) found that dynamic control of ankle stability is achieved by feed-forward mechanism of the central nervous system rather than by means of feedback affected by peripheral reflexes.

After ankle injury and ankle instability if the patient did not have correct rehabilitation, the instability would lead to repeated ankle sprain, called "recurrent ankle sprain". Proprioceptive training is necessary for rehabilitation program in ankle sprain which has the ankle instability. Proprioceptive training may be different up to researchers. However, the result of training is usually measured in 3 methods. The first method is Joint Position Sense which is measured errors of position in ankle joint; active joint position sense and passive joint position sense. The second one is muscle reaction time. It was measured by electromyography when muscles were activated. The third one is postural sway. It tested standing balance, composed of the visual input, vestibular input and somatosensory.

Tropp et al (1985) demonstrated 80% improvement of stabilometry and also reduced injury rate in previously 65 injured soccer players given a 10-weeks treatment program with ankle disk training when compared with control group, without ankle disk training. **Wester et al** (1996) studied effected of wobble board training. They demonstrated the reduction injury of by 50% in intervention group when compared with control group. **Gauffin et al** (1988) reported effect of ankle disk training on postural control in patients with functional instability of the ankle joint. The researcher found increased postural sway in men with functional instability. The researcher found improvement of postural control after ankle disk training as shown by stabilometry. **Bernier and Perrin** (1998) studied determined the effects of a 6-week coordination and balance training program on proprioception of subjects with functional ankle instability. The result suggested that balance and coordination training can improve some measures of postural sway. It is still unclear if joint position sense can be improved in the functionally unstable ankle. **Julie N. Bernier et al** (1998) studied effected of proprioceptive training and balance coordination training in ankle instability group for 6-weeks. The researcher found improved proprioception and decreased postural sway.

Eils E. And Rosenbaum D. (2001) investigated the effects of a 6-wk multi-station proprioceptive exercise program in 30 patients with chronic ankle instability with 48 unstable feet. The result suggested that a multi-station proprioceptive exercise program can be recommended for prevention and rehabilitation of recurrent ankle inversion injuries. **Sheth P. et al** (1997) investigated the effects of ankle disk training on the contraction pattern of the anterior tibialis, posterior tibialis, peroneus longus, and flexor digitorum longus muscles in a simulated ankle sprain. The experimental group underwent ankle disk training for 8 weeks between the pretraining and posttraining tests. In the pretraining test, four muscles started to contract simultaneously. In the posttraining test, the contractions of the anterior and posterior tibialis muscles were delayed. The results may explain why such training can help protect against ankle sprains. **Osborne MD. et al** (2001) studies whether 8 weeks of ankle disk training alters ankle muscle onset latency of patients with a history of lateral ankle sprain. Ankle inversion perturbations monitored by fine-wire electromyography were performed in four lower extremity muscles (anterior tibialis, posterior tibialis, peroneus longus, and flexor digitorum longus) of all subjects on both the injured (experimental) and noninjured (control) legs. These findings indicate that muscle onset latency decreases in specific ankle muscle groups after ankle disk training in previously injured ankles. **Shmidt R. et al** (2005) assessed the outcome of physical therapy based on both subjective patient's satisfaction and objective measurement of peroneal reaction time in patients with chronic ankle in a 6 week-long program with muscle strengthening and coordination exercises. They found decreased reaction time in peroneal muscle group.

Ground reaction force

1. Ground reaction force

For every action, according to Newton's 3rd Law of Motion (Law of Reaction) is an equal and opposite reaction. Due to the gravity, we constantly maintain contact with the ground, and in this process, there occur interactions between the body and the ground. The reaction force supplied by the ground is specifically called the ground reaction force (GRF), which is basically the reaction to the force the body exerts on the ground. The GRF, along with the weight, is an important external force. The GRF is normally measured by a force-plate.

Figure 2.5a shows the reference frame of the force-plate, with the *Z*- axis being the vertical. The interaction between the body and the ground occurs through the foot as shown in **Figures 2.5b**, which shows the reaction force vectors acting on small areas. A force-plate normally has four tri-axial force sensors embedded that measure the force acting between the foot and the ground in 3 axes: transverse (*X*), anteroposterior (*Y*), and vertical (*Z*). **Figure 2.5c** show the 4 reaction force vectors measured by the sensors. The sum of all the reactions from the ground shown in **Figure 2.5b** is equivalent to the sum of the four forces measured by the sensors (F_1, F_2, F_3, & F_4) shown in **Figure 2.5c**. Thus, system (b) is equivalent to system (c).

Figure 2.5d shows a single force, F ($F_1 + F_2 + F_3 + F_4$), and a torque, T_z. F here is the ground reaction force. T_z shown in the figure is the so-called free torque and has the vertical (*Z*) component only. The free torque is caused by the coupling effects of the forces about the vertical axis. System (d), $F + T_z$, is again equivalent to system (c). The ground reaction force has three components: F_x, F_y & F_z. Among these, F_y is along the direction of the motion which reflects the propulsive or braking force. F_z always thrusts the body upward (**Young-Hoo Kwon** 1998).

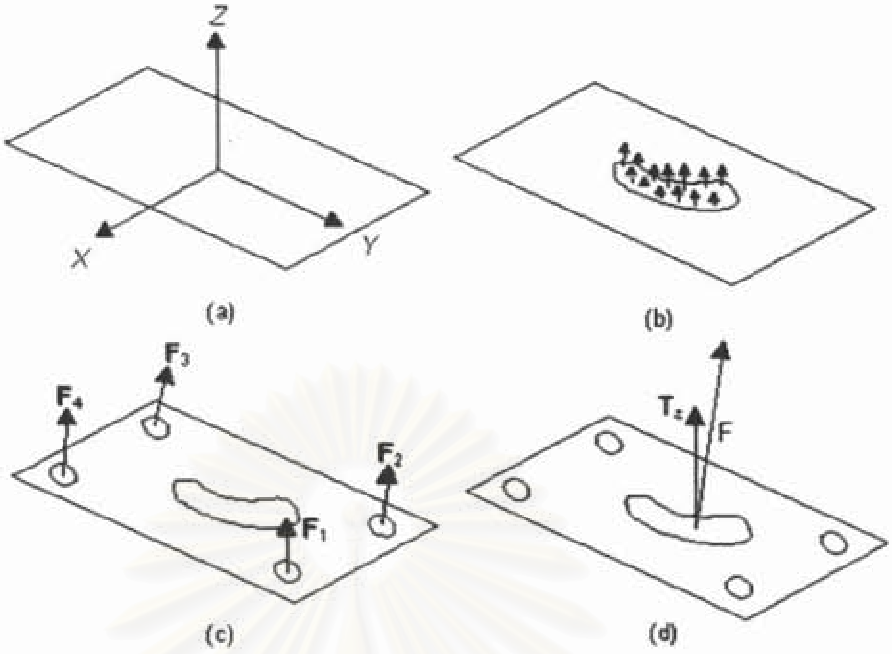

Figure 2.5 Frame of the force-plate

2. Center of Pressure (GRF Application Point)

As shown in **Figure 2.5**, all the forces acting between the foot and the ground can be summed to yield a single ground reaction force vector (F) and a free torque vector (T_z). The point of application of the ground reaction force on the plate is the center of pressure (CP). All the small reaction forces collectively exert on the surface of the plate at the CP (**Young-Hoo Kwon** 1998).

3. Plate Padding

When one adds a pad to the surface of the plate, the CP coordinates need to be corrected. **Figure 2.6** shows the relationship between the force plate reference frame (*X'Y'Z'* system) and the pad reference frame (*XYZ* system). F is the ground reaction force vector. Note that the coordinate system used in the figure is reaction-oriented rather than action-oriented. The *Y* axis is the direction of motion (**Young-Hoo Kwon** 1998).

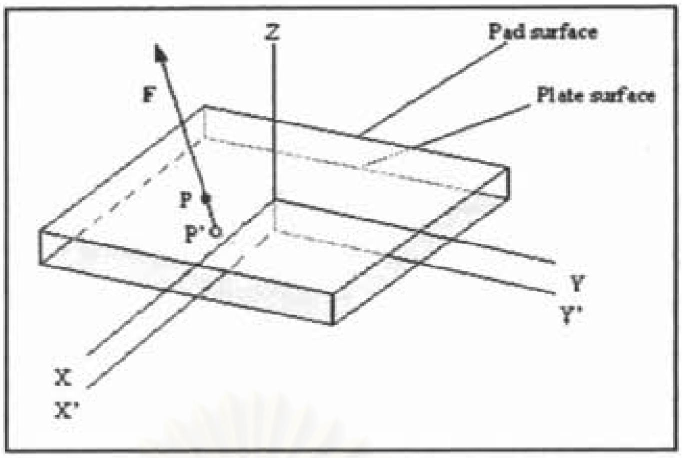

Figure 2.6 Plate Padding

Point *P'* shown in the figure is where the GRF is applied to the plate. In other words, the CP coordinates reported by the force plate software is the coordinates of point *P'* in the *X'Y'Z'* system. But if the investigator wants to use the pad reference frame (*XYZ* system), the coordinates of point *P* in the *XYZ* system must be obtained as the CP coordinates. Since the pad plane is where the interaction between the body and the environment occurs, it is likely that one wants to use the pad reference frame instead of the plate reference frame. Point *P* is the intersection of vector F and the pad surface. Since points *P'* and *P* are on the line of action of vector F, using *P* instead of *P'* as the CP does not affect the moment produced by F (**Young-Hoo Kwon** 1998).

There are numerous factors and mechanisms that are thought to contribute to this increased ankle sprain occurrence (**Lentell et al.** 1995). One of these factors is the inability to accurately position the foot prior to touchdown. Once the foot has touched the ground in a potential ankle sprain situation, it is questionable whether the ankle pronating muscles can react quickly enough to prevent an injury-causing excessive supination (**Isakov et al.** 1986). However, the position of the foot as it "first touches the ground may influence the sprain frequency. If the foot is already supinated at touchdown, the ground reaction force moment arm about the subtalar joint may be greater, causing excessive supination (**Figure 2.7**). Furthermore, if the foot is plantarflexed at touchdown, it may also increase the ground reaction force moment arm about the subtalar joint (**Figure 2.8**) (**Barrett and Bilisko** 1995, **Shapiro et al.** 1994). This inappropriate foot positioning prior to touchdown has been hypothesized to be a fundamental cause of ankle sprains

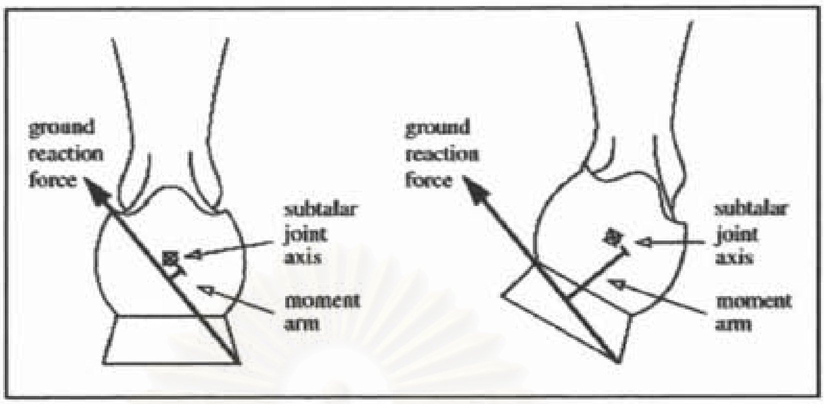

Figure 2.7 A view of the foot and ankle from behind at touchdown when performing a cutting or side-shuffle movement. The moment arm of the ground reaction force about the subtalar joint when the foot is flat (left) is much smaller than the moment arm when the foot is supinated (right).

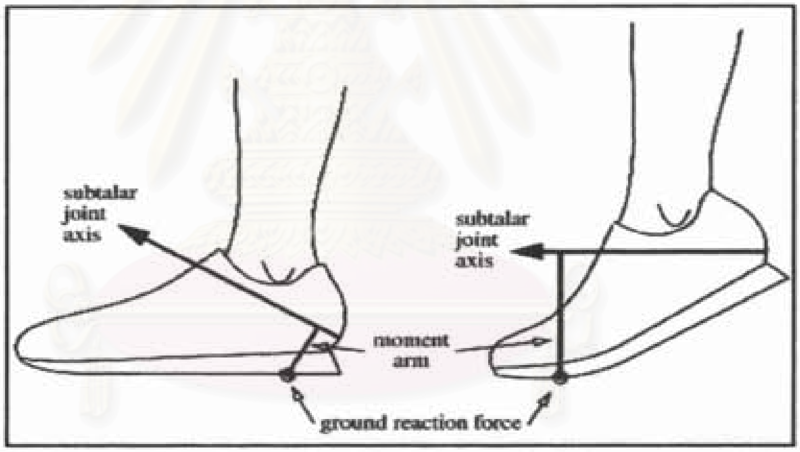

Figure 2.8 A view of the foot and ankle in the sagittal plane at touchdown when performing a cutting or side-shuffle movement. The moment arm of the horizontal component of the ground reaction force about the subtalar joint when first contact is made with the heel (left) is much smaller than the moment arm when the foot is plantarflexed and first contact is made at the toe (right).

Caulfield B. and Garrett M. (2004) observed changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. Fourteen subjects with unstable ankles and 10 age, sex and activity matched controls performed five single leg jumps onto a force platform whilst ground reaction forces were sampled.

The disordered force patterns observed in subjects with functional instability are likely to result in repeated injury due to significant increase in stress on ankle joint structures during jump landing. They suggested that subjects are most likely to result from deficits in feed-forward motor control. **Nyska M. et al** (2003) examined changes in the pattern of force transfer between the foot and the floor associated with chronically sprained ankles by measuring the peak forces and their timing under several regions of the feet during level walking. Twelve young male subjects with recurrent ankle sprains were studied. Twelve healthy men served as a control group. In patients with chronic ankle instability, there was a slowing down of weight transfer from heel strike to toe off, a reduced impact at the beginning and end of the stance phase, and a lateral shift of body weight. **Becker HP. et al** (1996) studied patients with longstanding chronic ankle instability to demonstrate whether dynamic measurement of plantar pressure distribution could identify patients with functional ankle instability. Sixty five patients were measured and calculated intraindividually, compared with a group of 100 healthy subjects. Plantar pressure patterns were measured during gait using a capacitive platform. Dynamic measurement of plantar pressure could identify a group of patients walking on the lateral side of the unstable foot when compared with the stable foot. This finding explained the deficit of peroneal strength during stance phase based on a proprioceptive defect after trauma. **Simpson K. J. and Jiang P.** (1998) determined foot landing position influenced on the ground reaction forces of two coordinate systems during gait. Thirty females were assigned to a foot landing group: toe-out, toe-in or neutral. Each participant walked 10 trials across a force platform while three-dimensional motion was captured. For toe-out participants, greater medio-lateral ground reaction forces of the room coordinate system indicate excessive forces are generated by toe-out participants that do not contribute to moving the participant forward. Furthermore, mediolateral loading on the foot increases proportionally with the degree of toe-out.

In previous study, patients with ankle instability or abnormal foot would have abnormal ground reaction force when compared with normal foot. Addition, they had reaction time less than normal foot.

The basketball players had ankle instability because of the ankle sprain. Ankle sprain caused proprioceptive signal deficit and it also caused ground reaction force which came from jump landing.

These studies showed that proprioceptive training will improve patients function by decrease rate of the occurrence of ankle instability. We are interested in applying proprioceptive training for rehabilitation program in injured basketball players with ankle instability. We would like to study the effect of proprioceptive training, especially with ankle disc, by measuring proprioception and ground reaction force in ankle injured basketball players with instability program compare to traditional training.

CHAPTER III

Research Methodology

Research design

This study is an experimental research which aims to examine the effect of proprioceptive training on basketball players and ankle instability.

Research methodology

Population and Sample

In this study, the target population was Thai basketball players who play in basketball association and have ankle joint-instability in age 18-30 years old. The samples were Thai basketball players who play in the association and have ankle joint-instability in age 18-30 years old who were recruiting by following the inclusion criteria.

Inclusion Criteria

- Being Thai male basketball players who play in association and have experience at least 3 years.
- Have history of inversion ankle sprain more than 2 times in 6 month.
- Have ankle instability or feel give way (Anterior Drawer Test: positive)

Exclusion Criteria

- Have history of ankle joint fracture or operate of ankle joint
- Have muscles weakness around ankle joint
- Have limit range of movement in ankle joint
- Have pain when move ankle joint

Sample size

Volunteers were chosen from the basketball association. The volunteers had to pass the inclusion and exclusion criteria.

Sample size calculation

Sample sizes were calculated from the study of **Eils E** (2001). They investigated the effects of a 6-wk multi-station proprioceptive exercise program in 30 patients with chronic ankle instability with 48 unstable feet. In this study, the mean error of joint position sense before training was 2.0 ± 0.6 and after was 1.5 ± 0.4. And the sample size was calculated below.

$$n = \frac{(Z_\alpha + Z_\beta)^2 S_p^2}{D^2}$$

$\alpha = 0.05$ (two-sided), $Z_\alpha = 1.96$

$\beta = 0.20$ (two-sided), $Z_\beta = 1.28$

D = differences of mean needed to be test

$$S_p^2 = \frac{(n_1 - 1)\, S_1^2 + (n_2 - 1)\, S_2^2}{n_1 + n_2 - 2} = \frac{(20\text{-}1)\,(0.6)^2 + (20\text{-}1)\,(0.4)^2}{20 + 20 - 2}$$

$$S_p^2 = 0.26$$

Substistute to $n = \dfrac{(1.96 + 1.28)^2\,(0.26)}{(0.5)^2}$

$$n = 10.92$$

n for each group will be 11 persons. To prevent drop out rate during the experimental and detect more reliability, subjects will add for more 10%. So, total subjects are 12 persons for each group.

Instruments

1. Case record form

2. Information form

3. Weighing machine (Hae Chang, China)

4. Altimeter (Figg®)

5. Wobble board (Diameter: 32 cm, Height: 9.5 cm) (**Figure 3.7**)

6. Isokinetic (CYBEX NORM, HUMAC NORM testing & rehabilitation system, Stoughton, Massachusetts, USA) (**Figure 3.1**)

7. Force plate size 46.4 x 50.8 cm (AMTI's model OR6-5, Advanced Mechanical Technology Inc., Watertown, MA) (**Figure 3.4**)

Assessment of the Ability to Perceive Joint Position

The assessment of the ability to perceive joint position is a test that quantitatively examines the ability of an individual to replicate a predetermined (target) joint position that has been previously demonstrated, termed the "repositioning test". The repositioning test is generally used to evaluate position sense at various joints, such as the shoulder, elbow, wrist, hip, knee and ankle joints (**Beynnon et al** 2000, **Borsa et al** 1994, **Friden et al** 1996, **Gandevia** 1996, **Hogervorst and Brand** 1998, **Jerosch and Prymka** 1996, **Lephart et al** 1997, **McCloskey** 1978). The testing procedure involves two separate steps. First, an examiner presents a target position to a subject. Second, a subject indicates the joint position perceived (**Clark and Horch** 1986). In previous studies, the angular difference (in degrees) between the target and perceived joint positions has been normally used to represent position sense acuity.

Active/passive movement

Active/passive movement refers to the manner by which the limb or body part is moved to the target and perceived joint positions. For "passive positioning" to a target position, a limb is usually secured and supported by an apparatus. The relaxed limb is moved passively from a starting position to a target position either by an examiner or apparatus at a constant speed. For "active positioning" to a target position, a subject, instead of an examiner or apparatus, actively moves their limb or body part from a starting position to a target position at either a controlled or uncontrolled speed. A subject moves the limb until either told to stop or a mechanical stop is reached. After reaching the target position, a subject is asked to remember the position while the limb is sustained in the position for a period of time. After that, the limb is moved away either actively or passively from the target position to the either starting position or a random position. To indicate a perceive position for "passive repositioning", the limb is passively moved toward the target position. A subject is then instrumented to inform an examiner or manipulate a switch to stop a mechanical arm when they feel the limb has regained the target position. For "active repositioning", a subject actively moves the limb back to the target position (**Janwantanakul** P. 2001). **Lephart et al** (1997) claimed that the repositioning test with passive movement maximally evaluates the contribution of joint mechanoreceptors to proprioceptive acuity while the repositioning test with active movement provides a more functional assessment of proprioceptive acuity. Functional activities are normally performed with active movement or muscle contraction. Therefore, testing with active movement may be more functionally relevant. However, the statement that testing with passive movement would maximally evaluate the proprioceptive contribution of joint receptors should be viewed with caution (**Janwantanakul** P. 2001).

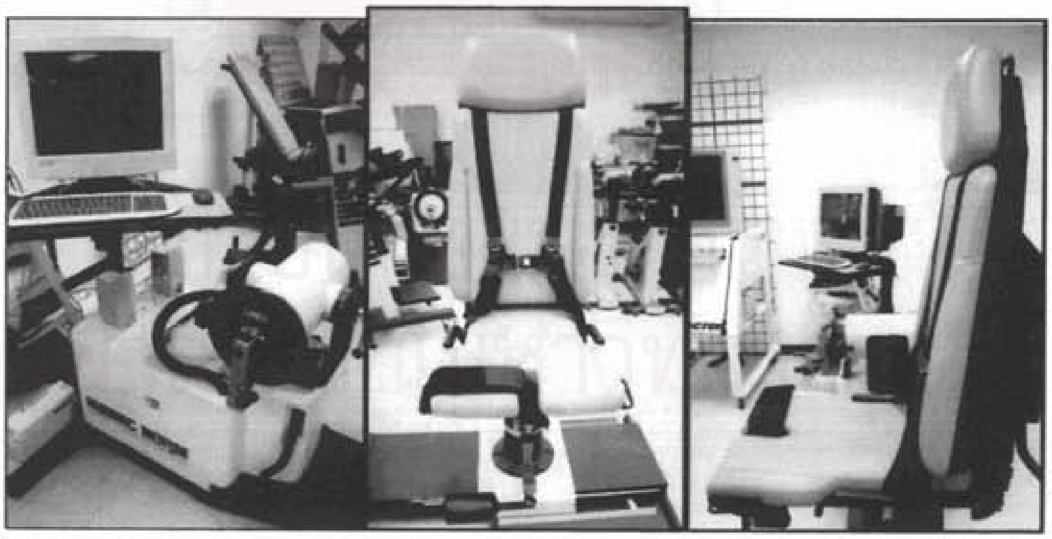

Figure 3.1 Isokinetic (CYBEX NORM)

Data collected from Force-plate

Force-plate is the instrument for measure force from body action. In this study, force-plate is AMTI's brand and transducer of force-plate is strain gauge type. It can measure force in X, Y and Z axis and moment X, Y and Z around axis (**Figure 3.4**). Force and moment are stimulating electrical signal from 4 transducers in 4 corners of plate. Transducer is necessary to calibrate metal plate or its call "Beam" for data's collect. Beam is assign to magnitude of force with vary of plate's figures. Beam is transform to digital signal and transfer to computer or CPU.

Force-plate is connecting to computer and analyzed by ELITE System program; analyze movement, from data (**Figure** 3.2, 3.3). ELITE System program can call data from force-plate; coordinates X data (Anteroposterior) and coordinates Y data (Mediolateral), which calculated from ground reaction force of center of pressure (COP) to display. That is calculating of distance sway and area sway.

Figure 3.2 Computer for collect data

Figure 3.3 Computer analyzed by ELITE System program

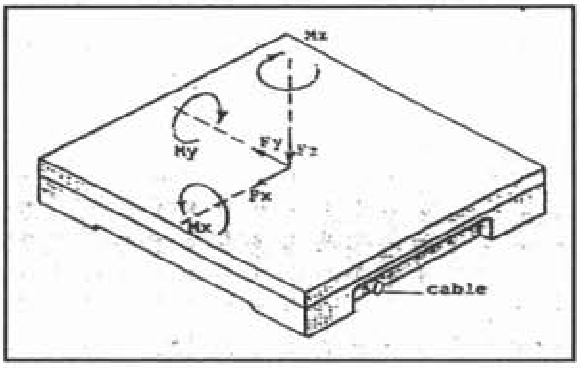

Figure 3.4 Force-plate

Procedure

Twenty-four Thai male basketball players between the age of 18 and 30 years were recruited concerning the basketball teams' conclusion criteria from Thai basketball association. There are divided twenty-four subjects into two groups; twelve subjects' control and twelve subjects' intervention group. **All received conventional Physical Therapy program for 6-weeks, which intervention group underwent supervised wobble board training. Furthermore, all received joint position sense test and ground reaction force measurement occurred before and after training for two sides of ankles.**

1. *Joint position test*

Experimental were setup for the passive and the active ankle joint repositioning test. Subjects lay prone, with the ankle in the neutral position of 90° of dorsiflexion and the forefoot strapped to the footplate of a Cyber Norm dynamometer (**Figure 3.5**). Target position was set as 10°, 20° dorsiflexion and 15°, 30° plantarflexion. The foot was moved at a constant speed 5 deg/ sec.

1.1 passive joint position tests

The ankle was passively moved to 10° of dorsiflexion at a peak velocity of 5 deg/ s. It was held for 2 seconds once the target position was reached. The ankle was then returned to the neutral position and was again moved passively toward the target position at the same speed of 5 deg/ s. When the subject perceived that the ankle had regained the previous target position, an examiner was a switch to stop a mechanical arm. To test 3 times in 1 target position and all test 4 target positions.

1.2 active joint position tests

The ankle was passively moved to 10° of dorsiflexion at a peak velocity of 5 deg/ s. It was held for 2 seconds once the target position was reached. The ankle was then returned to the neutral position and was actively moved the limb back to the target position at the same speed of 5 deg/ s. To test 3 times in 1 target position and all test 4 target positions.

Figure 3.5 Joint position tests

2. *Ground reaction force*

Subjects, who remained barefoot during testing, were firstly introduced to the required jumping technique (**Figure 3.6**). This entailed standing on a 40 cm high platform in front of a force-plate with the test leg relaxed and non-weight bearing. The subject then used the contralateral limb to propel himself from the platform and landed on the test leg on the centre of the force-plate. Each subject performed 5 single leg jumps onto the force-plate. None of the subjects involved in the study reported any subjective difficulty with the jumping technique or discomfort during testing.

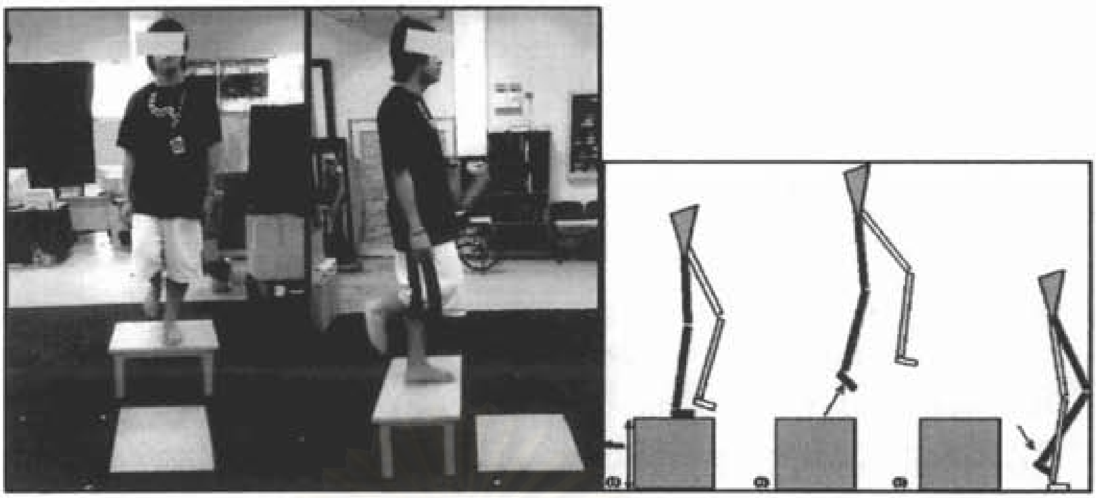

Figure 3.6 Jumping technique

Proprioceptive training

Intervention groups were trained by 6-weeks wobble board, which had an effect on accuracy of judging ankle inversion movements. The training session lasted 15-20 minutes per session for three sessions per week. An examiner explained and demonstrated details of the wobble board training (**For detail see in Appendix E**).

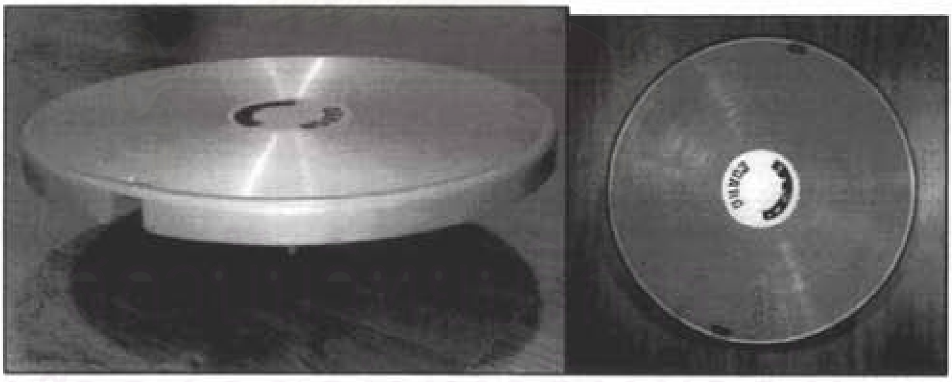

Figure 3.7 wobble board

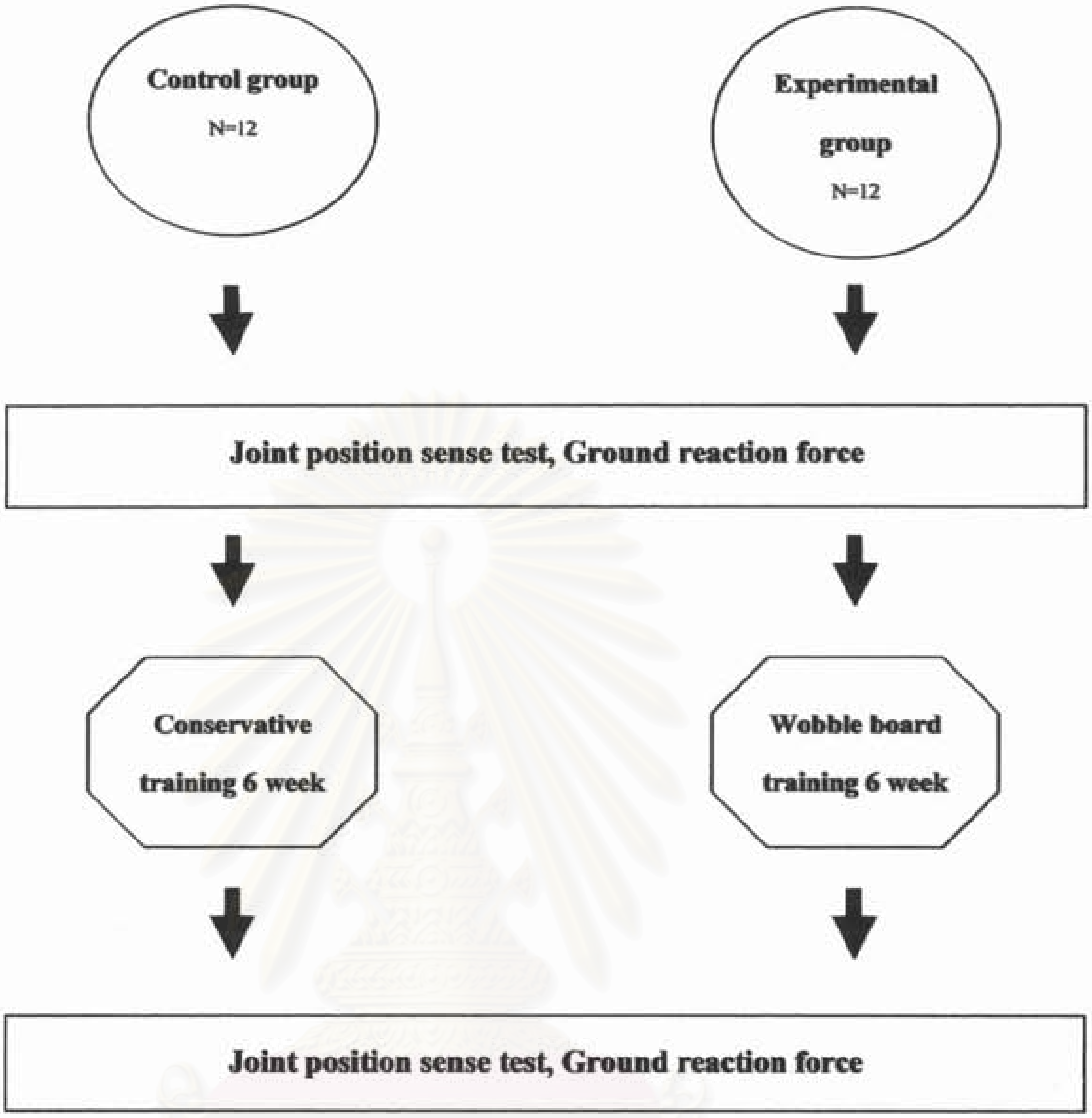

Figure 3.8 procedure

Data analysis

All results were expressed as the mean ± SD. The Wilcoxon signed-rank test were to detect the differences of the error in ankle joint repositioning and ground reaction force between before and after training group. The Mann-Whitney Test Statistics was to detect the differences of the error in ankle joint repositioning and ground reaction force between control and intervention group.

An alpha level of 0.05 was used to determine statistical significant. All analyses were performed on the Statistical Package for the Social Sciences version 11.5 (SPSS, Chicago, IL, USA).

CHAPTER IV

RESULTS

Characteristics of the subjects

Twenty-four Thai basketball players who play in association and have ankle joint-instability participated as subjects ranging in age for control from 20-28 years and 22-25 years for intervention. They are members of Thai national basketball team (SEA Game and Universiade).

Baseline characteristics of the subjects both in control and intervention group were summarized in **Table 4.1**. Ages of the 12 control subjects ranged from 20-28 years, mean age for this group were 23.6±2.7 years and the 12 intervention subjects aged from 22-25 years, mean age for this group were 23.8±1.2 years.

Table 4.1 Baseline characteristics of the subjects.

Characteristics	Group			
	Control Group		Intervention Group	
Age (years)	23.58 ± 2.71		23.75 ± 1.22	
Weight (kg.)	75.50 ± 9.32		84.42 ± 15.14	
Height (cm.)	180.21 ± 4.74		187.13 ± 6.09	
Ankle side injuries	L 3	R 9	L 5	R 7

L = Left ankle R = Right ankle

Joint position sense

Passive joint position sense

Baseline passive joint positional sense was tested in both groups. There was no statistical difference of passive joint positional sense between the two groups (**Table 4.2**). Therefore, the results of the post training positional sense of the two groups can be compared. **Table 4.3 and Table 4.4** summarized p-value and the mean error passive joint position sense of injured and non-injured ankle between control and intervention group. P-value was less than 0.05 when compared between control and intervention group at 10° dorsiflexion, 15° plantarflexion and 30° plantarflexion. The mean error passive joint position senses of non-injured were decrease and p-value was less than 0.05 only at 10° dorsiflexion.

Table 4.2 The mean error passive joint position sense of pre-test between control and intervention group.

Degree	control	intervention	P-value
Injured ankle dorsiflexion 10°	2.26 ± 0.90	1.69 ± 0.55	0.085
Injured ankle dorsiflexion 20°	1.86 ± 0.71	1.75 ± 0.63	0.661
Injured ankle plantarflexion 15°	3.05 ± 1.09	1.99 ± 0.62	0.009*
Injured ankle plantarflexion 30°	3.08 ± 1.23	2.30 ± 1.20	0.061
Non-injured ankle dorsiflexion 10°	2.12 ± 0.88	1.75 ± 0.65	0.145
Non-injured ankle dorsiflexion 20°	1.93 ± 0.84	1.35 ± 0.41	0.126
Non-injured ankle plantarflexion 15°	2.43 ± 0.55	2.17 ± 1.07	0.291
Non-injured ankle plantarflexion 30°	2.80 ± 0.89	2.78 ± 1.24	0.977

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, P<0.05.

Table 4.3 The mean error passive joint position sense of injured ankle between control and intervention group.

Degrees of Error (°) (passive)	Posttest of injured ankle		Mean differences	P-value
	Control n = 12	Intervention n = 12		
10° dorsiflexion	1.61 ± 0.74	0.81 ± 0.47	0.80 ± 0.99	0.005*
20° dorsiflexion	1.26 ± 0.47	1.00 ± 0.46	0.26 ± 0.76	0.215
15° plantarflexion	2.02 ± 0.97	1.07 ± 0.48	0.95 ± 0.91	0.007*
30° plantarflexion	2.32 ± 0.96	1.22 ± 0.82	1.10 ± 1.29	0.008*

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, P<0.05.

Table 4.4 The mean error passive joint position sense of non-injured ankle between control and intervention group.

Degrees of Error (°) (passive)	Posttest of non-injured ankle		Mean differences	P-value
	Control n = 12	Intervention n = 12		
10° dorsiflexion	1.73 ± 0.53	1.14 ± 0.59	0.58 ± 0.93	0.014*
20° dorsiflexion	1.43 ± 0.59	0.97 ± 0.57	0.46 ± 1.02	0.053
15° plantarflexion	1.55 ± 0.85	1.29 ± 0.79	0.26 ± 1.29	0.374
30° plantarflexion	1.83 ± 0.77	1.45 ± 0.84	0.38 ± 0.99	0.270

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, P<0.05.

In the passive joint reposition sense test, both groups improved joint reposition sense after 6 week of training. But there was no statistical difference at 10° dorsiflexion of control group and 20° dorsiflexion in non-injured ankle of intervention group. When compared training effected with injured ankle and non-injured ankle, the training injured ankle improved passive reposition sense better than the non-injured ankle, especially at 10° and 20° dorsiflexion but no statistical difference. For post training of intervention group, injured ankle group was more improvement in 10° dorsiflexion, 15° plantarflexion and 30° plantarflexion when compared with non-injured ankle group but no statistical difference. (**For detail see in Appendix E**)

Active joint position sense

Baseline active joint positional sense was tested in both groups. There was no statistical difference of active joint positional sense between the two groups (**Table 4.5**). Therefore, the results of the post training active joint positional sense of the two groups can be compared. **Table 4.6 and 4.7** summarized p-value and the mean error active joint position sense of injury and non-injury ankle between control and intervention group. P-value was less than joint positional sense between control and intervention group at 10° and 20° dorsiflexion. Post test of non-injured were improvement (except 10° dorsiflexion) and p-value was less than 0.05 only at 20° dorsiflexion.

Table 4.5 The mean error active joint position sense of pre-test between control and intervention group.

Degree	control	intervention	P-value
Injured ankle dorsiflexion 10°	2.16 ± 0.91	1.92 ± 1.98	0.146
Injured ankle dorsiflexion 20°	2.07 ± 0.93	1.65 ± 1.02	0.379
Injured ankle plantarflexion 15°	3.00 ± 1.40	4.19 ± 4.54	0.505
Injured ankle plantarflexion 30°	2.91 ± 1.39	3.58 ± 2.15	0.400
Non-injured ankle dorsiflexion 10°	1.77 ± 0.74	1.98 ± 1.38	0.953
Non-injured ankle dorsiflexion 20°	2.54 ± 1.24	2.13 ± 1.32	0.234
Non-injured ankle plantarflexion 15°	2.78 ± 1.36	2.20 ± 1.00	0.232
Non-injured ankle plantarflexion 30°	2.98 ± 1.09	2.88 ± 1.62	0.486

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, P<0.05.

Table 4.6 The mean error active joint position sense of injured ankle between control and intervention group.

Degrees of Error (°) (active)	Posttest of injured ankle		Mean differences	P-value
	Control n = 12	Intervention n = 12		
10° dorsiflexion	1.46 ± 0.72	0.83 ± 0.30	0.63 ± 0.91	0.015*
20° dorsiflexion	1.14 ± 0.62	0.80 ± 0.34	0.34 ± 0.45	0.284
15° plantarflexion	2.03 ± 1.10	1.63 ± 1.20	0.39 ± 1.37	0.305
30° plantarflexion	1.99 ± 1.15	1.92 ± 1.33	.075 ± 1.58	0.770

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, P<0.05.

Table 4.7 The mean error active joint position sense of non-injury ankle between control and intervention group.

Degrees of Error (°) (active)	Posttest of non-injury ankle		Mean differences	P-value
	Control n = 12	Intervention n = 12		
10° dorsiflexion	1.28 ± 0.55	1.38 ± 1.24	-0.10 ± 1.20	0.342
20° dorsiflexion	1.84 ± 0.72	1.25 ± 0.50	0.59 ± 0.97	0.049*
15° plantarflexion	1.93 ± 1.16	1.39 ± 0.70	0.53 ± 1.40	0.207
30° plantarflexion	2.12 ± 0.74	1.82 ± 1.24	0.30 ± 1.04	0.211

Compared between control and intervention group using Mann-Whitney Test Statistics.

* Significant difference between both phases, $P<0.05$.

In the active joint reposition sense test, both group improved joint reposition sense after 6 week of training. But there was no statistical difference at 10° dorsiflexion in injured ankle of intervention group and 10° dorsiflexion in non-injured ankle of control group. When compared training effected with injured ankle and non-injured ankle, the training injured ankle improved active reposition sense better than the non-injured ankle, especially at 20° dorsiflexion was less than 0.05 and 30° plantarflexion but no statistical difference. For post test of intervention group, injury ankle group was more improvement in 10° dorsiflexion but no significant and 20° dorsiflexion with significant when compared with non-injury ankle group but no significant. **(For detail see in Appendix E)**

Center of Pressure data

After the subjects had been tested by performing 5 single leg jumps onto the force-plate, center of pressure (COP) was calculated to determine X and Y co-ordinates. Range of movement (ROM) of maximum X and Y co-ordinates were determined by subtracting minimum from maximum values. Average ROM of maximum X and Y coordinates were averaged from 5 trials, and then average ROM of maximum X and Y co-ordinates was averaged among subjects in the group. Area of sway was calculated by multiplying maximum ROM of X-axis and Y-axis. **Table 4.8** and **Table 4.9** showed ROM of maximum X and Y axis. Center of pressure data from individuals were displayed in Appendix E.

Table 4.8 Center of pressure sway in injury foot from jump landing.

Groups	Mean contact area of injury Foot					
	Pretest			Posttest		
	Transverse (cm)	Longitudinal (cm)	Area sway (cm^2)	Transverse (cm)	Longitudinal (cm)	Area sway (cm^2)
Control	3.44 ± 0 .71	11.63 ± 1.45	39.62 ±10..29	2.88 ± 0.52	10.05 ± 1.34	29.05 ± 6.88
Intervention	3.85 ± 1.09	13.18 ± 1.78	38.43 ±13.49	3.24 ± 0.81	11.10 ± 1.50	28.76 ± 8.46

Table 4.9 Center of pressure sway in non-injury foot from jump landing.

Groups	Mean contact area of non-injury Foot					
	Pretest			Posttest		
	Transverse (cm)	Longitudinal (cm)	Area sway (cm^2)	Transverse (cm)	Longitudinal (cm)	Area sway (cm^2)
Control	3.21 ± 0.95	11.91 ± 1.33	51.39 ±18.22	2.78 ± 0.68	10.24 ± 1.45	35.56 ± 8.23
Intervention	3.83 ± 0.91	15.23 ± 8.64	58.07 ±31.50	3.19 ± 0.62	10.86 ± 1.43	34.94 ± 9.23

CHAPTER V

DISCUSSION AND CONCLUSION

The aim of this study is that whether the current study was to investigate the effect of proprioceptive training in basketball players with ankle instability, we expected that this program would lead to an improvement of proprioceptive capabilities in the intervention group and would therefore improve functional stability. At last, it would decrease in the frequency of recurrent ankle sprains.

Joint position sense

In the current investigation, the error of joint position sense was examined. The researcher found an improvement of proprioception in all injury ankle sides of both control and intervention groups. The intervention group was more improvement than control group. For the passive test, 10° dorsiflexion, 15° plantarflexion, and 30° plantarflexion of the intervention group had a great significant improvement as compared with the controlling group. As well as part of active test, 10° dorsiflexion of intervention group had a great significant improvement as compared with controlling group.

All non-injury ankle sides of intervention group were more improvement of proprioception as compared with controlling group, except 10° dorsiflexion of active test, but it was not significant. For the passive test, 10° dorsiflexion of the intervention group had a great significant improvement as compared with the controlling group. As well as part of active test, 20° dorsiflexion of intervention group had a great significant improvement as compared with controlling group.

From the data of the joint position sense test, it showed almost every the error joint position sense from plantarflexion direction has more than the error joint position sense from dorsiflexion direction. It was affected from Anterior Talofibular Ligament (ATFL) tear after ankle sprain had occurred.

Active and passive's joint position sense test are both different. The active joint position sense test has skeletal muscle mechanoreceptors process combined with articular mechanoreceptors. Owing to, subjects having ankle joint movement are controlled by the muscle control. In case of the passive joint position sense test, researcher has themselves ankle joint movement, as a consequence, occurring signal comes from articular mechanoreceptors. Thus, passive joint position sense test turns out more accurately the proprioceptive system than active joint position sense test.

In the current investigation, a post test of control and intervention group was the improvement for the errors of joint position sense test. It was consisted of passive and active test. This investigation was differed from the other studies. Most controlling groups in the other studies were not significant improvement for testing position; none decreased error of passive and active joint position sense. Thereby controlling group in the other studies was normal or healthy subject groups. However the best intervention or exercise groups in the other studies were accordance with this study, which was improvement for passive and active position test. For instance, **Elis E and Rosenbaum D** (2001) studied a multi-station proprioceptive exercise program in ankle instability patients which compared with healthy. The results turned out a large number of significant improvement in joint position sense and postural sway in the exercise group. The results of **Glencross and Thornton** (1981) were that they compared the injured and the noninjured legs in 24 subjects using an active angle reproduction test. Finally, they found an increased error on the injured side. There were differences between the injured and the noninjured side becoming greater as the increased plantarflexion.

For evaluation of the joint position sense of the ankle, an angle reproduction test was used in previous studies. **Jerosch et al** (1994) applied an active test design to distinguish between healthy and unstable subjects. They reported that it was significantly better joint position sense for inversion in the healthy group than the unstable group. **Bernier and Perrin** (1998) measured the active and passive joint position sense for inversion and eversion before and after a 6-week exercise program. They found no significant improvements after the exercise program in passive and active angle reproduction.

In this study, the result showed up that there were no differences in statistics between the intervention group controls. Because of all groups were exercise group which the controlling group was obtained conservative training program. The intervention group was obtained wobble board training program. Nevertheless, it had no differences in statistics; the intervention group had more decrease error of passive and active joint position sense than the controlling group every degree tests.

On the contrary, it points out that the angle reproduction test is suited to distinguish between healthy and unstable patients, between injured and noninjured legs, and to measure an effect of proprioceptive exercise program in chronically unstable patients.

In conclusion, the current results indicate that proprioception improved in all conservative training and wobble board training or it is called "rehabilitation program". It showed necessary training or exercise for proprioceptive improvement. The rehabilitation was necessary process for rehabilitating recurrent ankle sprain and decreasing rate of recurrent ankle sprain.

Center of Pressure

In the current investigation, data's contact areas from Transverse axis have decreased in post-test after proprioceptive training of control and intervention groups in both ankles when compared with pre-test, except data from post-test of control group in injury ankle that has only increased. In transverse axis, data should be decreased after proprioceptive training. Because of proprioceptive training will have more awareness of joint position and more decrease body shift weight to lateral side. Body shift weight to lateral side is to lead to ankle sprain and develops recurrent ankle sprain. When recurrent ankle sprain is happened, it affects on ankle instability and loss of proprioception (The proprioception is the joint position awareness). Hence, the proprioception loss will be affected on increasing foot contact area. Whether the ankle instability has proprioceptive training, it will be decreased the risk at recurrent ankle sprain and protection.

In a part of longitudinal axis, data have decreased in post-test after proprioceptive training control and intervention groups in both ankles when compared with pre-test. In longitudinal axis, data should be decreased after proprioceptive training. Because of the body balance control from jump landing should be controlled by the body center of gravity in order to protect falling or injuries. From ground reaction force study, a deficit in position sense during the period prior to ground impact is likely to result in a failure to adopt the optimal position of the foot as it absorbs force during landing (**Konradsen** 2002). We can measure ground reaction force in difference. Most of measurements are magnitude of peak force, timing of peak force and reaction time. Some measurements of ground reaction force are measure in plantar contact surface area pattern.

Caulfield B. and Garrett M. (2004) were identified changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. The disordered force patterns observed in subjects with functional instability are likely to result in repeated injury due to significant increase of the ankle joint structures stress on during jump landing. They suggest that subjects are most likely to result from deficits in feed-forward motor control. **Nyska M. et al** (2003) examined changes in the pattern of force transfer between the foot and the floor, associated with chronically sprained ankles by measuring the peak forces and their timing under several regions of the feet during level walking. For chronic ankle instability patients, there is a lateral shift of body weight. A treadmill is used which was developed to overcome limitations of regular methods for the analysis of spatio-temporal gait parameters and ground reaction forces during walking and running by **Verkerke GJ. et al** (2005). The centre position of pressure shows an error (SD) of 6mm in the lateral direction and 7mm in the for/aft direction, which allows accurate measuring of gait parameters. **Gravante G. et al** (2003) determine whether centre of pressure location, plantar surface areas, or plantar pressures differ from obese and control young adults during quiet standing. Although centre of pressure location was unaffected by obesity, these young obese individuals showed significantly increased plantar contact areas and pressures.

In the current investigation, data of plantar contact surface area are explained on descriptive data. Because of data from plantar contact surface area are not totally complete. All of these, subjects do not measure plantar contact surface area after suddenly proprioceptive training. It will be affected to proprioception and data from plantar contact surface area.

Conclusion

If a disorder of pre-programmed motor control is the cause of altered patterns of GRF in ankle instability subjects it has implications for rehabilitation. Restoration of safer landing from jumping during sports activity demands relearning a motor task. The behaviour of skilled motor relies on the brain learning to control the body and to predict the consequences of this control. The therapeutic goal should rather be retrain correct sensory feed back to motor commands when landing from a jump. One method is to use the wobble board to promote pre-programming of motor control re-education using a theoretical basis which is different offered by **Freeman et al.** (1965). Recent motor control theory indicates that learning the dynamics of an object or task is essential for retraining force and control in a motor learning task. Re-educating the ankle muscles to control bodyweight in tasks required for landing from a jump allows the patient to relearn the body dynamics involved. Biofeedback from computer-assisted goniometry and GRF from force plates may be an accomplishing assistance in this task.

Proprioceptive training program in this study: conservative training in the control group and wobble board training in the intervention group, can improve proprioceptive system and strengthening of muscle groups around ankle joint. Proprioceptive training program effect to improve proprioceptive signal from skeletal muscle mechanoreceptors and articular mechanoreceptors, it was deficit when ankle sprain occurred. It can measure by joint position sense test.

On view of the submission that has an effect on proprioceptive training, conservative and wobble board training led to the significant improvements of proprioceptive capabilities in chronically unstable basketball players. The main advantage compared pre-test and post-test is the relative to home program; the performance possibility of this exercise room training after training program in every day. The evaluation of subjective feedback rate of recurrent injuries should be collected on data from them. The objective parameters evaluation and the subjective feedback of the basketball players allowed the recommendation of such a proprioceptive exercise program in the recurrent inversion injuries treatment.

Limitation & Recommendation

Proprioceptive training system for athletes' ankle instabilities called home program practice. Thus, it is not be able to be controlled it directly regarding the training's amount and time. It also has an effect on Proprioceptive training system needed be tested. It hence leads to solve problems which are to set up the training program to the daily training program. Besides this program, it is supposed to separate the training between the injured athletes and normal athletes. In other words, this program should be setting up in weight training program. An advantage of this program is that the athletes' ankle instabilities would be practiced occasionally by proprioceptive system.

Nowadays, Thai athletes' training is always not organized to separate the training program between the injured athletes and the normal athletes. It brings about the chronic injured symptom or simply called chronic stage. Furthermore, it diminishes the athletes' performances.

REFERENCES

Allegrucci M, Whitney SL, Lephart, SM and Fu FH. Shoulder kinesthesia in healthy unilateral athletes participating in upper extremity sports. Journal of Orthopaedic and Sports Physical Therapy 21 (1995): 220-226.

Amassian VE and Berlin L. Early cortical projection of Group I afferents in the forelimb muscle nerves of cat. Journal of Physiology **143**(1958): 61.

Amy SN Fu, Christina WY and Hui-Chan. Ankle Joint Proprioception and Postural Control in Basketball Players with Bilateral Ankle Sprains. The American Journal of Sports Medicine 8(33) (2005): 1174-1182.

ATtfield SF, Wilton TJ, Pratt DJ and Sambatakakis A. Soft-tissue balance and recovery of proprioception after total knee replacement. Journal of Bone and Joint Surgery 78B (1996): 540-545.

Ashton-Miller JA. Proprioceptive thresholds at the ankles: Implications for the prevention of ligament injury. In Lephart SM and Fu FH (Eds.): **Proprioception and neuromuscular control in joint stability. Champaign: Human Kinetics, 2000**, pp. 279-290.

Ashton-Miller JA, McGlashen KM and Schultz AB. Trunk positioning accuracy in children 7-18 years old. Journal of Orthopaedic Research 10 (1992): 217-225.

Barker D. The morphology of muscle receptors. In Hunt CC (Ed.): **Handbook of sensory physiology: Muscle receptors. Vol III. Berlin: Springer-Verlag, 1974**, pp. 1-190.

Barrack RL, Skinner HB and Cook SD. Proprioception of the knee joint: Paradoxical effect of training. American Journal of Physical Medicine 63 (1984):175-181.

Barrack RL, Skinner HB, Brunet ME and Cook SD. Joint laxity and proprioception in the knee. Physician and Sport Medicine 11 (1983a): 130-135.

Barrack RL, Skinner HB, Cook SD and Haddad RJ. Effect of articular disease and total knee arthroplasty on knee joint-position sense. Journal of Neurophysiology 50 (1983c): 684-687.

Barrett J and Bilisko T. The role of shoes in the prevention of ankle sprains. Sports Medicine 20 (1995): 277-280.

Barrett DS, Cobb AG and Bentley G. Joint proprioception in normal, osteoarthritic and replaced knees. Journal of Bone and Joint Surgery 73B (1991): 53-56.

Baxendale RH and Ferrell WR. Discharge characteristics of the elbow joint nerve of the cat. Brain Research 261 (1983): 195-203.

Becker HP, Rosenbaum D, Claes L and Gerngro H. Measurement of plantar pressure distribution during gait for diagnosis of functional lateral ankle instability. Abstracts of the Fifth EMED User Meeting (1996): S19.

Beighton PH, Grahame R and Bird H. **Hypermobility of Joint** (2nd ed.). London: Springer-Verlag, 1989.

Beighton PH, Solomon L and Soskolne CL. Articular mobility in an African population. Annals of the Rheumatic Diseases 32 (1973): 413-418.

Bernier JN and Perrin DH. Effect of coordination training on proprioception of the functionally unstable ankle. J Orthop Sports Phys Ther 27 (1998): 264-275.

Beynnon BD, Renstrom PA, Konradsen L, Elmqvist LG, Gottlieb D and Dirks M Validation of techniques to measure knee proprioception. In Lephart SM and Fu FH (Eds.): **Proprioception and neuromuscular control in joint stability. Champaign: Human Kinetics, 2000,** pp. 127-138.

Blasier RB, Carpenter JE and Huston L. Shoulder proprioception: Effect of joint laxity, joint position and direction of motion. Orthopaedic Review 23 (1994): 45-50.

Borsa PA, Lephart SM, Kocher MS and Lephart SP. Functional assessment of rehabilitation of shoulder proprioception for glenohumeral instability. Journal of Sport Rehabilitation 3 (1994): 84-104.

Boruta PM, Bishop JO and Braly WG. Acute lateral ankle ligament injuries: a literature review. Foot Ankle 11 (1990): 107-113.

Boyd, P.M. and Bogdan, R.J. Sports injuries. In Lorimer, D.L. Neales Common Foot Disorders: **diagnosis and management: a general clinical guide (4th ed.). Churchill Livingstone, Edinburgh, 1993,** pp. 179-180.

Boyd IA and Roberts TDM. Proprioceptive discharges from stretch receptors in the knee joint of the cat. Journal of Physiological 122 (1953): 38-58.

Boyle J, Negus V. Joint position sense in the recurrently sprained ankle joint. Australian Journal of Physiotherapy 44 (1998): 159-163.

Brain Caulfield. Functional instability of the ankle. Features and underlying causes. **Physiotherapy** 86 (2000): 401-411.

Brain Caulfield and Mary Garrett. Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. **Clinical Biomechanics** 19 (2004): 617–621.

Bullock-Saxton JE. Sensory changes associated with severe ankle sprains. **Scandinavian Journal of Rehabilitation Medcine** 27 (1995): 161-167.

Burke D, Gandevia SC and Macefield G. Responses to passive movement of receptors in joint, skin and muscle of the human hand. **Journal of Physiology** 402 (1988): 347-361.

Buschbacher RM and Koch J. Race effect on nerve conduction studies: A comparison between 50 Blacks and 50 Whites. **Archives of Physical Medicine and Rehabilitation** 80 (1999): 536-539.

Carpenter RHS. **Neurophysiology** (2nded.). London: Edward Arnold, 1990.

Clark FJ and Horch KW. Kinesthesia. In Boff KR, Kaufman L and Thomas JP (Eds.): **Handbook of perception and human performance. Vol 1. New York: John Wiley and Sons, 1986,** pp. 13.2-13.62.

Clark FJ, Burgess RC, Chapin JW and Lipscomb WT. Role of intramuscular receptors in the awareness of limb position. **Journal of Neurophysiology** 54 (1985): 1529-1540.

Clark FJ, Grigg P and Chapin JW. The contribution of articular receptors to proprioception with the fingers in humans. **Journal of Neurophysiology** 61 (1989): 186-193.

Cohen LA. Analysis of position sense in human shoulder. **Journal of Neurophysiology** 21 (1957): 550-562.

Craske B. Perception of impossible limb positions induced by tendon vibration. **Science** 196 (1977): 71-73.

Crow JL. The neural control of human movement. In Trew M and Everett T (Eds.): **Human movement (3rded.) New York: Churchill Livingstone, 1997**, pp. 73-86.

Davis SG and Trevino PF. Ankle injuries. In Baxter, D.E.: **The Foot and Ankle in Sport. Mosby, St Louis, 1995**, pp.147-161.

Decarlo MS and Talbot RW. Evaluation of ankle joint proprioception follows injection of the anterior talofibular ligament. J Orthop Sports Phys Ther 8(2) (1986): 70-75.

Edin BB. Quantitative analysis of static strain sensitivity in human mechanoreceptors from hairy skin. Journal of Neurophysiology 67 (1992): 1105-1113.

Edin BB and Abbs JH. Finger movement responses of cutaneous mechanoreceptors in the dorsal skin of the human hand. Journal of Neurophysiology 65 (1991): 657-669.

Eils E and Rosenbaum D. A multi-station proprioceptive exercise program in patients with ankle instability. Med. Sci. Sports Exerc 33(12) (2001): 1991-1998.

Euzet JP and Gahery Y. Relationships between position sense and physical practice. Journal of Human Movement Studies 28 (1995): 149-173.

Faccini R, Traina GC, Graziani S, Tugnoli V and Serra G. Electrophysiological study of meniscal innervation in arthroscopy. Journal of Sports Traumatology 12 (1990): 33-39.

Ferrell WR The adequacy of stretch receptors in the cat knee joint for signaling joint angle throughout a full range of movement. Journal of Physiology 299 (1980): 85-99.

Ferrell M and Richards JG. Analysis of the reliability and validity of the kinetic communicator exercise device. Medicine and Science in Sports and Exercise 18 (1986): 44-49.

Ferrell WR and Craske B. Contribution of joint and muscle afferents to position sense at the human proximal interphalangeal joint. Experimental Physiology 77 (1992): 331-342.

Freeman M.A.R., Dean M.R.E., Henham I.W.F. The etiology and prevention of functional instability of the foot. J Bone Joint Surg 47B (1965): 678-685.

Friden T, Roberts D, Zatterstrom R, Lindstrand A and Moritz U. Proprioception in the nearly extended knee: Measurements of position and movement in healthy individuals and in symptomatic anterior cruciate ligament injured patients. Knee Surgery, Sports Traumatology, Arthroscopy 4 (1996): 217-224.

Gandevia SC. Kinesthesia: Roles for afferent signals and motor commands. In Rowell LB and Shepherd JT (Eds.): **Handbook of physiology: Section 12: Exercise:**

Regulation and integration of multiple systems. New York: Oxford University Press, 1996, pp. 128-172.

Gandevia SC and Burke D. Projection to the cerebral cortex from proximal and distal muscles in the human upper limb. **Brain** 111 (1988): 389-403.

Gandevia SC, Allen GM and Mckenzie DK. Central fatigue: Critical issues, quantification and practical implications. In Gandevia SC, Enoka RM, McComas AJ, Stuart DG, Thomas CK (Eds.): Fatigue: **Neural and muscular mechanisms: Advances in experimental medicine and biology. Vol 384. New York: Plenum Press, 1995,** pp. 281-294.

Garsden LR and Bullock-Saxton JE. Joint reposition sense in subjects with unilateral osteoarthritis of the knee. **Clinical Rehabilitation** 13 (1999): 148-155.

Gauffin H, Tropp H and Odenrick P. Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. **Int J Sports Med** 9 (1988):141-144.

Gelfan S and Carter S. Muscle sense in man. **Experimental Neurology** 18 (1967): 469-473.

Glencross D and Thornton E. Position sense following joint injury. **Journal of Sports Medicine** 21 (1981): 23-27.

Goodwin GM, McCloskey DI and Matthews PBC. The contribution of muscle afferents to kinesthesia shown by vibration induced illusions of movements and by paralyzing joint afferents. **Brains** 95 (1972): 705-748.

Gordon S, Roger D. The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly. **JAGS** 52 (2004): 573–576.

Gravante G, Russo G, Pomara F and Ridola C. Comparison of ground reaction forces between obese and control young adults during quiet standing on a baropodometric platform. **Clinical Biomechanics** 18 (2003): 780–782.

Gregory JE and Proske U. Development of proprioception. In Meisami E and Timiras PS (Eds.): **Handbook of human growth and developmental biology. Vol 1: Part B. Florida: CRC Press (1990)**, pp. 95-108.

Grigg P. Peripheral neural mechanisms in proprioception. **Journal of Sport Rehabilitation** 3 (1994): 2-17.

Grigg P and Hoffman AH. Properties of Ruffini afferents revealed by stress analysis of isolated sections of cat knee capsule. **Journal of Neurophysiology** 40 (1982): 41-54.

Gross MT Effects of recurrent lateral ankle sprains on active and passive judgments of joint position. **Phys Ther.** 67 (1987):1505–1509.

Guanche CA, Solomonow M and D' Ambrosia RD. Peripheral afferents of the shoulder: Relationship between active and passive restrains regulating muscle activation. In Lephart SM and Fu FH (Eds.): **Proprioception and neuromuscular control in joint stability. Champaign: Human Kinetics, 2000**, pp. 99-108.

Guyton AC and Hall JE. 1996. **Textbook of medical Physiology** (9th ed.). Philadelphia: WB Suanders company.

Hall MG, Ferrell WR, Sturrock RD, Hamblen DL and Baxandale RH. The effect of the hypermobility syndrome on knee joint proprioception. **British Journal of Rheumatology** 34 (1995): 121-125.

Hamann W. Mammalian cutaneous mechanoreceptors. Progress **in Biophysic and Molecular Biology** 64(1995): 81-104.

Hearn M, Crowe A and Deessen W. Influence of age on proprioceptive accuracy in two dimentions. **Perceptual and Motor Skills** 69 (1989): 811-818.

Hockenbury R and Sammarco G. Evaluation and Treatment of Ankle Sprains. **THE PHYSICIAN AND SPORTSMEDICINE** 29(2), 2001.

Hogervorst T and Brand RA. Mechanoreceptors in joint function. **Journal of Bone and Joint Surgery** 80A (1998): 1365-1378.

Hollis JM, Blasier RD, Charlene MF and Hofmann OE. Biomechanical comparison of reconstruction techniques in stimulated lateral ankle ligament injury. **The American Journal of Sports Medicine** 23 (6) (1995): 678-682.

Hulliger M, Nordh E, Thelin AE and Vallbo AB. The responses of afferent fibres from the glabrous skin of the hand during voluntary finger movements in man. **Journal of Physiology** 291 (1979): 233-249.

Hurley MV, Rees J and Newham DJ. Quadriceps function, proprioceptive acuiry and functional performance in healthy young, middle-age and elderly subjects. Age and Ageing 27 (1998): 55-62.

Hurley MV, Scott DL, Rees J and Newham DJ. Sensorimotor changes and functional performance in patients with knee osteoarthritis. Annals of the Rheumatic Diseases 56 (1997): 641-648.

Hutton RS and Atwater SW. Acute and chronic adaptations of muscle receptors in response to increased use. Sports Medicine 14 (1992): 406-421.

Hutton RS and Nelson DL. Stretch sensitivity of Golgi tendon organs in fatigued gastrocnemius muscle. Medicine and Science in Sports and Exercise 18 (1986): 69-74.

Isakov E, Mirzrahi J, Solzi P, Susak Z and Lotem M. Response of the peroneal muscles to sudden inversion of the ankle during standing. **International Journal of Sport Biomechanics 2** (1986), 100-109.

Jami L. **Golgi tendon organs in mammalian skeletal muscle: Functional properties and central actions.** Physiology Review 72 (1992): 623-666.

Janwantanakul P. การฟื้นฟูระบบ proprioception ในผู้ป่วยที่ได้รับบาดเจ็บที่ข้อต่อ. **วารสารกายภาพบำบัด** ปีที่ 23 ฉบับที่ 3กันยายน-ธันวาคม 2544: 45-47.

Janwantanakul P. **Proprioception at the Shoulder Complex**: The Effects of Test-Associated Variables, 2001.

Janwantanakul P, Magarey ME, Jones MA and Dansie BR. Variation in shoulder position sense at mid- and extreme range of motion. **Archives of Physical Medicine and Rehabilitation**, 2001.

Jerosch J, Prymka M. Proprioception and joint stability. **Knee Surgery, Sports Traumatology, Arthroscopy** 4 (1996): 171-179.

Jerosch J, Prymka M and Castro WHM. Proprioception of knee joints with a lesion of the medial meniscus. Acta Orthropaedica Belgica 62 (1996a): 41-45.

Jerosch J, WHM Castro, Hoffstetter I and Bischof M. Proprioception of the ankle in healthy volunteers and in athletes with unstable ankle joints. Deutsche Zeitschrift fur Sportmedizin 45 (1994): 380-389.

Julie N. Bernier and David H. Effect of Coordination Training on Proprioception of the Functionally Unstable Ankle. J Orthop Sports Ther Apr 27(4) (1998): 264-75.

Kaplan FS, Nixon JE, Reitz M, Rindfleish L and Tucker J. Age-related changes in proprioception and sensation of joint position. Acta Orthopeadica Scandinavica 56 (1985): 72-74.

Kleinrensink GJ, Stoeckart R, Meulstee J, Kaulesar-Sukul DMKS, Vleeming A, Snijders CJ and van Noort A. Lowered motor conduction velocity of the peroneal nerve after inversion trauma. Medicine and Science in Sports and Exercise 26 (1994): 877-883.

Koff E, Naeser MA, Pieniadz JM, Foundas AL and Levine HL. Computed tomographic scan hemispheric asymmetries in right- and left-handed male and female subjects. Archives of Neurology 43 (1986): 48491.

Konradsen L. Sensori-motor control of the uninjured and injured human ankle. **J. Electromyogr. Kinesiol.** 12 (2002), 199–203.

Konradsen L and Magnusson P. Increased inversion angle replication error in functional ankle instability. Knee Surgery Sports Traumatology Srthroscopy 8 (2000): 246-251.

Konradsen L, Voight M, Hojsgaard C. Ankle inversion injuries. The role of the dynamic defense mechanism. Am J Sports Med 25 (1997): 54-58.

Koralewicz LM and Engh GA. Comparison of proprioception in arthritic and age-matched normal knees. Journal of Bone and Joint Surgery 82A (2000): 1582-1588.

Lattanzio PJ, Petrella RJ, Sproule JR and Fowler PJ. Effect of fatigue on knee proprioception. Clinical Journal of Sport Medicine 7 (1997): 22-27.

Lentell G, Baas B, Lopez D, McGuire L, Sarrels M. and Snyder, P. The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. Journal of Orthopaedic and Sports Physical Therapy 21 (1995), 206-215.

Lephart SM and Henry TJ. The physiological basis for open and closed kinetic chain rehabilitation for the upper extremity. Journal of Sport Rehabilitation 5 (1996): 71-87.

Lephart SM, Pincivero DM, Giraldo JL and Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. American Journal of Sports Medicine 25 (1997): 130-137.

Lephart SM, Swanik CB and Boonriong T. Anatomy and Physiology of proprioception and neuromuscular control. Athletic Therapy Today 3 (September issue) (1998b): 6-9.

Lord SR and Ward JA. Age-associated differences in sensori-motor function and balance in community dwelling women. Age and Ageing 23 (1994): 454602.

Mallik AK, Ferrell WR, McDonald AG and Sturrock RD. Impaired proprioceptive acuity at the proximal interphalangeal joint in patients with hypermobility syndrome. British Journal of Rheumatology 33 (1994): 631-637.

Marks R, Quinney HA and Wessel J. Proprioceptive sensibility in women with normal and osteoarthritic knee joints. Clinical Rheumatology 12 (1993): 170-175.

Marks R. Effect of exercise induced fatigue on position sense of the knee. Australian Journal of Physiotherapy 40 (1994): 175-181.

Macefield G, Gandevia SC and Burke D. Perceptual responses to microstimulation of single afferents innervating joints, muscles and skin of the human hand. Journal of Physiology 429 (1990): 113-129.

Macefield G, Hagbarth KE, Gorman R, Gandevia SC and Burke K. Decline in spindle support to alpha motorneurones during sustained voluntary contractions. Journal of Physiology 44 (1991) 0: 497-512.

Maier A, Eldred E and Edgerton VR. The effects on spindles of muscle atrophy and hypertrophy. Experimental Neurology 37 (1972): 100-123.

Matthews PBC. Proprioc eptors and their contribution to somatosensory mapping: Complex messages require complex processing. Canadian Journal of Physiology and Pharmacology 66 (1988): 430-437.

Matthews PBC and Simmons A. Sensations of finger movement elicited by pulling upon flexor tendons in man. Journal of Physiology 239 (1974): 27-28.

McCloskey DI. Kinesthetic sensibility. **Physiological Reviews** 58 (1978): 763-820.

McCloskey DI. Kinesthesia, Kinesthetic Perception. In Adelman G (Ed.): **Encyclopedia of neuroscience. Boston: Birkhaeuser**, 1987.

McCloskey DI, Cross MJ, Honner R and Potter EK. Sensory effects of pulling or vibrating exposed tendons in man. **Brain** 106 (1983): 21-37.

McCloskey DI. Muscle, cutaneous and joint receptors in kinaesthesia. In Ferrell WR and Proske U (Eds.): **Neural control of movement. New York: Plenum Press, 1995,** pp. 53-60.

Mense S and Skeppar P. Discharge behaviour of feline gamma-motoneurones following induction of an artificial myositis. **Pain** 46 (1991): 201-210.

Merton PA. Human position sense and sense of effort. **Symposia of the Society for Experimental Biology** 18 (1964): 387-400.

Mitz AR and Winstein C. The motor system I: Lower centers. In Cohen H (Ed.): **Neuroscience for rehabilitation. Philadephia: JB Lippincott Company, 1993**, pp. 141-175.

Moberg E. The role of cutaneous afferents in position sense, kinesthesia, and motor function of the hand. **Brain** 106 (1983): 1-19.

Moore JC. The Golgi tendon organ: A review and update. **American Journal of Occupational Therapy** 38 (1984): 227-236.

Nakanishi T, Takita K and Toyokura Y. SEPs to tactile tap in man. **Electroencepphalography and Clinical Neurophysiology** 34 (1973): 1-6.

Nitz AJ, Dobner JJ and Kersey D. Nerve injury and grades II and III ankle sprains. **American Journal of Sports Medicine** 13 (1985): 177-182.

Newton RA. Joint receptor contributions to reflexive and kinesthetic responses. **Physical Therapy** 62 (1982): 22-29.

Nyska M, Shabat S, Simkin A, Neeb M, Matan Y and Mann G. Dynamic force distribution during level walking under the feet of patients with chronic ankle instability. **Br J Sports Med** 2003; 37: 495-497.

Osborne MD, Chou LS, Laskowski ER, Smith J and Kaufman KR. The effect of ankle disk training on muscle reaction time in subjects with a history of ankle sprain. **AmJ Sports Med** 29(5) (2001): 627-32.

Oscarsson O and Rosen I. Projection to cerebral cortex of large muscle-spindle afferents in forelimb nerves of the cat. Journal of Physiology 169 (1963): 924-945.

Pai YC, Rymer WZ, Chang RW and Sharma L. Effect of age and osteoarthritis on knee proprioception. Arthritis and Rheumatism 40 (1997): 2260-2265.

Payne KA Berg K and Latin RW. Ankle injuries and ankle strength, flexibility, and proprioception in college basketball players. J Athl Train. 32(1997):221-225.

Petrella RJ, Lattanzio PJ and Nelson MG. Effect of age and activity on knee joint proprioception. American Journal of Physical Medicine and Rehabilitation 76 (1997):235-241.

Phillips CG, Powell TPS and Wiesendanger M. Projection from low threshold muscle afferents of hand and forearm to area 3a of baboon's cortex. Journal of Physiology 217 (1971): 419-446.

Pitman MI, Nainzadeh N, Menche D, Galsaberti R and Song EK. The intra-operative evaluation of the neurosensory function of the anterior cruciate ligament in humans using somatosensory evoked potentials. Arthroscopy 8 (1992): 442-447.

Proske U, Wise AK and Gregory JE. The role of muscle receptors in the detection of movements. Progress in Neurobiology 60 (2000): 85-96.

Provins KA. The effect of peripheral nerve block on the appreciation and execution of finger movements. Journal of Physiology 143 (1958): 55-67.

Restuccia D, Valeriani M, Barba C, Le Pera D, Tonali P and Mauguiere F. Different contribution of joint and cutaneous inputs to early scalp somatosensory evoked potentials. Muscle and Nerve 22 (1999): 910-919.

Rossi A and Grigg P. Characteristics of hip joint mechanoreceptors in the cat. Journal of Neurophysiology 47 (1982): 1029-1042.

Ryan L. Mechanical stability, muscle strength, and proprioception in the functionally unstable ankle. J Physiother 40 (1994): 41-47.

Rymer WZ and D'Almeida A. Joint position sense: The effects of muscle contraction. Brain 103 (1980): 1-22.

Sakai H, Tanaka S, Kurosawa H and Masujima A. The effect of exercise on anterior knee laxity in female basketball players. International Journal of Sports Medicine 13 (1992): 552-554.

Schaible HG and Schmidt RF. Effects of experimental arthritis on the sensory properties of fine articular afferent units. Journal of Neurophysiology 54 (1985): 1109-1122.

Schaible HG and Schmidt RF. Responses of fine medial articular nerve afferents to passive movements of knee joint. Journal of Neurophysiology 49 (1983): 1118-1126.

Schmidt RF. Somatovisceral sensibility. In Schmidt RF (Ed.): **Sensory physiology (3rd ed.). Germany: Springer-Verlag, 1986**, pp. 30-53.

Schmidt R, Benesch S, Bender A, Claes L and Gerngroß H. Training of Proprioceptive and Coordinative Parameters in Patients with Chronic Ankle Instability. Z Orthop Ihre Grenzgeb. 143(2) (2005): 227-32.

Schutte MJ and Happel LJ. Joint innervation in joint injury. Clinics in Sports Medicine 9 (1990): 511-517.

Shapiro MS, Kabo JM, Mitchell PW and Loren G. Ankle sprain prophylaxis: an analysis of the stabilizing effect of braces and tape. The American Journal of Sports Medicine 22 (1) (1994): 78-82.

Sharma L, Pai YC, Holtkamp K and Rymer WZ. Is knee joint proprioception worse in the arthritic knee versus the unaffected knee in unilateral knee osteoarthritis? Arthritis and Rheumatism 40 (1997): 1518-1525.

Sharpe MH and Miles TS. Position sense at the elbow after fatiguing contractions. Experimental Brain Research 94 (1993): 179-182.

Shepherd GM. **Neurobiology** (3rd ed). New York: Oxford University Press (1994).

Sherrington CS. On proprio-ceptive system especially in its reflex aspect. Brain 29 (1906): 467-482.

Sheth P, Yu B, Laskowski ER and An KN. Ankle disk training influences reaction times of selected muscles in a simulated ankle sprain. AmJ Sports Med 25(4) (1997): 538-43.

Shimoyama I, Ninchoji T and Uemura K. The finger-tapping test: A quantitative analysis. Archives of Neurology 47 (1990): 681-684.

Simpson KJ and Jiang P. Foot landing position during gait influences ground reaction forces. <u>Clinical Biomechanics</u> 14 (1998): 396-402.

Skinner HB, Barrack RL and Cook SD. Age related decline in proprioception. <u>Clinical Orthopaedics and Related Research</u> 184 (1984): 208-211.

Skinner H, Wyatt MP, Hodgdon JA, Conard DW and Barrack RL. Effect of fatigue on joint position sense of the knee. <u>Journal of Orthopaedic Research</u> 4 (1986a): 112-118.

Skinner HB, Wyatt MP, Hodgdon JA, Conrad DW and Barrack RL. Exercise related knee joint laxity. <u>American Journal of Sports Medicine</u> 14 (1986b): 30-34.

Skoglund S. Anatomical and physiological studies of knee joint innervation in the cat. <u>Physiologica Scandinavica</u> 36 (suppl.) (1956): 1-101.

Sperry RW. Neural basis of the spontaneous optokinetic responses produced by visual neural inversion. <u>Journal of Comparative and Physiological Psychology</u> 43 (1950): 482-489.

Stephens JA ,Reinking RM and Stuart DG. **Tendon organs of cat medial gastrocnemius: Responses to active and passive forces as a function of muscle length**, 1975

Stuart DG. Goslow GE, Mosher CG and Reinking RM. Stretch responsiveness of Golgi tendon organs. <u>Experimental Brain Reseach</u> 10 (1970): 463-476.

Taimela S, Kankaapaa M and Luoto S. The effect of lumbar fatigue on the ability to sense a change in lumbar position. <u>Spine</u> 24 (1999): 1322-1327.

Taylor JL, Butler JE and Gandevia SC. Changes in muscle afferents, motorneurons and motor drive during muscle fatigue. <u>European Journal of Applied Physiology</u> 83 (2000): 106-115.

Tibone JE, Fechter J and Kao JT. Evaluation of a proprioception pathway in patients with stable and unstable shoulders with somatosensory cortical evoked potentials. <u>Journal of Shoulder and Elbow Surgery</u> 6 (1997): 440-443.

Todor JI and Kyprie Pm. Hand differences in the rate and variability of rapid tapping. <u>Journal of Motor Behaviour</u> 12 (1980): 57-62.

Tracey DJ. Characteristics of wrist joint receptors in the cat. <u>Experimental Brain Research</u> 34 (1979): 165-176.

Tropp H. Commentary: Functional Ankle Instability Revisited. **Journal of Athletic Training** 37(4) (2002): 512-515.

Tropp H, Askling C and Gillquist J. Prevention of ankle sprains. **Am J Sports Med** 13 (1985): 259-262.

Vallbo AB. Afferent discharge from human muscle spindles in noncontracting muscles: Steady state impulse frequency as a function of joint angle. **Acta Physiologica Scandinavia** 90 (1974a): 303-318.

Vallbo AB, Olsson KA, Westberg KG and Clark FJ. Microstimulation of single tactile afferents from the human hand. **Brain** 107 (1984): 727-749.

Van Emden J. Motor asymmetry in normal adults. **Unpublished master in Applied Scince thesis.** University of South Australia, 1994

Verkerke GJ, Hof AL, Zijlstrab W, Amenta W and Rakhorsta G. Determining the centre of pressure during walking and running using an instrumented treadmill. **Journal of Biomechanics** 38 (2005): 1881–1885.

Victoria M and Adrian M. A 4-week wobble board exercise programme improved muscle onset latency and perceived stability in individuals with a functionally unstable ankle. **Physical Therapy in Sport** 6 (2005): 181–187.

Visser J and Geuze RH. Kinaesthetic acuity in adolescent boys: A longitudinal study. **Developmental Medicine and Child Neurology** 42 (2000): 93-96.

Voight ML, Hardin JA, Blackburn TA, Tippett S and Canner GC. The effect of muscle fatigue on and the relationship of arm dominance to shoulder proprioception. **Journal of Orthopaedic and Sports Physical Therapy** 23 (1996): 562-572.

Weisman G, Pope MH and Johnson RJ. Cyclic loading in knee ligament injuries. **American Journal of Sports Medicine** 8 (1980): 24-30.

Wester JU, Jespersen SM, Nielsen KD and Neumann L. Wobble board training after partial sprains of the lateral ligament of the ankle: a prospective randomized study. **J Orthop Sports Phys Ther** 23 (1996): 332-336.

Willems T, Witvrouw E, Verstuyft† J, Vaes P and Dirk De Clercq. Proprioception and Muscle Strength in Subjects With a History of Ankle Sprains and Chronic Instability. **Journal of Athletic Training** 37(4) (2002): 487-493.

Yamashita T, Cavanaugh JM, Ozaktay AC, Avramov AI, Getchell TV and King AI. Effect of substance P on mechanosensitive units of tissues around and in the lumbar facet joint. **Journal of Orthopaedic Research** 11 (1993): 205-214.

Young-Hoo Kwon **Ground Reaction Force**. Available from: http://www.kwon3d.com/theory/grf/grf.html [1998]

Zimny ML. Mechanoreceptors in articular tissues. **American Journal of Anatomy** 182 (1988): 16-32.

APPENDICES

APPENDIX A

เอกสารชี้แจงข้อมูล/คำแนะนำแก่ผู้เข้าร่วมโครงการ

(Patient Information Sheet)

ชื่อโครงการ ผลของการฝึกระบบโพรพริโอเซ็พทีฟที่เกิดขึ้นในนักบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้า

ผู้ทำการวิจัย นาย ธนาวุฒิ อาจกิจโกศล
นิสิตหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาเวชศาสตร์การกีฬา

อาจารย์ที่ปรึกษาโครงการ รศ.นพ. พงศ์ศักดิ์ ยุกตะนันทน์

อาจารย์ที่ปรึกษาร่วม ผศ.นพ. สมพล สงวนรังศิริกุล

ผู้ดูแลที่ติดต่อได้

1. รศ.นพ. พงศ์ศักดิ์ ยุกตะนันทน์ ภาคออร์โธปิดิกส์ คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โทรศัพท์ 081-627-5141
2. ผศ.นพ. สมพล สงวนรังศิริกุล ภาคสรีรวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โทรศัพท์ 02-252-7854 ต่อ 129 (ที่ทำงาน)
3. นาย ธนาวุฒิ อาจกิจโกศล ภาควิชาสรีรวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โทรศัพท์ 09-785-7058

สถานที่วิจัย

1. ภาคสรีรวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
2. การกีฬาแห่งประเทศไทย

ความเป็นมาของโครงการ

กีฬาบาสเก็ตบอลเป็นกีฬาที่มีความเสี่ยงต่อการเกิดการบาดเจ็บของข้อเท้าอยู่ในลำดับต้นๆ เมื่อนักกีฬาได้รับบาดเจ็บแล้วก็จะเข้าไปรับการรักษาที่สถานพยาบาล แต่ไม่ได้คำนึงถึงโปรแกรมการฟื้นฟูการทำงานของข้อเท้า ซึ่งในส่วนของการแพทย์พบว่าเมื่อเกิดการบาดเจ็บของข้อเท้าแล้วอีกสิ่งหนึ่งที่เกิดขึ้นพร้อมกันก็คือ เกิดการสูญเสียของระบบโพรพริโอเซ็ฟทีฟ

การสูญเสียของระบบโพรพริโอเซ็ฟทีฟนี้เป็นปัจจัยหนึ่งที่ทำให้เกิดภาวะความไม่มั่นคงของข้อเท้าและจะส่งผลให้เกิดความเสี่ยงต่อการบาดเจ็บซ้ำ หรือที่เรียกว่า recurrent ankle sprain ได้ ซึ่งโปรแกรมการฟื้นฟูด้วยการฝึกระบบโพรพริโอเซ็ฟทีฟโดยใช้ wobble board จึงเป็นโปรแกรมหนึ่งที่มีการแนะนำให้ฝึก เพื่อเป็นการกระตุ้นให้ระบบโพรพริโอเซ็ฟทีฟกลับมาทำงานอีกครั้ง

ผู้ทำการวิจัยจึงมีความสนใจว่าการฝึกระบบโพรพริโอเซ็ฟทีฟโดยใช้ wobble board นั้นสามารถเพิ่มหรือกระตุ้นการทำงานของระบบโพรพริโอเซ็ฟทีฟได้จริงหรือไม่ และการที่เกิดการสูญเสียของระบบโพรพริโอเซ็ฟทีฟจะส่งผลอย่างไรต่อแรงปฏิกิริยาที่เกิดขึ้นจากการกระโดด เพื่อที่จะได้นำความรู้นี้ไปประยุกต์ใช้ในการรักษาและการป้องกันการบาดเจ็บต่อไป

วัตถุประสงค์

1. เพื่อศึกษาระบบโพรพริโอเซ็ฟทีฟในนักบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้าหลังได้รับการฝึกระบบโพรพริโอเซ็ฟทีฟ
2. เพื่อศึกษาแรงปฏิกิริยาที่เกิดขึ้นจากการกระโดดในนักบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้าหลังได้รับการฝึกระบบโพรพริโอเซ็ฟทีฟ

รายละเอียดที่จะปฏิบัติต่อผู้เข้าร่วมโครงการ

1. ท่านจะได้รับการสัมภาษณ์โดยผู้ทำการวิจัย เพื่อสอบถามข้อมูลทั่วไป ประวัติการเกิดข้อเท้าแพลง ประวัติในการรักษา

2. ผู้เข้าร่วมการวิจัยทั้ง 2 กลุ่มจะได้รับการขอร้องให้มาทำการทดสอบและประเมินผลทั้งหมด 2 ครั้งคือ ครั้งแรกเป็นการทดสอบก่อนการฝึก ครั้งที่ 2 จะเป็นการทดสอบและประเมินผลหลังการฝึกเป็นเวลา 6 สัปดาห์ ซึ่งการทดสอบและการประเมินจะประกอบไปด้วย การทดสอบ joint position sense และการวัด ground reaction force ในห้องปฏิบัติการ โดยมีผู้ทำวิจัยคอยดูแลอยู่อย่างใกล้ชิด ดังนั้นจึงจะไม่มีอันตรายเกิดขึ้นแก่ตัวท่านแต่อย่างใด

3. ขั้นตอนการวิจัย เมื่อท่านมาถึงสถานที่ทำวิจัย ผู้ทำการวิจัยจะทำการจัดเตรียมให้ท่านอยู่ในท่านั่งบนเครื่อง Cybex 6000 เพื่อทำการทดสอบ joint position sense แล้วทำการอธิบายรายละเอียดในการทดสอบ โดยท่านจะต้องทำการทดสอบทั้งหมด 3 ครั้ง จากนั้นผู้ทำการวิจัยจะจัดเตรียมให้ท่านยืนขาเดียวบนกล่องที่มีความสูง 40 เซนติเมตร โดยมี force plate วางอยู่ด้านหน้าแล้วทำการอธิบายถึงรายละเอียด เมื่อท่านพร้อม ผู้ทำการวิจัยจะทำการกำหนดให้ท่านกระโดดลงมายัง force plate ที่อยู่ด้านหน้า โดยให้ท่านกระโดดทั้งหมด 5 ครั้ง ในระหว่างการทดสอบดังกล่าว ท่านจะอยู่ภายใต้การดูแลของผู้ทำการวิจัย และจะไม่ก่อให้เกิดอันตรายใดๆแก่ท่าน

4. ท่านที่อยู่ในกลุ่มทดลองจะได้รับการอธิบายถึงรายละเอียดในการฝึก wobble board และจะต้องทำการฝึก wobble board เป็นเวลา 6 สัปดาห์

5. ท่านจะได้รับค่าชดเชยในการเดินทางท่านละ 200 บาท

ประโยชน์และผลข้างเคียงที่จะเกิดขึ้นแก่ผู้เข้าร่วมโครงการ

1. ท่านจะได้ทราบถึงระบบโพรพริโอเซ็ฟทีฟของข้อเท้าตนเองทั้งก่อนและหลังการฝึกระบบ โพรพริโอเซ็ฟทีฟโดยใช้ wobble board

2. ท่านจะได้ทราบถึงแรงปฏิกิริยาที่เกิดขึ้นจากการกระโดดที่กระทำต่อเท้าทั้งก่อนและหลังการฝึกระบบโพรพริโอเซ็ฟทีฟโดยใช้ wobble board

3. ท่านจะได้รับคำแนะนำเกี่ยวกับการรักษา การฟื้นฟู และการป้องกันการบาดเจ็บที่เกิดขึ้นอย่างถูกต้อง

การเก็บข้อมูลเป็นความลับ

ผู้ทำการวิจัยขอยืนยันว่า ข้อมูลที่เกี่ยวกับตัวท่านจะถูกเก็บไว้เป็นความลับ และจะใช้สำหรับงานวิจัยนี้เท่านั้นและชื่อของท่านจะไม่ปรากฏในแบบฟอร์มการเก็บข้อมูลและในฐานข้อมูลทั่วไป โดยมีผู้ทำวิจัยคนเดียวเท่านั้นที่ทราบรายละเอียดของข้อมูลนี้ ผู้ทำการวิจัยขอกราบขอบพระคุณทุกท่านที่ให้ความร่วมมือในการทำวิจัยครั้งนี้ และท่านสามารถขอถอนตัวออกจากโครงการวิจัยได้ทุกเวลา

APPENDIX B

ใบยินยอมเข้าร่วมการวิจัย (Consent form)

การวิจัยเรื่อง ผลของการฝึกระบบโพรพริโอเซ็พทีฟและแรงปฏิกิริยาที่เกิดขึ้นต่อพื้นในนักกีฬาบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้า

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

ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยในครั้งนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่เกิดขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆที่ข้าพเจ้าสงสัยด้วยความเต็มใจไม่ปิดบังซ่อนเร้น จนข้าพเจ้าพอใจ

ข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้ และเข้าร่วมโครงการวิจัยนี้โดยสมัครใจ และการบอกเลิกการเข้าร่วมการวิจัยนี้ จะไม่มีผลต่อการรักษาโรคที่ข้าพเจ้าจะพึงได้รับต่อไป

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็น ด้วยเหตุผลทางวิชาการเท่านั้น

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ

ลงนาม... ผู้ยินยอม

(...)

ลงนาม ....พยาน

(...)

ลงนาม ....ผู้ทำวิจัย

(...)

APPENDIX C

แบบบันทึกข้อมูลส่วนบุคคล

การวิจัยเรื่อง ผลของการฝึกระบบโพรพริโอเซ็พทีฟและแรงปฏิกิริยาที่เกิดขึ้นต่อพื้นในนักกีฬาบาสเก็ตบอลที่มีภาวะความไม่มั่นคงของข้อเท้า

ส่วนที่ 1 ข้อมูลพื้นฐาน

เลขที่ ....

น้ำหนัก............................กิโลกรัมส่วนสูง.......................................เซนติเมตร

วัน/เดือน/ปีเกิด...อายุ.....................................ปี

ส่วนที่ 2 เกณฑ์ในการคัดเข้า

หากท่านอยู่ในเกณฑ์ของแต่ละข้อ ให้ขีดเครื่องหมาย X ลงในช่อง ☐ **ใช่ และหากท่านไม่ได้อยู่ในเกณฑ์ให้ขีดเครื่องหมาย X ลงในช่☐ ไม่ใช่**

	ใช่	ไม่ใช่
1. ท่านเป็นนักบาสเก็ตบอลชายอายุ 18-30 ปี และมีประสบการณ์ในการเล่นบาสมาไม่น้อยกว่า 3 ปี	☐	☐
2. ท่านมีประวัติการเกิดข้อเท้าแพลงมากกว่า 2 ครั้งในระยะเวลา 6 เดือน	☐	☐
3. ท่านมีความรู้สึกว่าข้อเท้าไม่มั่นคง หรือข้อเท้าหลวม	☐	☐

เกณฑ์ในการคัดออก

	ใช่	ไม่ใช่
1. มีประวัติการหักของข้อเท้า หรือเข้ารับการผ่าตัดบริเวณข้อเท้า	☐	☐
2. มีการอ่อนแรงของกล้ามเนื้อบริเวณรอบข้อเท้า	☐	☐
3. มีการจำกัดองศาการเคลื่อนไหวของข้อเท้า	☐	☐
4. อาการเจ็บหรือปวด เมื่อมีการเคลื่อนไหวของข้อเท้า	☐	☐

คู่มือในการฝึก wobble board

สัปดาห์ที่ 1 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาทั้ง 2 ข้าง เป็นเวลา 10 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 2 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาทั้ง 2 ข้าง เป็นเวลา 15 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 3 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาทั้ง 2 ข้าง เป็นเวลา 15 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 4 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 10 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 5 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 15 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 6 : ให้ท่านยืนทรงตัวบน wobble board ด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 20 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่	ครั้งที่ 1	ครั้งที่ 2	ครั้งที่ 3
1			
2			
3			
4			
5			
6			

***หมายเหตุ...

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คู่มือการฝึก Proprioceptive

สัปดาห์ที่ 1 : ให้ท่านยืนหลับตาทรงตัวด้วยขาทั้ง 2 ข้าง เป็นเวลา 10 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 2 : ให้ท่านยืนทรงตัวด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 10 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 3 : ให้ท่านยืนทรงตัวด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 15 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 4 : ให้ท่านยืนทรงตัวด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียวบนเบาะหรือหมอน เป็นเวลา 10 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 5 : ให้ท่านยืนหลับตาทรงตัวด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 15 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่ 6 : ให้ท่านยืนหลับตาทรงตัวด้วยขาข้างที่มีภาวะความไม่มั่นคงของข้อเท้าข้างเดียว เป็นเวลา 20 นาที โดยทำ 3 วันต่อสัปดาห์

สัปดาห์ที่	ครั้งที่ 1	ครั้งที่ 2	ครั้งที่ 3
1			
2			
3			
4			
5			
6			

***หมายเหตุ..

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APPENDIX D

Table I The mean error passive joint position sense of injury ankle between pre-test and post-test

Degrees of Error (°) in left ankle	Control Group		p-value	Intervention group		p-value
	Pretest	Posttest		Pretest	Posttest	
10° dorsiflexion	2.26 ± 0.90	1.61 ± 0.74	0.014*	1.69 ± 0.55	0.81 ± 0.47	0.002*
20° dorsiflexion	1.86 ± 0.71	1.26 ± 0.47	0.005*	1.75 ± 0.63	1.00 ± 0.46	0.011*
15°plantarflexion	3.05 ± 1.09	2.02 ± 0.97	0.003*	1.99 ± 0.62	1.07 ± 0.48	0.002*
30°plantarflexion	3.08 ± 1.23	2.32 ± 0.96	0.010*	2.30 ± 1.20	1.22 ± 0.82	0.002*

Compared between control and intervention group using Wilcoxon signed-rank test.

* Significant difference between both phases, P<0.05.

Table II The mean error passive joint position sense of non-injury ankle between pre-test and post-test

Degrees of Error (°) in right ankle	Control Group		p-value	Intervention group		p-value
	Pretest	Posttest		Pretest	Posttest	
10° dorsiflexion	2.12 ± 0.88	1.73 ± 0.53	0.126	1.75 ± 0.64	1.14 ± 0.59	0.024*
20° dorsiflexion	1.93 ± 0.84	1.43 ± 0.59	0.018*	1.35 ± 0.41	0.97 ± 0.57	0.096
15° plantarflexion	2.43 ± 0.55	1.55 ± 0.85	0.003*	2.17 ± 1.07	1.29 ± 0.79	0.023*
30° plantarflexion	2.80 ± 0.89	1.83 ± 0.77	0.003*	2.78 ± 1.24	1.45 ± 0.84	0.003*

Compared between control and intervention group using Wilcoxon signed-rank test.

* Significant difference between both phases, P<0.05.

Table III The mean error active joint position sense of injury ankle between pre-test and post-test

Degrees of Error (°) in right ankle	Control Group		p-value	Intervention group		p-value
	Pretest	Posttest		Pretest	Posttest	
10° dorsiflexion	2.16 ± 0.91	1.46 ± 0.72	0.009*	1.92 ± 1.98	0.83 ± 0.30	0.055
20° dorsiflexion	2.07 ± 0.93	1.14 ± 0.62	0.003*	1.65 ± 1.02	0.80 ± 0.34	0.018*
15° plantarflexion	3.00 ± 1.40	2.03 ± 1.11	0.004*	4.19 ± 4.54	1.63 ± 1.20	0.002*
30° plantarflexion	2.91 ± 1.39	1.99 ± 1.15	0.002*	3.58 ± 2.15	1.92 ± 1.33	0.002*

Compared between control and intervention group using Wilcoxon signed-rank test.

* Significant difference between both phases, $P<0.05$.

Table IV The mean error active joint position sense of non-injury ankle between pre-test and post-test

Degrees of Error (°) in right ankle	Control Group		p-value	Intervention group		p-value
	Pretest	Posttest		Pretest	Posttest	
10° dorsiflexion	1.77 ± 0.74	1.28 ± 0.55	0.055	1.98 ± 1.38	1.38 ± 1.24	0.024*
20° dorsiflexion	2.54 ± 1.24	1.84 ± 0.72	0.015*	2.13 ± 1.32	1.25 ± 0.50	0.022*
15° plantarflexion	2.78 ± 1.36	1.93 ± 1.16	0.003*	2.20 ± 1.00	1.39 ± 0.70	0.040*
30° plantarflexion	2.98 ± 1.09	2.12 ± 0.74	0.002*	2.88 ± 1.62	1.82 ± 1.24	0.028*

Compared between control and intervention group using Wilcoxon signed-rank test.

* Significant difference between both phases, $P<0.05$.

APPENDIX E

Data's error passive joint position sense of injury ankle

	cipd10	cipod10	cipd20	cipod20	cipp15	cipop15	cipp30	cipop30
1	2.70	1.00	2.70	1.30	4.30	1.00	2.30	1.00
2	2.00	2.00	1.00	.70	3.00	2.70	3.00	2.70
3	2.70	1.30	1.30	1.30	2.70	2.30	4.70	3.70
4	2.00	1.30	1.30	1.30	4.30	3.30	2.30	2.70
5	3.70	3.30	1.70	1.30	4.00	3.30	5.00	3.70
6	1.30	.70	2.30	.70	.70	1.00	1.00	1.00
7	.70	.70	1.00	.70	2.30	1.30	2.30	1.70
8	3.00	1.70	2.70	1.70	3.30	2.00	4.70	3.00
9	3.00	1.30	2.30	1.70	3.00	2.00	3.30	3.00
10	1.70	2.00	2.70	1.70	2.70	1.30	3.70	2.00
11	1.30	1.70	1.00	.70	2.00	.70	2.30	1.30
12	3.00	2.30	2.30	2.00	4.30	3.30	2.30	2.00

	iipd10	iipod10	iipd20	iipod20	iipp15	iipop15	iipp30	iipop30
1	2.30	1.00	2.00	1.30	3.00	1.30	3.00	1.00
2	1.30	1.00	.70	1.70	2.30	2.00	5.00	3.00
3	1.30	.30	1.70	1.30	2.00	.70	2.00	.70
4	1.00	.00	1.30	.30	2.00	.70	2.00	.30
5	2.00	.70	3.30	1.70	2.30	2.00	2.00	1.00
6	1.70	1.30	2.00	1.00	1.30	1.00	1.30	1.00
7	2.30	1.70	2.00	1.00	1.30	.70	2.30	2.00
8	1.30	.70	2.00	.70	2.70	1.00	4.00	2.30
9	2.70	1.00	1.30	1.00	1.30	.70	.70	.30
10	1.00	.30	1.30	1.00	1.30	1.00	1.70	1.00
11	1.70	.70	1.70	.70	1.70	.70	2.30	1.30
12	1.70	1.00	1.70	.30	2.70	1.00	1.30	.70

Data's error passive joint position sense of non-injury ankle

	cnpd10	cnpod10	cnpd20	cnpod20	cnpp15	cnpop15	cnpp30	cnpop30
1	.70	1.70	1.00	.70	2.30	.70	2.30	1.30
2	2.30	2.00	3.00	2.70	2.70	2.30	3.00	2.30
3	2.70	2.30	2.70	2.00	3.70	3.30	3.30	3.00
4	1.00	2.00	1.30	1.30	2.30	2.00	2.00	1.70
5	2.30	2.00	.70	1.30	2.30	2.00	1.00	1.00
6	.70	.70	1.00	.70	2.30	.30	2.30	1.00
7	1.70	.70	1.70	.70	2.00	1.00	2.70	1.00
8	3.00	2.00	2.70	1.70	2.00	1.00	4.00	2.30
9	3.00	2.00	2.70	1.70	2.00	1.00	4.00	2.30
10	2.70	2.00	2.30	1.70	2.00	2.00	3.70	3.00
11	3.00	1.30	2.70	1.30	3.30	1.00	2.30	1.00
12	2.30	2.00	1.30	1.30	2.30	2.00	3.00	2.00

	inpd10	inpod10	inpd20	inpod20	inpp15	inpop15	inpp30	inpop30
1	2.70	1.70	1.00	2.30	1.30	2.70	4.00	2.00
2	2.00	2.00	1.30	.00	3.30	2.30	4.70	2.70
3	1.70	.30	1.70	1.00	1.30	.70	2.70	.70
4	1.00	1.00	.70	.70	2.70	1.00	1.70	.70
5	2.00	1.70	1.30	1.30	1.70	1.00	4.00	1.70
6	1.30	1.70	1.00	1.00	1.00	.70	.70	.30
7	2.30	1.30	1.70	1.00	4.00	2.00	2.00	1.70
8	.30	1.00	.70	1.00	.70	.70	1.30	1.30
9	1.70	1.00	1.70	1.30	3.70	2.30	2.30	2.00
10	2.00	1.00	1.70	1.00	2.00	.70	4.00	2.70
11	2.30	1.00	1.70	.30	2.00	.70	3.30	1.30
12	1.70	.00	1.70	.70	2.30	.70	2.70	.30

Data's error active joint position sense of injury ankle

	cipd10	cipod10	cipd20	cipod20	cipp15	cipop15	cipp30	cipop30
1	1.30	.30	3.70	1.00	3.00	.70	2.30	1.70
2	2.30	2.00	2.70	2.30	6.00	4.00	2.00	1.30
3	1.30	1.30	1.30	1.00	4.30	3.70	1.30	1.00
4	3.70	2.30	1.70	1.00	2.00	2.30	2.30	1.00
5	2.00	2.30	2.30	2.00	5.00	3.30	6.30	4.70
6	1.30	.30	1.70	.30	3.00	1.30	1.70	.70
7	2.00	1.00	1.30	.70	1.70	1.00	4.00	2.70
8	2.00	1.70	2.30	1.00	1.70	1.00	3.00	2.70
9	3.00	1.70	3.70	2.00	2.00	1.30	4.00	2.70
10	2.30	1.30	1.70	1.00	3.00	2.00	3.70	2.70
11	1.00	1.00	.70	.70	2.30	1.70	2.00	1.70
12	3.70	2.30	1.70	.70	2.00	2.00	2.30	1.00

	iipd10	iipod10	iipd20	iipod20	iipp15	iipop15	iipp30	iipop30
1	.30	1.30	3.00	1.00	3.30	2.00	2.70	1.00
2	7.70	.30	3.00	1.30	18.30	5.00	9.30	5.00
3	1.00	1.00	2.70	.70	1.70	.30	1.00	.00
4	1.30	1.00	.30	1.00	4.30	1.00	3.70	2.30
5	3.00	.70	.70	1.00	3.70	1.30	4.00	2.30
6	1.30	1.00	.30	.30	2.70	2.00	2.30	1.70
7	.30	1.00	1.30	1.00	3.30	2.00	5.30	3.00
8	1.70	.70	2.70	.70	1.00	.70	3.30	2.70
9	.70	.30	1.70	1.00	2.30	1.00	3.00	2.30
10	1.70	.70	1.70	1.00	4.00	2.00	1.30	1.00
11	2.30	1.00	1.70	.30	3.00	1.00	3.30	1.00
12	1.70	1.00	.70	.30	2.70	1.30	3.70	.70

Data's error active joint position sense of non-injury ankle

	cnpd10	cnpod10	cnpd20	cnpod20	cnpp15	cnpop15	cnpp30	cnpop30
1	1.00	1.00	.70	.70	1.70	1.00	2.00	1.70
2	1.30	1.30	2.00	2.00	2.30	2.00	3.00	2.30
3	2.30	2.00	1.70	1.70	.70	1.00	1.30	1.00
4	1.00	2.00	4.00	3.00	5.00	3.70	3.30	3.00
5	1.00	1.00	2.00	1.70	4.00	3.70	2.30	2.00
6	1.00	1.00	.30	.70	1.30	.30	1.70	1.00
7	2.00	1.00	2.70	1.30	3.00	1.70	2.30	1.30
8	3.00	1.70	2.70	2.00	3.00	1.70	4.30	3.00
9	2.70	.70	3.00	2.00	3.00	1.70	4.30	2.70
10	2.30	1.30	3.70	2.00	2.00	1.30	4.70	2.70
11	1.30	.30	3.70	2.00	2.30	1.30	3.30	2.00
12	2.30	2.00	4.00	3.00	5.00	3.70	3.30	2.70

	inpd10	inpod10	inpd20	inpod20	inpp15	inpop15	inpp30	inpop30
1	1.70	1.00	2.00	2.30	1.30	1.30	1.70	1.00
2	1.70	2.30	5.70	1.30	2.70	3.00	2.30	4.70
3	2.30	.70	1.00	1.00	2.00	1.00	3.00	.70
4	1.00	1.70	2.00	1.70	1.70	2.00	6.70	2.70
5	.30	1.00	1.00	1.30	4.70	1.00	2.70	1.30
6	2.00	1.00	.70	1.00	2.30	2.00	1.00	.70
7	1.70	1.00	2.30	1.00	1.70	2.00	2.00	1.70
8	6.00	5.00	1.70	1.00	2.30	1.00	4.70	3.30
9	1.30	.70	3.00	2.00	.70	.70	2.70	1.70
10	2.00	.70	2.70	1.00	1.70	1.00	4.30	2.30
11	1.70	.70	1.70	.70	2.30	1.00	1.70	.70
12	2.00	.70	1.70	.70	3.00	.70	1.70	1.00

Center of pressure data

Pre-test injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Control 1	32.47	136.37	4427.93	27.78	113.94	3165.25	34.67	117.33	4067.83	24.80	145.80	3615.84	30.62	130.26	3988.56
Control 2	28.90	123.36	3565.10	30.82	115.48	3559.09	30.00	113.98	3419.40	27.78	125.53	3487.22	21.20	128.81	2717.89
Control 3	25.58	140.28	3588.36	26.36	103.28	2722.46	20.12	130.36	2622.84	20.05	106.4	2133.32	27.64	118.43	3273.41
Control 4	27.13	110.8	3006.00	28.32	137.34	3889.47	25.40	125.91	3198.11	30.63	110.52	3385.23	33.17	135.72	4501.83
Control 5	32.97	82.44	2718.05	42.24	63.62	2687.31	33.75	92.87	3134.36	27.58	88.59	2443.31	30.61	72.68	2224.74
Control 6	58.47	123.68	7231.57	36.11	123.68	4466.09	50.11	128.21	6423.32	61.66	121.47	7489.84	51.60	114.81	5924.20
Control 7	26.42	100.78	2662.61	22.75	123.23	2803.48	27.35	117.54	3214.72	29.96	93.54	2802.46	60.63	108.76	6594.12
Control 8	48.54	102.26	4963.70	30.64	82.57	2529.95	42.44	92.79	3938.01	34.67	125.38	4346.93	34.59	107.62	3722.58
Control 9	28.69	139.87	4012.87	36.54	110.23	4027.80	35.23	122.50	4315.68	37.01	132.76	4913.45	37.08	137.09	5083.30
Control 10	41.21	103.69	4273.07	32.26	125.52	4049.28	37.74	113.36	4278.21	43.03	114.48	4926.07	43.86	170.50	7478.13
Control 11	42.87	111.23	4768.43	30.18	107.62	3247.97	25.09	117.94	2959.12	31.62	94.51	2988.41	34.29	106.80	3662.17
Control 12	34.91	140.80	4915.33	39.33	122.38	4813.21	41.21	114.69	4726.38	29.13	119.75	3488.32	47.47	135.33	6424.12

Post-test injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Control 1	23.76	126.46	3004.69	24.93	112.56	2806.12	22.44	134.61	3020.65	37.57	123.26	4630.88	27.20	115.94	3153.57
Control 2	26.14	106.69	2788.88	23.09	97.16	2243.42	22.16	81.76	1811.80	28.39	104.48	2966.19	23.22	97.51	2264.18
Control 3	33.64	120.34	4048.24	37.53	92.29	3463.64	27.51	83.80	2305.34	19.05	128.25	2443.16	25.36	79.97	2028.04
Control 4	20.20	126.31	2551.46	20.79	85.24	1772.14	23.08	86.48	1995.96	24.44	90.81	2219.40	22.14	98.24	2175.03
Control 5	40.76	85.52	3485.80	34.19	87.54	2992.99	39.18	73.35	2873.85	35.05	66.93	2345.90	43.77	77.41	3382.82
Control 6	21.50	81.59	1754.19	19.05	122.11	2326.20	29.04	99.25	2882.22	25.55	73.79	1885.34	20.86	84.61	1764.97
Control 7	36.47	70.07	2555.45	20.06	93.66	1878.82	28.41	119.30	3389.31	29.88	67.44	2015.11	24.03	79.23	1903.90
Control 8	21.70	98.42	2135.71	28.86	92.41	2666.95	24.45	75.52	1846.46	21.69	86.76	1881.82	24.20	90.79	2197.12
Control 9	36.67	123.37	4523.98	32.18	107.79	3468.68	24.44	99.99	2443.76	30.11	102.68	3091.70	26.95	122.22	3293.83
Control 10	30.03	120.12	3607.20	28.75	104.51	3004.66	39.98	99.81	3990.40	34.12	102.36	3492.52	43.27	119.20	5157.78
Control 11	22.51	138.53	3118.31	19.36	115.20	2230.27	33.40	106.90	3570.46	39.62	74.65	2957.63	30.76	85.87	2641.36
Control 12	35.05	122.05	4277.85	29.81	111.21	3315.17	32.41	107.62	2487.96	27.99	126.64	2544.65	20.39	127.38	2597.28

Pre-test non-injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Control 1	47.06	160.98	7575.72	35.68	131.89	4705.84	40.13	148.00	5939.24	35.19	122.29	4303.38	45.90	126.41	5802.22
Control 2	30.37	128.19	3893.13	15.12	156.53	2366.73	15.34	92.15	1413.58	20.15	125.87	2536.28	20.42	125.36	2559.85
Control 3	24.76	120.24	2977.14	30.19	124.26	3751.41	20.88	106.25	2218.50	24.38	114.04	2780.30	25.04	140.65	3521.88
Control 4	26.67	103.29	2754.74	25.27	126.70	3201.71	26.5	124.78	3306.67	40.00	129.63	5185.20	38.96	121.10	4718.06
Control 5	25.68	73.56	1889.02	36.51	76.05	2776.59	44.44	110.34	4903.51	29.40	87.67	2577.50	34.02	85.63	2913.13
Control 6	55.95	121.82	6815.83	44.45	133.78	5946.52	55.51	123.27	6842.72	48.27	111.29	5371.97	55.67	144.28	8032.07
Control 7	16.64	115.55	1922.75	15.81	115.10	1819.73	14.05	112.60	1582.03	16.16	112.61	1819.78	15.69	113.99	1788.50
Control 8	45.94	120.79	5549.09	33.63	118.10	3971.70	23.16	124.44	2882.03	24.31	108.42	2635.69	23.31	117.95	2749.42
Control 9	28.56	110.28	3149.60	30.18	108.29	3268.19	27.45	97.51	2676.65	36.72	102.36	3758.66	37.69	108.86	4102.93
Control 10	29.95	123.35	3694.33	32.23	103.32	3330.00	40.11	130.27	5225.13	30.97	101.11	3131.07	34.84	116.80	4069.31
Control 11	28.93	122.57	3545.95	27.23	133.13	3625.13	39.41	120.38	4744.18	29.81	138.05	4115.27	25.02	128.67	3219.32
Control 12	38.76	136.56	5293.07	40.05	112.25	4495.61	28.79	121.78	3506.05	42.78	119.75	5122.91	47.27	156.16	7334.41

Post-test non-injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Control 1	26.69	130.09	3472.10	19.24	117.68	2264.16	27.08	128.23	3472.47	21.21	116.16	2463.75	37.51	135.07	5066.48
Control 2	15.81	113.31	1791.43	23.19	70.35	1631.42	22.27	87.48	1948.18	16.15	79.12	1277.79	19.33	87.59	1693.12
Control 3	20.00	102.5	2050.00	15.08	71.96	1085.16	18.80	96.29	1810.25	22.52	121.25	2730.55	20.40	80.54	1644.04
Control 4	24.99	115.84	2894.84	27.56	105.07	2895.73	27.19	95.98	2609.70	32.38	104.44	3381.77	24.73	103.32	2555.10
Control 5	40.65	93.23	3789.80	35.71	85.66	3058.92	32.28	74.29	2398.08	36.68	70.18	2574.20	41.93	80.34	3368.66
Control 6	24.42	123.68	3020.27	38.58	96.70	3730.69	33.70	120.44	4058.83	40.55	91.84	3724.11	23.41	108.09	2530.39
Control 7	37.92	83.91	3181.87	27.87	79.39	2212.60	25.43	116.17	2954.20	29.17	92.66	2702.89	29.86	103.17	3080.66
Control 8	15.44	73.49	1134.69	15.78	82.55	1302.64	13.51	100.39	1356.27	17.31	75.61	1308.81	16.86	83.76	1412.19
Control 9	27.75	121.25	3364.69	34.53	103.78	3583.52	29.01	114.93	3334.12	36.56	109.65	4008.80	42.00	101.29	4254.18
Control 10	34.59	112.23	3882.04	25.02	93.13	2330.11	26.76	122.08	3266.86	37.79	99.78	3770.69	21.34	102.53	2187.99
Control 11	36.67	123.53	4529.85	22.13	105.78	2340.91	29.93	120.17	3596.69	27.74	127.28	3530.75	19.23	128.29	2370.87
Control 12	35.28	123.38	4352.85	28.93	138.53	4007.67	30.07	101.07	3039.18	41.21	100.01	4121.41	43.16	101.77	4392.39

Pre-test injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Intervention 1	34.80	118.06	4108.49	63.19	150.67	9520.84	36.38	142.77	5193.97	50.64	124.61	6310.25	29.24	129.52	3787.17
Intervention 2	53.67	120.98	6493.00	43.82	124.25	5444.64	69.80	170.50	11900.9	55.82	151.53	8458.41	55.79	141.84	7913.25
Intervention 3	41.30	113.35	4681.36	43.40	156.87	6808.16	33.53	94.01	3152.16	37.59	116.26	4370.21	41.23	131.41	5418.03
Intervention 4	29.76	128.79	3832.79	26.22	120.88	3169.47	32.21	142.51	4590.25	25.69	173.32	4452.59	26.06	137.54	3584.29
Intervention 5	59.75	132.95	7943.76	50.56	123.45	6241.63	37.79	125.94	4759.27	23.67	131.39	3110.00	34.28	126.26	4328.19
Intervention 6	43.37	243.40	10556.26	70.27	142.37	10004.34	58.59	127.93	7495.42	52.52	109.00	5724.68	57.55	106.01	6100.88
Intervention 7	36.72	153.78	5643.86	63.56	132.42	8416.62	49.59	143.44	7113.19	30.03	149.25	4481.98	45.35	113.74	5158.11
Intervention 8	22.92	103.03	2361.45	25.62	101.71	2605.81	36.95	100.87	3727.15	33.75	95.24	3214.35	29.81	99.10	2954.17
Intervention 9	46.50	158.50	7370.25	32.32	127.46	4119.51	35.62	165.38	5890.84	24.61	180.47	4441.37	34.75	194.99	3639.55
Intervention 10	45.34	135.61	6148.56	25.43	86.15	2190.80	23.09	89.39	2064.02	35.78	111.98	4006.64	32.41	105.77	3428.01
Intervention 11	32.02	129.89	4159.08	31.73	154.54	4903.55	28.47	142.22	4049.00	28.79	137.96	3971.87	35.71	139.39	4977.62
Intervention 12	20.02	111.21	2226.42	22.44	123.37	2768.42	25.08	128.09	3212.50	23.56	120.88	2847.93	21.45	120.90	2593.31

Post-test injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Intervention 1	37.66	237.18	8932.20	59.08	139.99	8270.61	53.33	147.93	7889.11	60.82	175.76	10689.72	52.13	181.19	9445.44
Intervention 2	41.31	134.48	5555.37	58.71	241.32	14167.90	82.10	171.88	14111.35	43.13	157.42	6789.53	44.08	173.32	7639.95
Intervention 3	30.08	108.20	3254.66	38.54	94.05	3624.69	29.68	93.58	2777.45	27.12	108.30	2937.10	48.38	90.93	4399.19
Intervention 4	24.98	138.82	3467.72	21.35	132.32	2825.03	23.53	92.81	2183.82	28.55	114.16	3259.27	37.74	95.34	3598.13
Intervention 5	45.83	85.48	3917.55	51.17	81.07	4148.35	37.36	120.00	4483.20	49.90	87.62	4372.24	36.36	77.18	2806.27
Intervention 6	38.03	113.95	4333.52	49.86	127.4	6352.16	42.13	121.95	5137.75	30.19	100.0	3019.00	40.04	112.68	4511.71
Intervention 7	21.92	132.78	2910.54	31.96	103.24	3299.55	24.32	109.42	2661.09	29.18	82.16	2397.43	53.33	106.90	5700.98
Intervention 8	24.15	110.66	2670.99	22.01	93.60	2060.14	21.80	62.99	1373.18	20.30	125.04	2538.31	22.49	75.42	1696.20
Intervention 9	21.07	150.51	3171.25	20.74	133.33	2765.26	22.73	178.06	4047.30	22.55	166.66	3758.18	20.46	105.38	2156.08
Intervention 10	35.43	99.29	3517.85	45.52	119.42	5436.00	46.16	111.23	5134.38	33.65	89.26	3003.60	45.24	104.80	4741.15
Intervention 11	25.64	118.92	3049.11	25.89	122.50	3171.53	21.62	124.61	2694.07	22.63	118.52	2682.11	28.63	125.70	3598.79
Intervention 12	19.51	102.22	1994.31	37.27	98.49	3670.72	23.54	117.14	2757.48	19.57	102.40	2003.97	22.30	106.67	2378.74

Pre-test non-injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Intervention 1	43.47	106.44	4626.95	41.27	96.64	3988.33	40.02	111.84	4475.84	40.88	103.27	4221.68	52.44	149.73	7851.84
Intervention 2	69.00	156.95	10829.55	31.92	153.36	4895.25	37.05	117.34	4347.45	39.25	119.30	4682.53	38.39	136.75	5249.83
Intervention 3	39.20	114.60	4492.32	27.58	124.00	3419.92	23.34	101.68	2373.21	39.53	151.72	5997.49	32.40	93.72	3036.53
Intervention 4	55.58	155.20	8626.02	35.06	165.95	5818.21	28.98	148.98	4317.44	37.21	178.28	6633.80	54.41	167.04	9088.65
Intervention 5	31.84	115.52	3678.16	27.97	168.58	4715.18	36.45	177.04	6453.11	29.00	111.10	3221.90	36.96	135.66	5013.99
Intervention 6	52.04	125.36	6523.73	39.40	136.44	5375.74	31.10	149.87	4660.96	52.13	189.45	9876.03	36.24	150.28	5446.15
Intervention 7	36.03	112.59	4056.62	58.29	99.70	5811.51	57.22	100.48	5749.47	42.49	122.33	5197.80	47.98	100.11	4803.28
Intervention 8	22.76	106.50	2423.94	21.64	127.30	2754.11	35.86	96.47	3459.41	23.42	177.41	4154.94	26.41	96.95	2560.45
Intervention 9	43.26	188.29	8145.43	40.52	138.31	5604.32	47.89	147.27	7052.76	51.33	154.16	7913.03	41.75	157.02	6555.59
Intervention 10	27.59	137.53	3794.45	24.19	148.18	3584.47	31.34	121.45	3806.24	28.57	132.09	3773.81	21.81	134.80	2939.99
Intervention 11	36.08	93.90	3387.91	35.58	83.14	2958.12	47.08	102.35	4818.64	33.01	124.80	4119.65	27.45	102.35	2809.51
Intervention 12	32.85	91.62	3009.72	28.32	85.19	2412.58	27.34	82.78	2263.21	26.63	108.31	3967.40	29.75	107.30	3192.18

Post-test non-injury ankle

Group	Trial 1			Trial 2			Trial 3			Trial 4			Trial 5		
	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)	T (mm)	L (mm)	A (mm)
Intervention 1	37.73	124.64	4702.67	54.02	180.66	9759.25	46.05	191.02	8796.47	33.74	139.29	4699.65	42.91	226.66	9725.98
Intervention 2	54.70	150.18	8214.85	50.12	139.59	6996.25	48.78	128.62	6274.08	56.75	159.75	9065.81	45.65	92.76	4234.49
Intervention 3	28.96	96.26	2787.69	20.50	127.07	2604.94	27.71	92.74	2569.83	37.96	103.51	4157.00	18.25	116.06	2118.10
Intervention 4	31.73	126.10	4001.15	44.91	95.84	4304.17	33.09	132.47	4383.43	29.84	84.02	2507.16	28.37	87.30	2476.70
Intervention 5	44.44	126.25	5610.55	29.63	129.87	3848.05	26.52	96.70	2564.48	40.72	100.40	4088.29	52.67	122.21	6436.80
Intervention 6	44.90	149.72	6722.43	25.87	105.29	2723.85	65.45	117.15	7667.47	30.65	97.26	2981.02	41.73	117.38	4898.27
Intervention 7	28.75	85.46	2456.98	24.16	98.08	2369.61	21.91	79.42	1740.09	23.47	140.61	3300.12	24.56	100.88	2477.61
Intervention 8	30.19	76.15	2298.97	27.08	114.73	3106.89	30.77	122.91	3781.94	34.68	85.40	2961.67	26.24	89.91	2359.24
Intervention 9	28.56	134.77	3849.03	38.39	155.67	5976.17	26.13	157.95	4127.23	28.74	138.25	3973.31	29.30	135.78	3978.35
Intervention 10	17.14	76.94	1318.75	33.26	74.86	2489.84	19.74	108.93	2150.28	21.61	96.06	2075.86	22.95	139.17	3193.95
Intervention 11	37.31	129.76	4841.35	32.00	119.99	3839.68	21.47	116.42	2499.54	44.41	109.80	4876.22	29.44	112.22	3299.27
Intervention 12	28.71	86.77	2491.17	30.26	108.34	3278.37	28.42	102.09	2901.40	28.36	75.73	2147.70	28.95	109.16	3160.18

BIOGRAPHY

Mr. Thanavud Ardkijkosol was born in 13 October 1981. He graduated Bachelor of Science in Physiotherapy from the Faculty of Allied Health Sciences Chulalongkorn University in 2003.

He had been worked as a physiotherapist at Samitivej Hospital from June to July 2003 and worked as a physiotherapist in Thai national football team (world cup qualified zone Asia 2003). He had been worked as a physiotherapist in Thai national basketball team (male) SEA Games 23rd and SEA Games 24th. He had been worked as a physiotherapist in Thai national volleyball team (male) Asian Games 15th.

inappropriate foot positioning prior to touchdown has been hypothesized to be a fundamental cause of ankle sprains

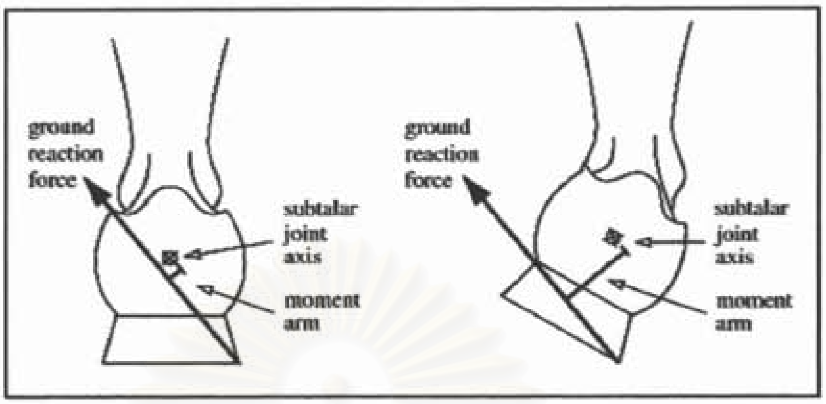

Figure 2.7 A view of the foot and ankle from behind at touchdown when performing a cutting or side-shuffle movement. The moment arm of the ground reaction force about the subtalar joint when the foot is flat (left) is much smaller than the moment arm when the foot is supinated (right).

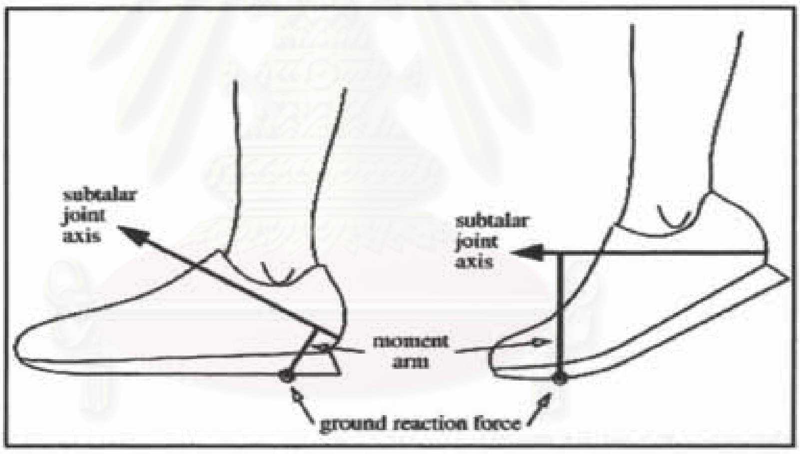

Figure 2.8 A view of the foot and ankle in the sagittal plane at touchdown when performing a cutting or side-shuffle movement. The moment arm of the horizontal component of the ground reaction force about the subtalar joint when first contact is made with the heel (left) is much smaller than the moment arm when the foot is plantarflexed and first contact is made at the toe (right).

Caulfield B. and Garrett M. (2004) observed changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. Fourteen subjects with unstable ankles and 10 age, sex and activity matched controls performed five single leg jumps onto a force platform whilst ground reaction forces were sampled.

The disordered force patterns observed in subjects with functional instability are likely to result in repeated injury due to significant increase in stress on ankle joint structures during jump landing. They suggested that subjects are most likely to result from deficits in feed-forward motor control. **Nyska M. et al** (2003) examined changes in the pattern of force transfer between the foot and the floor associated with chronically sprained ankles by measuring the peak forces and their timing under several regions of the feet during level walking. Twelve young male subjects with recurrent ankle sprains were studied. Twelve healthy men served as a control group. In patients with chronic ankle instability, there was a slowing down of weight transfer from heel strike to toe off, a reduced impact at the beginning and end of the stance phase, and a lateral shift of body weight. **Becker HP. et al** (1996) studied patients with longstanding chronic ankle instability to demonstrate whether dynamic measurement of plantar pressure distribution could identify patients with functional ankle instability. Sixty five patients were measured and calculated intraindividually, compared with a group of 100 healthy subjects. Plantar pressure patterns were measured during gait using a capacitive platform. Dynamic measurement of plantar pressure could identify a group of patients walking on the lateral side of the unstable foot when compared with the stable foot. This finding explained the deficit of peroneal strength during stance phase based on a proprioceptive defect after trauma. **Simpson K. J. and Jiang P.** (1998) determined foot landing position influenced on the ground reaction forces of two coordinate systems during gait. Thirty females were assigned to a foot landing group: toe-out, toe-in or neutral. Each participant walked 10 trials across a force platform while three-dimensional motion was captured. For toe-out participants, greater medio-lateral ground reaction forces of the room coordinate system indicate excessive forces are generated by toe-out participants that do not contribute to moving the participant forward. Furthermore, mediolateral loading on the foot increases proportionally with the degree of toe-out.

In previous study, patients with ankle instability or abnormal foot would have abnormal ground reaction force when compared with normal foot. Addition, they had reaction time less than normal foot.

The basketball players had ankle instability because of the ankle sprain. Ankle sprain caused proprioceptive signal deficit and it also caused ground reaction force which came from jump landing.

These studies showed that proprioceptive training will improve patients function by decrease rate of the occurrence of ankle instability. We are interested in applying proprioceptive training for rehabilitation program in injured basketball players with ankle instability. We would like to study the effect of proprioceptive training, especially with ankle disc, by measuring proprioception and ground reaction force in ankle injured basketball players with instability program compare to traditional training.

CHAPTER III

Research Methodology

Research design

This study is an experimental research which aims to examine the effect of proprioceptive training on basketball players and ankle instability.

Research methodology

Population and Sample

In this study, the target population was Thai basketball players who play in basketball association and have ankle joint-instability in age 18-30 years old. The samples were Thai basketball players who play in the association and have ankle joint-instability in age 18-30 years old who were recruiting by following the inclusion criteria.

Inclusion Criteria

- Being Thai male basketball players who play in association and have experience at least 3 years.
- Have history of inversion ankle sprain more than 2 times in 6 month.
- Have ankle instability or feel give way (Anterior Drawer Test: positive)

Exclusion Criteria

- Have history of ankle joint fracture or operate of ankle joint
- Have muscles weakness around ankle joint
- Have limit range of movement in ankle joint
- Have pain when move ankle joint