BIOMECHANICAL ALTERATIONS OF JUMPING IN VOLLEYBALL PLAYERS AFTER JOINT STRAPPING OF THE LOWER EXTREMITY OF THE BODY

NUTTIKA NAKPHET

A THESIS SUBMITTED IN PARTIAL FULFILLMENT REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (SPORTS SCIENCE) FACULTY OF GRADUATE STUDIES MAHIDOL UNIVERSITY

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Nuttika Nakphet
Miss. Nuttika Nakphet
Candidate

Sirirat Hirunrat
Assoc.Prof. Sirirat Hirunrat, Ph.D.
Major-Advisor

Thyon Chentanez, Ph.D.
Assoc.Prof. Thyon Chentanez, Ph.D.
Co-advisor

Mr. Suwat Sidthilaw, Ph.D.
Co-advisor

Prof. Liangchai Limlomwongse, Ph.D.
Dean
Faculty of Graduate Studies

Asst.Prof. Panya Kaimuk, M.D.
Board of Orthopedic Surgery Chair
Master of Science Program in Sports Science
College of Sports Science and Technology

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on

May 28, 2002

Miss. Nuttika Nakphet
Candidate

Assoc.Prof. Sirirat Hirunrat, Ph.D.
Chair

Assoc.Prof. Thyon Chentanez, Ph.D.
Member

Prof. Liangchai Limlomwongse, Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

Mr. Ruengsak Sirhiphon, M.D.
Member

Mr. Suwat Sidthilaw, Ph.D.
Member

Asst.Prof. Panya Kaimuk, M.D.
Board of Orthopedic Surgery
Director
Master of Science Program in Sports Science
College of Sports Science and Technology

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Finally, I give my deepest gratitude to my parents for their love, support and encouragement throughout my life.

Nuttika Nakphet
The purpose of this study was to investigate biomechanical alterations of jumping in volleyball players after joint strapping of the lower extremities of the body. Ten male volleyball players aged between 19-25 years participated in this study. A method of partial fixing of joints (e.g. knee, ankle, arch of foot) by adhesive strapping was used on subjects. Vertical jumps were tried in order to evaluate the effects of adhesive strapping on vertical jumping ability. Vertical jumping performance was significantly decreased by taping treatment of knees, ankles, and arch of feet in descending order. The data obtained indicated that muscles and moving mechanisms concerned with the knee contributed most to vertical jumping performance, and the ankle contributed more than the plantar fascia muscle. Paired t-test on the active range of motion (AROM) resulted in a significant difference (p<0.05) between pre- and post-application of adhesive strapping. Taping applications demonstrated reductions in ROM of ankle plantarflexion, ankle dorsiflexion, ankle inversion, ankle eversion, knee flexion, and knee extension. The partial fixing of joints by taping and vertical jumping analysis proposed may be capable of identifying the degree of contribution of each joint of the lower extremity to vertical jumping.
วิธีการอธิบายข้อต่อ (ข้อเข่า, ข้อเท้า, และฝ่าเท้า) โดยการวิเคราะห์ด้วยภาพพลาสเตอร์แบบธรรมดาตูกใช้ในกลุ่มตัวอย่างแล้วดูผลของการกระโดดในแนวตั้ง เพื่อที่จะประเมินการมีส่วนร่วมของแต่ละข้อต่อและความสามารถของการกระโดด การวิจัยครั้งนี้เปรียบเทียบผลของการกระโดดด้วยภาพพลาสเตอร์แบบธรรมดาต่และความสามารถในการกระโดดชนิดในแนวตั้งกับตัวอย่างกลุ่มตัวอย่างที่เข้าร่วมในงานวิจัยนี้ถือว่าผลเยี่ยมยอดขั้นตอน 10 คน อายุระหว่าง 19-25 ปี ความสามารถในการกระโดดในแนวตั้งแสดงผลต่างกันอย่างมีนัยสำคัญโดยการกระโดดข้อเข่า ข้อเท้า และฝ่าเท้าตามลำดับ จากข้อมูลที่ได้ก็จะว่า กลับเนื่องและกลไกการเคลื่อนไหวอยู่ที่เชิงพันธุ์ข้อเข่าข้อเท้าข้อฝ่าเท้าในขณะที่สูงต่ำต่างกันในแนวตั้ง และข้อเท้ามีส่วนร่วมมากกว่ากลับเนื่องในฝ่าเท้า (plantar fascia) จากการวิเคราะห์ทางสถิติด้วย paired t-test พบว่ามีความแตกต่างอย่างมีนัยสำคัญของการเคลื่อนไหวระหว่างตอน และหลังจากกระโดดข้อต่อทุกข้อต่อ โดยช่วงการเคลื่อนไหวของการบิดปลายเท้า การกระโดดข้อเข่าข้อเท้าข้อฝ่าเท้าใน การบิดปลายเท้าของต้นขา การยืดข้อ และการเหยียดเพาะต่อมอันที่มีเรียงข้อต่อ วิธีการอธิบายข้อต่อต่าง ๆ ด้วยภาพพลาสเตอร์แบบธรรมดาตามขั้นตอน важในการกระโดดในแนวตั้งสามารถบ่งชี้ระดับการมีส่วนร่วมของแต่ละข้อต่อของข้อต่อการกระโดดได้
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<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>min</td>
<td>Minute</td>
</tr>
<tr>
<td>ROM</td>
<td>Range of motion</td>
</tr>
<tr>
<td>AROM</td>
<td>Active range of motion</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>SEM</td>
<td>Standard error of mean</td>
</tr>
<tr>
<td>CMJ</td>
<td>Vertical jump from an erect standing position with preliminary counter movement</td>
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<tr>
<td>SJ</td>
<td>Vertical jump from a squatting position</td>
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CHAPTER I

INTRODUCTION

Jumping is one of the fundamental movements made by children after learning to walk and run. (1) A jump is a motor skill in which the body is propelled into the air by a thrust from one or both legs and then lands on one or both feet. (2) There are several kinds of jumps, such as the standing jump, standing vertical jump, long jump, high jump, and pole vault, as well as certain specialized jumps made in games and contests. (1) Vertical jumping (standing jump for height) is very important for playing of many sports such as volleyball. The spikers in volleyball may play more effectively if they can add to their reach by a jump for height during spiking. The spiker’s trunk remains upright during the crouch and preliminary arm swing. The jump begins with the upward lift of the arms and continues with extension at the hips, knees, and ankles prior to takeoff. The spiker uses a two-footed takeoff because with this from of vertical jump more upward thrust is possible and arm action can be coordinated more effectively after the takeoff. (2) If the purpose of the vertical jump is to gain greater height, the range of motion in the preparatory position should be slightly more than 90° and full extension of the body. (1) Much research has studied on both kinetics and kinematics variables of vertical jumping. (3, 4) which included the degree of contribution of various joints to jumping. (4, 5, 6, 7)

Cinematography and EMG analysis were the methods that the most researchers used to analyze the degree of joint contribution to jumping. (4, 5, 6, 7, 8)
Robertson and Fleming (1987) studied kinetics of standing broad and vertical jumping. They proposed that all three-extensor moments of hip, knee and ankle act simultaneously to produce leg extension. For the propulsive phase of the standing broad jump the contributions of the hip, knee, and ankle muscles were 45.9%, 3.9%, and 50.2%, respectively, whereas, for the vertical jump the contributions were 40.0%, 24.2%, and 35.8%, respectively. These results indicate that broad jumping utilizes the muscle groups differently than vertical jumping and show the importance of the hip and ankle musculature in the production of external work in jumping. The percentages for relative muscle contribution to the vertical jump in this study differ from the results reported by Hubley and Wells (1983). They found that the average relative contributions of the ankle and hip muscles were approximately 23% and 28% respectively, with the remaining 49% of the work being done by the muscles acting at the knee joint. In addition to, Jaric et al. (1989) demonstrated significant positive correlation between kinetic parameters of the active muscle groups and jumping height ($r = 0.217 - 0.464$). The dominant effect on these correlations was due to the knee extensors. Viitasalo and Bosco (1982) indicated that the utilization of elastic energy during jumping was possible better in subjects having a high percentage of slow twitch muscle fibers in their vastus lateralis muscles in vertical jumps.

Fukashiro and Komi (1987) reported joint reaction forces, moments, mechanical powers, and work of the lower limb during vertical jump. All the peak values of moments of maximal vertical jump from an erect standing position with a preliminary countermovement (CMJ) were greater than those of maximal vertical jump from a squatting position (SJ), but in both cases they appeared in the same rank order (hip greater than knee greater than ankle). The mechanical work of the hip
extensors was much greater than that of SJ although the work by the knee extensors and the ankle plantar flexors was almost the same in these jumps.

The present study will use the method of partial immobilization of each joint in volleyball players by using strapping technique to reveal the degree of joint contribution to vertical jumping.

1. Objectives

(1) To investigate the effects joint partial fixing in vertical jump.

(2) To evaluate degree of contribution of each joint of lower extremity on vertical jumping performance.

(3) To simulate an orthopedics abnormality of joints on jumping performance in volleyball player.
CHAPTER II
LITTERATEUR REVIEW

1. ANATOMY OF LOWER EXTREMITY

1.1 The knee

The knee joint is the largest and most complex synovial joint in the body. (10, 11) There are three articulations in the region known as the knee joint: the tibiofemoral joint, the patellofemoral joint, and the superior tibiofibular joint. (12) The structure of the knee joint is illustrated in Figure 2.1.

Figure 2.1 The knee joint is a condyloid joint allowing movement in two directions, flexion and extension, and rotation. Movements at the knee joint are complex due to the structural differences in the medial and lateral compartments of the joint.
The tibiofemoral joint is the articulation between femur and tibia illustrated in Figure 2.1. At the end of the femur are two large convex surfaces, the medial and lateral condyles, separated by the intercondylar notch in the back and the patellar, or trochlear groove in the front. (13) The lateral condyle is flatter, it has a larger surface area, it is more prominent anteriorly to hold the patellar in place, and it is basically aligned with the femur. (12) The medial condyle projects more longitudinally and medially, it is longer in the anteroposterior direction, it angles away from the femur in the rear, and it is aligned with the tibia. (12)

The condyles rest on the tibial plateau, a medial and lateral surface separated by a ridge of bone termed the intercondylar eminence. (14) The ridge of bone serves as an attachment site for ligaments, centers the joint, and stabilizes the bones in weight bearing. (12) The medial surface of the plateau is oval in shape, longer in the anteroposterior direction, and concave to accept the convex condyle of the femur. The lateral tibial plateau is circular and slightly convex. (12) Consequently, the medial tibia and femur fit fairly snugly together, but the lateral tibia and femur do not fit together because both surfaces are convex. (12) This structural difference is one of the determinate of rotation as the lateral condyle has more excursion with flexion and extension at the knee. (14)

Menisci are wedge-shaped, semilunar disc interposed between tibia and femur. (Figure 2.2) (11) Its purpose is to provide shock absorption by transmitting half of the weight-bearing load in full extension and a significant portion of the load in flexion (15), increase contact surface within the joint (11, 16), enhance lubricant of the joint (11, 14) assist with nutrition and assist the ligament in providing stability, moving...
across the tibial plateau during flexion and extension to accommodate the changing curvatures of the femoral condyles. (11)

Figure 2.2 Two fibrocartilage menisci are located in the lateral and medial compartments of the knee. The medial meniscus is crescent-shaped and the lateral meniscus is oval-shaped to match the surfaces of the tibial plateau and the differences in the shape of the femoral condyles.

The knee joint role primarily on ligaments for stability. The collateral ligaments provide stability on the medial and lateral sides of the knee and the cruciates, located inside the joint, prevent the femur from moving forward or backward on the tibial and also provide rotational stability. (16)

The strongest group of muscles in the body, the quadricep muscles, crosses the knee joint and attaches onto the tibia (tibial tubercle). (16) The quadriceps function is to extend the knee. (16) Flexion at the knee is produced by the hamstring muscles, assisted by sartorius, gracilis, popliteus and gastrocnemius. (11) The hamstring muscles attach at the back of the knee joint. In addition, four of these (semitendinosus, semimembranosus, gracilis and popliteus) are considered to medially rotate the knee, while the biceps is normally described as a lateral rotator. (11) The muscles of the
knee joint are predominantly two-joint muscles acting also at the hip: the hamstrings, the rectus femoris, the gracilis, the sartorius, and the tensor fascia latae, so hip position can influence knee range of motion. (10)

1.2 The ankle

The ankle (talocrural) joint is a uniaxial hinge joint. (10, 14, 16) It is formed by the articulations between the talus and the distal tibia and fibula. The ankle gets its stability from the bones, ligaments and tendons surrounding the joint. (16)

The deltoid ligament provides medial support (10), and the anterior and posterior talofibular ligaments and calcaneofibular ligament provide lateral support for the capsule and joint. (17)

The motions available of the talocrural joint are dorsiflexion and plantar flexion. (11) Dorsiflexion performed by the tibialis anterior, peroneus tertius, extensor digitorum longus, and extensor hallucis longus. (10) Plantar flexion performed by the gastrocnemius, soleus, and peroneus longus, with possible help from the tibialis posterior, peroneous brevis, flexor digitorum longus, and flexor hallucis longus. (10)

1.3 Subtalar joint (Talocalcaneal)

The subtalar joint is composed of posterior, anterior, and middle articulations between the talus and the calcaneus. The posterior articulation, which is the largest, is composed of a concave facet on the inferior surface of the talus and a convex facet on the body of the calcaneus. The anterior and middle articulations are formed by two convex facets on the talus and two concave facets on the calcaneus. The anterior and middle articulations share a joint capsule with the talonavicular joint; the posterior
articulation has its own capsule. The subtalar joint is reinforced by anterior, posterior, lateral, and medial talocalcaneal ligaments and the interosseus talocalcaneal ligament. (17)

The motions permitted at the joint are inversion and eversion. Which occur around an oblique axis. (17) Inversion performed by the tibialis anterior, with possible help from the flexor digitorum longus and flexor hallucis longus. (10) Eversion performed by the peroneus longus, brevis, and tertius, with possible help from the extensor digitorum longus. (10)

2. TAPING AND WRAPPING

Taping refers to the application of some type of adhesive backed tape (e.g. athletic tape or elastic tap), that adheres to the skin of a particular joint or to a limb. (16) Wrapping refers to the application of a non-adhesive cloth wrap to a joint or limb. Strapping technique have been used to prevent and treat the foot (18) and ankle (19, 20, 21, 22, 23, 24) from injuries. Strapping with adhesive tape plays a significant part in the prevention of joint injuries, particularly at the ankle and hand, and is important during early management of injury and rehabilitation. (19, 24)

Taping and bracing methods are commonly used in the management of joint injuries. (25, 26, 27, 28, 29) Athletic taping, semirigid orthosis and its effect on motor performance have been well documented. The result of Burks et al (1991) indicated that ankle taping significantly decreased performance in the vertical jump (4%), shuttle run (1.6%), and sprint (3.5%), and also restricted dorsiflexion and plantar flexion. The Swede-O brace decreased the height of vertical jump (4.6%), distance of the broad jump (3.6%), and time of sprint (3.2%). (25) The Kallasy brace decreased
performance (3.4%) in the vertical jump. (25) As well as, the result of Verbrugge (1996) reported the brace and ankle taping reduced the jump height by 2.5% and 2.9% of the mean control height. (26) The investigators of the second study indicated neither the brace nor the tape slowed the agility run times substantially. (26) These results showed quite opposite the first study. There is no evidence that sprinting is slowed by the brace more than by the tape. (26) Additionally, the investigators suggested application of adhesive tape did not significantly affect the performance of vertical jumping (26, 30) or running. (26, 27) The Modified Gibney technique with medial to lateral stirrups and continuous heel locks was the method of application, which the investigators use in their study.

Mayhew (1972) found that taping ankles decreased performance in the vertical jump and standing broad jump compared to their performance without tape. (31) Juvenal (1972) similarly described a decrease in vertical jump ability with taping. (32)

Kauranen et al. (1997) examined the effect of strapping on different components of motor performance of wrist and ankle joints and they suggested that the strapping of ankle and wrist joints reduces motor performance as measured by the following parameters: simple reaction time, choice reaction time, tapping speed and muscle strength. (33)

Refshauge et al. (2000) tested the effect on proprioception at the ankle in 25 subjects with recurrent ankle inversion sprain, with a group of 18 healthy control subjects. They suggest that the preventative effect of taping the ankle during challenging sports activities does not arise from enhanced proprioceptive performance in the dorsiflexion - plantarflexion plane of movement. (34)
Most studies on taping and bracing have focused on examining the change in range of motion or stiffness of the tape and brace after application (28, 30, 35, 36, 37, 38, 39). It has been well documented the stabilizing effect of taping and bracing rapidly decrease with exercise. (35, 36, 37, 38) Tracy et al. (1990) compared the relative effectiveness of athletic taping and a semirigid orthosis in providing inversion-eversion range restriction before, during, and after a 3 hour volleyball practice. (35) The effect of each support method on the subjects' vertical jumping ability was also assessed. Passive inversion-eversion range of motion was measured on an ankle stability test instrument during five testing sessions: 1) before support, 2) before exercise, 3) 20 minutes during exercise, 4) 60 minutes during exercise, and 5) after exercise. The result showed that both support systems significantly restricted ankle inversion-eversion ROM approximately 40% (P<0.01), but there was no significant difference between the amount of restriction provided by each of the two methods (P>0.01). That is, both adhesive taping and the semirigid orthosis were equally effective at providing initial inversion-eversion range restriction. The orthosis demonstrated no mechanical restrictive failure until before and after exercise comparisons were made, and then only eversion range of motion was compromised, but adhesive taping condition revealed maximal losses of ankle ROM restriction for both inversion and eversion at 20 minutes into exercise. Tracy found that neither the athletic taping nor the application of the orthosis had a significant effect on the athlete's ability to perform a vertical jump. Tracy et al. (1989) described that the ankle orthosis demonstrated effective range restriction capabilities, did not interfere with maximum inversion-eversion muscular performance, and retained its support effectiveness following 20 minute of dynamic exercise. (37)
The results of previous studies suggested that the use of an ankle joint orthosis might be more beneficial than the use of taping in the prevention of ankle injuries. (35, 37, 40) Ankle taping was less effective in preventing ankle injury and reinjury during football practices and games than was a laced ankle stabilizer. (40)

2.1 General objectives of taping and wrapping (strapping) (16)

Historically, taping has emerged as an important part of athletic training. The primary aim of taping and wrapping techniques is to provide support and protection to soft tissues without limiting their function unnecessarily. These techniques can be applied both before and injury (e.g. injury prevention) and after an injury during both the early, and/or later stages of injury management.

2.2.1 Injury prevention goals

Protecting against acute injuries is another major use of tape support. This protection can be achieved by limiting the motion of a body part or by securing some special device.

(1) To support areas subject to excessive or repeated stresses, therefore, decreasing the frequency or severity of injury.

(2) To support joints that have a history of injury, thus reducing the risk of re-injury.
2.2.2 Injury management goals

Early stages of injury management.

(1) To secure sterile dressings in place.

(2) To minimize the chance of further damage and/or the possibility of secondary complications (i.e. provide protection).

(3) To maintain the position of splints.

(4) To provide compression, which controls the swelling, that frequently accompanies injuries.

Later stages of injury management.

(1) To provide a measure of soft tissue (i.e. skin, muscle, tendon, ligament and joint capsule) support by placing injured structures in a position of minimal stress. This assists with optimal healing and repair, therefore, elimination the need for total immobilization of minor injuries.

(2) To enable the injured athlete to resume activity (often modified) which assists in regaining strength and flexibility of the joint or limb.

3. JUMPING

Jumping is a projection of the body into the air by means of a force made by the feet or hands against a surface. (1) In addition, a jump is a motor skill in which the body is propelled into the air by a thrust from one or both legs and then lands on one or both feet. (16)
3.1 Vertical jumping

The standing jump for height or vertical jump is widely used as a test item, and its successful performance adds to playing ability in many sports. Sargent was the first to propose the jump for height as a measure of motor ability. (41) The jump and reach test or Sargent jump test is a valuable item in a test battery, which is the simplest, and most effective of all tests of physical ability. (41) The spikers in volleyball will play more effectively if they can add to their reach by a jump for height. (1)

In the preparatory position of the vertical jumping, the muscle-connective tissue system is stretched in eccentric tension, and elastic energy is stored. If the eccentric contraction is followed immediately by concentric contraction, some of the stored elastic energy is reused during the concentric contraction, so the crouch should be followed as soon as possible by the jump. The ability to integrate the downward movement of the legs and to integrate the movement of the arms was related to use of stored elastic energy. (1)

The mature pattern in the vertical jump and reach consists of four movements in the following sequence (2):

3.1.1 There is flexion at the hips, knees, and ankles during the preparatory crouch.
3.1.2 The jump begins with a vigorous forward and upward lift by the arms.
3.1.3 The thrust is continued by forceful extension at the hips, knees, and ankles.
3.1.4 The body remains in extension until the feet are ready to retouch, and then the ankles, knees, and hips flex to absorb the shock of landing.
3.2 Movement pattern of vertical jump

3.2.1 Arm action

The movement pattern of the arms depends upon the purpose of the jump. When there is no spatial task for the arms and no demand for maximum height, arm action could be mostly a shoulder shrug with the arms not rising above shoulder level during the jump. In the jump and reach test, the non-reaching arm is pushed downward just prior to the peak of the jump. This final downward arm movement tilts the shoulder girdle laterally and raises the hand of the reaching arm higher in reaction. (2) (Figure 2.3)

3.2.2 Leg action

Following the initial movement by the arms, powerful forces from the hips and the legs are applied to thrust the body upward. In close and overlapping succession, extension occurs at the hips, knees, and ankles, with the forces that provide the movement at the hips and the knees being the most powerful. (42) The optimal crouch for the vertical jump is an individual matter but includes and effective angle at the hip as well as at the knee. Couper found that good jumpers had more erect trunks at the low point of the prejump crouch than poor jumpers. (43)
Figure 2.3 Mature form in the vertical jump and reach. There is a preparatory crouch. Then the arms begin the upward movement, followed quickly by extension at the hips, knees, and ankles. As one arm reaches upward, the other swings downward sharply in opposition.
3.3 Analysis of form in vertical jump (2)

3.3.1 Feet are nearly parallel and not more than shoulder width apart in the ready stance.

3.3.2 Knees are bent to about a right angle, and the trunk is only slightly forward in the preparatory crouch.

3.3.3 Body is in full extension from head to toes at takeoff.

3.3.4 Forward travel during the jump is minimal.

Arm action in the vertical jump is task-oriented, but the arms are not greatly hyperextended during the crouch regardless of their specific task after takeoff.

3.4 Biomechanics of vertical jump (44)

The entire jump has been divided into three distinct phases consisting of an upward propulsion, a flying and a landing phase, and is also reflected in the determined muscle excitations.

In the first part of the jump, a plantar movement of the foot must be performed for the acceleration of the body in vertical direction. This motion is produced primarily by the gastrocnemius and the soleus. As tibialis anterior muscle counteracts the plantar motion of the foot this muscle does not seem to be activated during the first part of the jump.

During vertical acceleration, extension of the shank is produced by simultaneous action of the rectus femoris and the vastus group.

During the first phase, extension of the thigh can be produced by the gluteus group and the hamstring group. The hamstrings and the biceps femoris counteract the
required motion of the shank. They are therefore not controlled during the entire jump movement. The dynamics of the thigh is primarily generated by the gluteus group.

During flight phase, the largest torque acts in the knee joint at the beginning of the landing phase. Therefore, intense activation of the rectus femoris and vastus muscle group must be expected for deceleration of the body after landing. This is also achieved by the ability of the muscles to develop high forces during eccentric muscle actions.

### 3.5 Use of the basic pattern of jumping in volleyball spike

Jumping is the primary basic skill in the pattern of volleyball spike. A short run precedes the jump, and a striking motion follows it. The function of the jump is to gain height so that the ball can be struck in such a way that it crosses the net at an acute downward angle. The movements in the pattern must be timed precisely in relation to the flight of the ball. Two or three running steps toward the net build up momentum for added height in the jump and move the spiker into the correct takeoff position slightly behind the downward trajectory of the ball. A two-footed takeoff is used by the spiker because with this form of vertical jump more upward thrust is possible and arm action can be coordinated more effectively after the takeoff. The spiker's trunk remains upright during the crouch and preliminary arm swing. The jump begins with the upward lift of the arms and continues with extension at the hips, knees, and ankles prior to takeoff. The arms contribute to the propulsion and general coordination of the jump and then continue to move into position for the striking motion that is the climax of the complex pattern. As in the jump ball in basketball, the timing of the jump in relation to the flight of the ball is a critical factor in the performance of the skill.
3.6 The factors which have influence on jumping performance

3.6.1 The influence of counter movement on jumping performance

In 1885 Marey and Demeny observed that the jumping height increased if human subjects were allowed to perform a preparatory counter movement (prestretching of the leg extensor muscles) before a vertical take off when compared to a take-off starting from semi-squatting position (no prestretch). (45)

There are a number of theories as to how a countermovement may enhance performance, included in these is the storage of energy during the countermovement and the subsequent reuse of that energy (46). The amount of stored elastic energy that can be released from human leg muscles during explosive jumps. (47) A considerable amount of the energy imposed on the legs by prestretch loading can be stored in the tendons (2663%). (48)

The contribution of the elastic energy depends on the mechanical properties of the tendons i.e. the Young’s modulus of the tendon tissue, the shape of the tendon force-deformation function, the tendon dimensions, the loading rate and the hysteresis. (49)

The movement of the body segments during the prestretches (countermovement) induced a forward rotation and during the take off, a backward rotation of the body. (48)

Jumping is usually preceded by a counter movement, which can be described as a quick bend of the knees during which the body's center of mass drops somewhat before being propelled upwards. (50) Enoka (1988) reported a 12% jump height advantage with the countermovement among a group of 44 subjects. (51)
performance-enhancing effects of the countermovement is that a concentric contraction immediately following an eccentric stretch begins with the muscle already under considerable tension, making more chemical energy available for generation of force. In addition, the countermovement uses the stretch-shortening cycle in which is in part released during immediately subsequent concentric muscle contraction. (50)

Vertical jumps are often characterized by swinging of arms a countermovement. Harman et al. (1990) examined the effects of arms and countermovement on vertical jumping. Eighteen male subjects jumped maximally from a force platform in four different ways in random order: arms with countermovement (AC), arms with no countermovement (ANC), no arms with countermovement (NAC), and no arms with no countermovement (NANC). The subjects performed three trials of each type jump and rested between trial 1-3 min. They found that both counter movement and arm swing significantly (r<0.05) improved jump height, but arm-swing's effect was greater enhancing peak total body center of mass rise both pre and post takeoff. Total body center of mass rise attributable to the arms amounted to 10% for the no countermovement jump and 39% for the countermovement jump. Trial number produced no significant effects on the dependent variables, indicating that neither practice nor fatigue influenced the jumps over the three trials of each type. (50)

In aspect of bi-lateral deficit of jumping, when the countermovement jump was from two legs, the load acting of each leg to assist the countermovement would be less than when performing a countermovement from one leg, this would change the potential for performance enhancement due to the countermovement. (52)
3.6.2 The influence of bi-lateral deficit on one-and two-legged maximal vertical jumps.

Challis (1998) defined the bi-lateral deficit means that the muscles for the two-legged jumps will not be fully activated whereas they can be for the one-legged condition. (53)

During a maximal bi-lateral muscle action the force produced has been reported to be less than the sum of the maximal uni-lateral actions; the phenomenal is known as the bi-lateral deficit. (53) Secher et al. (1988) reported a bi-lateral deficit of 82% (61.3%) for 155 subjects for a leg extension task. Using a smaller group they reported this figure increased with habituation to the task. (54) Schantz et al. (1989) looking a number of different groups reported bi-lateral deficits, for a leg extension task, from 81% to 89%. (55) Both groups proposed that the deficit was caused by an inability to maximally activate the relevant muscles during a bi-lateral activity. (54, 55) There is evidence that the deficit was caused by the fast motor units not being fully activated during the bi-lateral task compared to the uni-lateral task. (56)

van Soest et al. (1985) investigated the bi-lateral deficit, which is a pertinent factor during coordinated human movement. (52) They compared one- and two-legged counter movement jumps. The difference in performance between the two types of jumps was attributed to a number of factors including the inability to produce maximal voluntary force in both limbs simultaneously during the bi-lateral actions. They reported that the difference of the ranges of motion and the influence of the counter movement are the important factor in the differences off jumping performance between one- and two-legged jumps. One of the results showed mean maximum knee flexion angles of one- and two-legged jumps differed by 248.
The bi-lateral deficit has implications for the coordination of muscles for the production of movement. (53) Challis (1998) compared one- and two-legged static jumps to assess the possible influence of bi-lateral deficit. (53) Subjects performed maximal vertical jumps with no counter movement from their preferred jumping leg and from both legs. Static jumps were constrained to ensure similar ranges of joint motion for one- and two-legged jumps. The height jumped from one leg was significantly different from being 50% of that jumped from two legs; the height jumped from one leg was 58.1% of that jumped from two. (53) Challis (1998) support to the hypothesis that in both one- and two-legged counter movement and static jumps differences are in jump height are due in large part to the bi-lateral deficit. (55) The similarity of the ratio of jump heights from one- and two-legged counter movement of van Soest et al reported 58.5% (54) and of Challis was 58.1%. (53) The general pattern of the angular velocities of ankle, knee, and hips, and resultant joint moment in these static jumps indicated that the sequencing of joint extensions was similar regardless of jump condition.

In addition, a one-foot takeoff provides the greater forward momentum at takeoff but is the hardest to control in relation to timing a hit while the jumper is in the air, such as in a block in basketball.

3.6.3 The influence of arms and legs movement on jumping performance (1)

The moving of the arms and legs while the jumper is in flight (airborne) does not add to the distance covered nor to the height of the center of gravity of the body. However, movement of the center of gravity within the body or outside of it can be accomplished by moving the body parts. Many of the leg, trunk, and arm
movements are made for balance purposes and to project the center of gravity vertically or horizontally within the path prescribed to aid in the performance of the skill.

If the airborne jumper moves a part of the body in one direction, another part will move in the opposite direction. For example, movement of the head and upper torso forward and downward (clockwise) causes the feet and lower body to move upward and forward (counterclockwise). This action-reaction principle may be an asset or a liability, depending on its use. In addition, the timing of one movement to cause reaction in another is crucial to performance. One arm moving clockwise too soon may cause the performer's other arm to move counterclockwise, striking a crossbar and nullifying an otherwise effective action.

3.6.4 The effect of running before jumping

Whenever a run precedes the jump, there develops a problem of redirecting some of the horizontal velocity into vertical velocity. Inevitably there is some sacrifice of one in an attempt to optimize the other. (1)

3.6.5 The effect of the angle at takeoff, takeoff velocity and force on jumping performance

The ability to project the body at an optimal angle at the takeoff is one of the factors determining the distance or height of jump. (1) Takeoff velocity is another factor involved in the quality of jumps. (1) Usually the force multiplied by the time of application \((F \times t = \text{Impulse})\) determines the longest or highest jump. The best jumpers have the greatest impulse. In addition, they apply the force in the shortest time but have greater vertical force than the poorer jumpers. (1)
4. VOLLEYBALL INJURIES

Ankle sprains are the most common acute injury in volleyball player. In addition to, patellar tendinitis represents the most common overuse injury, although shoulder tendinitis secondary to the overhead activities of spiking and serving is also commonly seen. Hand injuries are the next most common injury to occur while blocking. (57) Dufek and Bates (1991) identified the lower extremities and specifically the knee joint as being a primary injury site of jump sports during landing. (58) Watkins and Bcreen (1992) reported that the most of the injuries in Scottish male volleyball players occurred at the muscles, tendons and ligaments. The cause of most injuries was blocking or spiking. (59) Bahr et al. (1997) examined the effects of injury prevention program in volleyball player with recurrent sprains. (60) They found that the incidence of ankle injuries was reduced if the technical training program was emphasized on proper take-off and landing technique for blocking and attacking, and prevention program consisted of an injury awareness session and a balance board training program. (60)
5. STANDING BROAD JUMP

The standing broad jump is most frequently used in schools and colleges as one measure of motor ability and physical or motor fitness. The standing long jump is an explosive flash of closely integrated movements with a distinct underlying pattern (Figure 2.4). In a skillful performance, the following pattern of movements occurs:

1. Joints are cocked by crouching and swinging the arms backward and upward.
2. Arms swing forward and upward and body extension begins in quick succession at the hips, knees, and ankles. (The movements continue until the body is fully extended and off the ground.)
3. Lower legs flex.
4. Hips flex, bringing knees forward, and arms and trunk move forward and downward.
5. Lower legs extend just prior to landing.
6. Knees bend at impact and body weight continues forward and downward in the line of flight.
**Figure 2.4** Mature form in standing long jump prior to takeoff and at landing. Before takeoff: (a) Weight moves forward as arms perform preliminary swing; (b) weight continues to move forward as the arms start a downward and forward swing; and (c) heels are lifted, arms swing forward and upward, and a series of propulsive forces thrust the body into full extension. Landing; (d) Legs are extended ad well forward, and trunk and arms are forward in reaction; and (e) knees flex when heels contact the ground, and arms and trunk reach forward to prevent a backward fall.
5.1 The crouch

Because the entire body weight does not have to be lifted directly upward in the standing long jump as it does in the vertical jump, the preparatory crouch can be deeper. The benefit of the deeper crouch is the increased distance provided over which to apply force prior to the takeoff. The 16 male college students studied by Henry were able to crouch an average of 6 inches more in the standing broad jump than in the vertical jump without sacrificing maximum performance. (61) Felton found that the good jumper among the college women she studied obtained deeper flexion all the joints involved in the preliminary crouch than the poor jumpers. (62) Skilled jumpers automatically seem to assume the amount of crouch that is the most effective for them, considering the strength they have available for propulsion in the jump. Extremes of either depth or shallowness in the crouch do not produce effective propulsion.

5.2 The arm swing

One important role of the arms is to help move the center of gravity of the body forward before the takeoff. (63) The contribution of the arms in performing this task is apparent from the outset of the jump. When the arms swing backward and upward, the forward shift of body weight begins (Figure 2.4). The forward movement of the body weight continues as the arms change direction and move vigorously downward and forward. During the forward swing the arms remain nearly straight and form a ling lever, which is useful initially in the development of momentum and later in reaction to leg movement. (64) Flexion at the shoulder continues until the arms are fully extended and in line with the trunk. This position is reached just before takeoff, and when arm movement decelerates the last phase of leg extension can be accomplished against less resistance. The arms remain essentially in line with the trunk, forming a
long lever to react against the forward movement of the legs during the flight phase. When the knees are well under the body on the forward swing, the spine flexed slightly, and the arms extend somewhat at the shoulder joint in reaction to the rapid movement of the tucked legs. A continued forward reach of the arms after landing assists in moving the center of gravity forward over the feet for the retention of balance. The analysis of mechanics of the jump of girls 12 to 17 years of age show that the arms are back of the trunk at an angle of 88 degree as the heels leave the ground. They are moved downward by flexion at the shoulder, pass the trunk between 0.09 and 0.105 second. And reach the height of their swing just before the thigh reach the vertical.

Arm action after takeoff is basically compensatory, and an alternate form is used by some skilled jumpers. Immediately after the body is airborne, the arms are moved backward to a hyperextend position as the legs are brought forward. Arms are then swung vigorously forward at landing to conserve momentum and carry the center of gravity forward ahead of the two points of support. The double-reversal arm action in this form must be performed swiftly. A pseudo-winging motion through the high-guard arm position sometimes is used to get the arms into the hyperextend position quickly enough to be effective at landing, and this should not be regarded as an immature form.

5.3 Actions at the hip, knee, and ankle joints prior to takeoff

The crouch cocks the hip, knee, and ankle joints by placing them in deeper flexion. There is a minor crouch when the arms swing backward, and the crouch deepens when they swing downward and forward. The heels are pulled off the floor, and the arms begin to move upward to mark the beginning of the sequence of
propulsive extension. Extension begins in quick succession at the hip, the knee, and the ankle with an imperceptible time lag before each new action begin. (65) The joints reach full extension immediately after takeoff. Zimmerman's poor performers had simultaneous rather than successive initiation of movement at these joints, and the movements failed to produce complete extension. (66)

5.4 Joint action in takeoff phase. (1)

The analysis of the mechanics of the jump is based on a film of 12-year-old girl whose score ranks above the ninety-fifth percentile in a nationwide sampling of girls 12 to 17 years of age. The time that the heels leave the ground slightly more than 0.25 second from raising of the heel until the final thrust is made. For the first 0.18 second, as the foot in raised from the floor, no action (or very little) occurs at the ankle joint, except for the slight flexion and immediate recovery at 0.09 seconds. As the center of gravity of the body is moved downward by gravitational force, the foot rotating at the metatarsophalangeal joint is moved in an upward direction. This occurs only when the ankle extensors prevent flexion at the ankle.

Once the leg has reached the desired angle of inclination, extension at the ankle parallels extension at the metatarsophalangeal joint from 0.135 to 0.21 second, and by this means the inclination on the leg ankle exceeds action at the metatarsophalangeal joint, and the leg is raised 10 degree adding to the upward thrust.

The lower leg flexed for the first 0.135 second, carrying the thigh downward and backward in reference to the knee. However, from 0.06 to 0.135 second, the thigh is not inclined backward with reference to the horizontal because the forward inclination of the leg at this time exceeds flexion at the knee. At 0.21 second, the thigh reached the vertical, and after this point all limb actions increase in speed. Up to 0.21 second,
thigh extension has lifted the thigh and the toes against gravitational pull. After that
time, both thigh extension and gravity are applying force in a downward direction. All
joints (metatarsophalangeal, ankle, knee, and hip) react to this change in gravitational
pull; all rotations at these joints increase in speed.

5.5 The takeoff angle

The projectile angle of 45° theoretically is the most effective takeoff angle for
producing maximum distance when the initial velocity remains constant. When the
angle is too large, not enough horizontal velocity is produced. If the angle with the
horizontal is too small, there is insufficient height and not enough time to swing the
legs forward under the body into effective position for landing. Generally, the angle of
takeoff is lowered as propulsive force is increased and the better jumpers in a group
tend to have a lower angle. The good jumper studied by Zimmerman (1956) had an
average takeoff angle approaching 45° (66) and the college men studied by Henry had
and average takeoff angle of 41.3°. (61) The takeoff angle in most reported studies has
been measured directly from high-speed film. In contrast, Roy et al. computed takeoff
angle for his average jumpers from horizontal and vertical velocities at takeoff and
found angles of 26 to 29° for the 4 groups. (67) The difference between his findings
and other reported results is significant and seems to be related to method because the
film in his study actually shows angles in the 45° range.

5.6 Actions at the hip, knee, and ankle joints during flight.

Full body extension is reached at takeoff. Then the lower begin to flex, and as
they approach an angle of approximately 90°, the thighs also begin to flex. While the
knees swing forward, the heels continue to move toward the buttocks. The delay in
starting hip flexion tightens the tuck of the legs on the forward swing. A shortened
lever created in this way can be moved forward more swiftly and with less effort.

Continued flexion at the hips brings the thigh close to the trunk and permits the lower leg to swing forward into position for landing. The leg is essentially straight at the knee at the moment the heel touches the ground.

5.7 The landing

The effective position for landing is with legs well forward and as straight as possible at the knees and with the trunk close to the thighs. The closeness of the trunk and thighs keeps the center of gravity high but forward and allows the legs to reach forward for maximum distance without increasing the danger of falling backward when landing. The angle of the legs with the ground in 458 or less in skilled jumpers and the angle generally coincide with the in-flight path of the center of gravity. The instant the foot has purchase with the ground, there is flexion at the knees and ankles that permits a continued and uninterrupted movement of the body weight down its line of flight. Arms continue reaching forward to help keep the center of gravity moving forward and downward.
CHAPTER III

MATERIALS AND METHODS

1. SUBJECTS

Ten Thai male subjects were participated in this study. All subjects were normal and physically active. They were healthy with no history of neuromusculoskeletal disease and they did not have any disorder in the lower extremities and other parts of the body before taking part in this experiment. These subjects were the amateur athletes of Mahidol University. All of them were volleyball players. Nine male subjects were intercollegiate students and another subject were the graduate student in master program of Sport Science from the College of Sport Science and Technology, Mahidol University. They used to participate continuous in volleyball sport ranged from 4 to 15 years. The highest levels of competition of them were from intercollegiate to national level. The frequency of training was ranged from 3-5 times per week. However, before this experiment, they were requested to participate in the competition at least 2 weeks.

The age of these subjects were ranged from 19-25 years. The general characteristics of the subjects were shown in Table 4.2.
2. EQUIPMENT

The following instruments were used to measure physical fitness and vertical jumping tests:

1. Adhesive tape 1 and 2 inches wide (Leucoplast self-adhesive plaster white cloth backing zinc-oxide plaster made by Beiersdorf Thailand Co., Ltd. Samutprakarn, Thailand under license of BDF Beiersdorf AG Hamburg Germany).
4. Leg and back dynamometer
5. Weight and height balance (Detecto).
6. Chalk dust
7. Cotton wool
8. Rubbing alcohol
9. Black paper

3. EXPERIMENTAL PROCEDURES

3.1 General procedure

3.1.1 Subject’s consent and health history.

Each subject who had criteria as mentioned above and agreed to participate in this study was informed about the objectives and experiment procedure before giving his informed consent signed. The individual's health history, type, intensity,
duration, and frequency of sport that the subjects participated, the experience of activity participation and sport, the highest competition level, and sport injury were interviewed and recorded.

The experimental protocol was approved by Mahidol University Committee for Approval of Experiment in Human Subjects. The written informed consent was obtained from each subject.

3.1.2 Special test of lower extremities.

Several special tests consisted of ankle and knee stability assessments were performed to examine the possible disorder and injury of ankle and knee joints. These tests were performed to each subject as screening tests. The subjects were positioned comfortably supine on the examining table, head down on a pillow and hands relaxed.

3.1.2.1 Ankle ligament stability assessment (68)

Anterior drawer test

Indication. Anterior drawer test was used to determine the integrity of the structures involves in preventing forward displacement of the tibia on the talus, especially anterior talofibular ligament.

Method. The subjects were supine. The test ankle was relaxed, and slightly in a plantar-flexed position. The examiner stabilized the distal leg with one hand, while the other hand gripped the calcaneus. By pulling the calcaneus forward and causing it to impact the talus, the examiner attempted to displace the talus anteriorly. (68)

Results. Straightforward displacement of the talus on the tibia indicated both medial and lateral ligament in stability involving the superficial and deep deltoid ligaments,
the anterior talofibular ligament, and the anterolateral capsule. If there is instability and laxity on one side only, then only that side will displace forward.

Posterior drawer test

Indication. Posterior drawer test was used to determine the integrity of structures involved in preventing downward displacement of tibia on talus, especially posterior talofibular ligament.

Method. The subjects were positioned as for the anterior drawer test. The examiner stabilized the distal leg with one hand and grip the talus with the other. Force was applied downward to talus.

Results. Posterior downward displacement and posterior gaping of talus indicated instability. (68)

Inversion stress test (or Varus stress test)

Indication. The varus stress test was used to assess the integrity of the lateral ligaments of the ankle (anterior and posterior talofibular and calcaneofibular ligaments).

Method. The subject was supine with the ankle in a relaxed slightly plantar-flexed position. The examiner stabilized the lower leg and gripped and inverted the calcaneus maximally. The examiner palpated all three lateral ligaments with the stabilizing hand as the inversion force was applied.

Results. Lateral gapping and rocking of the talus beneath the mortise indicated instability. All three ligaments must be lax or torn for gross instability to be present.
Eversion stress test (Valgus stress test)

Indication. Eversion stress test assessed instability of the medial side of the ankle, most notably the deltoid ligament.

Method. The subjects were positioned as for the eversion stress test. The examiner stabilized the lower leg with one hand and gripped the calcaneus with the other. A maximal eversion force was applied to the calcaneus as the lower leg was stabilized. The stabilizing hand palpated over the deltoid ligament as the eversion force was applied.

Result. Medial gapping of the talus indicated instability.

3.1.2.2 Knee ligament stability assessment (68)

Abduction test (or Valgus stress test)

Indication. Abduction test was used to assess the integrity of the structures responsible for medial stability of the joint.

Method. This test performed in both full extension and in an unlocked position of about 20 to 30 degrees of flexion to allow testing of both the primary and secondary restraints. In the position of flexion, the posterior capsule was relaxed, thereby allowing for isolated testing of the medial collateral ligament. The examiner placed one hand along the lateral side of the knee joint and the other medially on the subject's leg. Using the lateral hand as a fulcrum, the examiner applies a valgus force to the knee by pulling the leg from the midline of the body.

Results. Medial gapping and/or pain during the procedure were evidence of dysfunction. A positive result with the knee in the unlocked flexed position could mean dysfunction of the medial collateral ligament, the middle third of the medial
capsule, the posterior cruciate ligament, or the posterior oblique ligament. Gapping or pain noted when testing the knee in full extension represented more extensive joint damage in terms of stability. Structures that maybe damaged in associated with this instability may include superficial and deep fibers of the medial collateral oblique ligament, the anterior and posterior cruciate ligaments, the semimembranosus muscle, and the medial quadriceps expansion. (68)

Adduction test (Varus stress test)
Indication. The varus stress test was indicated in persons who may have sustained damage to the lateral stabilizing structures of the knee.
Method. The subjects were relaxed and supine. The examiner placed one hand along the medial aspect of the joint and the other on the lateral side of the leg. With the hand of the knee acting as a fulcrum, the examiner imparts a varus force on the joint by pulling the leg into adduction. This test was performed with the knee in extension as well as in an unlocked position of 20 to 30 degrees. As in the valgus stress test, laxity in the completely extended position represented a more serious injury.
Results. Gapping or pain while the test was performed in the unlocked position indicated possible injury to the lateral collateral ligament, the middle third of the lateral capsule, the posterolateral capsule, the arcuate complex (lateral collateral ligament, short lateral ligament, arcuate ligament, tendinous aponeurotic expansion of the popliteus muscle, the iliotibial band, and the biceps femoris tendon). (68)
Anterior drawer test

Indication. Suspicion of anterior cruciate ligament laxity or rupture was an indication for the anterior drawer examination.

Method. The subject lay supine with the knee flexed to 90 degrees. The examiner stabilized the foot on the table in neutral rotation by sitting. The examiner grasped the proximal tibia, ensuring relaxation of the hamstrings, and attempts to pull the tibia anteriorly on the femur. Simultaneous palpation of the anterior joint line with the thumb allowed the examiner to feel the forward translation of the tibia accurately.

Results. Approximately 6 mm. Anterior translation of the tibia on the femur was normal. A positive straight drawer test was one in which there was excessive, equal forward condyles. Excessive anterior displacement of the tibia may represent involvement of any of the following structures. The anterior cruciate ligament, the posterolateral or posteromedial capsule, the deep fibers of the medial collateral ligament, the posterior oblique ligament, the iliotibial band, and the arcuate complex.

(68)

Posterior drawer test

Indication. The posterior drawer examination technique was used to assess posterior-in instability.

Method. The subject lay supine, with the knee being examined flexed to 90 degrees and the foot resting of the examining table. The examiner sat of the foot to stabilize it, grasped the proximal tibia, and pushed the tibia posteriorly on the femur.

Results. Excessive posterior translation of the tibia backward on the femur represented a positive result. Any of the following structures may be damaged and associated with
a positive finding: the posterior cruciate or posterior oblique ligament, the arcuate complex, or the anterior cruciate ligament. (68)

**McMurray test**

**Indication.** McMurray test indicated injury to lateral and medial meniscus.

**Method.** The subject lay supine with his legs flat and in the neutral position. With one hand, take hold of his heel and flex his leg fully. Then, the examiner placed free hand on the knee joint with the fingers touching the medial joint line and thumb and thenar eminence against the lateral joint line, and rotated the leg internally and externally to loosen the knee joint. Pushes on the lateral side of the joint while, at the same time, rotation the leg externally. Maintain the valgus stress and external rotation, and extend the leg slowly as the examiner palpate the medial joint line. (69)

**Results.** If this maneuver causes a palpable or audible "click" within the joint, there is a probable tear in the medial meniscus, most likely in its posterior half.

### 3.1.3 Anthropometric measurements.

These were comprised of height, body weight, BMI and lower extremity segment length and circumference.

**Body height**

Subject stood upright with bare feet while arms were hanging freely by the sides. Subject' s heels, buttocks, upper part of back and back of head were resting against the wall. For the real body stretched, his orbit of the eye and tragus of the ear were in the same horizontal line. The stretched height was obtained from the distance between the vertex and heel.
Body weight

Body weight was measured by weight balance.

Lower extremity segment length and circumference

Leg length; To determine true leg length, first asked subject to lie supine and place the subject’s legs in precisely comparable, and then measured the distance from the anterior superior iliac spines the medial malleoli of the ankles. The examiner measured true leg length both sides. (70)

Thigh length was measured from greater trochanter to upper border and edge of the inner tuberosity of the head of tibia.

Lower leg length was measured from edge of the inner tuberosity of the head of tibia to medial malleolus.

Foot length was measured from calcaneous (heel) to the tip of the second toe. (71)

Circumference measurements were performed to assess the severity of swelling or the atrophy of muscles. The examiner measured at least the following: 1) joint line, 2) 5 cm superior to the joint line, 3) 15 cm superior to the joint line, and 15 cm distal to the joint line. (72)

BMI (body mass index)

The BMI is the ratio of body weight to height squared: BMI (kg/m²) = Weight (in kg) / Height² (in m). BMI provides a crude index of obesity. Table 3.1 describes standards for classifying BMI. (73)
Table 3.1 Obesity Classification Based on Body Mass Index (BMI)

<table>
<thead>
<tr>
<th>Classification</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>24-27</td>
<td>23-26</td>
</tr>
<tr>
<td>Moderately obese</td>
<td>28-31</td>
<td>27-32</td>
</tr>
<tr>
<td>Severely obese</td>
<td>&gt;31</td>
<td>&gt;32</td>
</tr>
</tbody>
</table>

3.1.4 Muscle strength measurements

Leg strength testing procedures

Leg strength was assessed by a leg and back dynamometer. Subject stood on the platform with trunk erect and the knees flexed to an angle of 130 to 140. Subject held the handbar using a pronated grip and positioned it across the thighs by adjusting the length of the chain. If a belt was available, attached it to each end of the handbar after positioning the belt around the subject’s hips. The belt helped to stabilize the bar and to reduce the stress placed on the hands during the leg lift. Without using the back, the subject slowly but vigorously extended the knees. The maximum indicator needle remained at the peak force achieved. Each subject was asked to perform two trials with a 1-minute rest interval, and used the best score in kg. (73)

3.1.5 The range of motion measurements

Active range of motion was assessed before and after partial fixing of each joint by universal goniometer. The standard goniometer is a protractor-like device with two steel or plastic arms that measure the joint angle at the extremity of the ROM. The stationary arm of the goniometer is attached at the zero line of the protractor and the other arm is movable. To use the goniometer, place the center of the instrument so it
coincides with the fulcrum, or axis of rotation, of the joint. Align the arms of the goniometer with bony landmarks along the longitudinal axis of each moving body segment. Measure the ROM as the difference between the joint angles (degrees) at the extremity of the movement. (73) All movements of these joints were assessed.

Ankle joint dorsiflexion (68)

Position. Subject lay supine with the knee joint flexed 20 to 30 degrees and supported by a pillow. The ankle joint was in the anatomical position.

Goniometric alignment

Axis. Placed over the lateral malleolus of the fibula.

Stationary arm. Stationary arm was placed parallel to the lateral midline of the fibula projecting toward the fibular head.

Moving arm. Placed parallel to the lateral midline of calcaneus.

Stabilization. The leg was stabilized.

Ankle joint plantarflexion (68)

Position. Subject lay supine with the hip and knee joints extended and the ankle in the anatomical position.

Goniometric alignment

Axis. Placed over the lateral malleolus of the fibula.

Stationary arm. Placed parallel to the lateral midline of the leg projecting to the head of the fibula.

Moving arm. Placed parallel to the bottom of the calcaneus.

Stabilization. The leg was stabilized.
Inversion (68)

Position. Subject lay supine with the hip in the anatomical position and the ankle relaxed. The knee might be either flexed or extended.

Goniometric alignment

Axis. Placed over the dorsal surface of the foot, midway between the malleoli.

Stationary arm. Placed along the anterior surface over the crest of the tibia in the line with the tibial tuberosity.

Moving arm. Placed along the dorsal surface of the second metatarsal shaft.

Stabilization. The leg was stabilized.

Eversion (68)

Position. Subject lay supine with the hip in neutral position and the ankle joint relaxed. The knee might be either flexed or extended.

Goniometric alignment.

Axis. Placed over the dorsal aspect of the foot midway between the malleoli.

Stationary arm. Placed on the crest of the tibia.

Moving arm. Placed on the dorsum of the foot in line with the dorsal shaft of the second metatarsal.

Stabilization. The leg was stabilized.

Knee flexion (68)

Position. Subject was in side lying position on the non-test side. The hip and knee flexed simultaneously.
Goniometric alignment

Axis. Placed over the lateral epicondyle of the femur.

Stationary arm. Placed parallel to the lateral midline of the femur on a line from the lateral epicondyle to the greater trochanter.

Moving arm. Placed parallel to the lateral midline of the fibula toward the lateral malleolus.

Stabilization. The thigh was stabilized.

Knee extension (68)

Position. Subject was prone, with the hip joint in the anatomical position.

Goniometric alignment

Axis. Placed over the lateral epicondyle of the femur.

Stationary arm. Placed parallel to the lateral midline of the femur on a line from the lateral epicondyle to the greater trochanter.

Moving arm. Placed parallel to the lateral midline of the fibula toward the lateral malleolus.

Stabilization. The weight of the lower limb proceeded sufficient stabilization.

3.2 The partial fixing

The joints partially fixed were the feet, ankles, and knees. In complete fixing of each joint partially impaired jumping but balance during performance was still good enough to prevent falling.
3.2.1 General application of taping

Special attention must be given when applying tape directly to the skin. Perspiration and dirt collected during sport activities will prevent tape from properly sticking to the skin. Whenever tape was used, the skin surface was cleansed with soap and water to remove all dirt and oil. Hair was removed by shaving to prevent additional irritation when the tape was removed. Included below were a few of the important rules to be observed in the use of adhesive tape. (74)

1. If the part to be taped is a joint, place it in the position is which it is to be stabilized or, if the part is musculature, make the necessary allowance for contraction and expansion.

2. Overlap the tape at least half the width of the tape below. Unless tape is overlapped sufficiently, the active athlete will separate it, thus exposing the underlying skin to irritation.

3. Avoid continuous taping. Tape continuously wrapped around a part may cause constriction. It is suggested that one turn be made at a time and the each encirclement be torn to overlap the starting end by approximately 1 inch. This rule is particularly true of the nonyielding linen-backed tape.

4. Keep the tape roll in hand whenever possible. By learning to keep the tape roll in the hand, seldom laying it down, and by learning to tear the tape, an operator can develop taping speed and accuracy.

5. Smooth and mold the tape as it is laid on the skin. To save additional time, tape strips should be smoothed and molded to the body part as they are put in place; this is done by stroking the top with the fingers, palms, and heels of both hands.
6. Allow tape to fit the natural contour of the skin. Each strip of tape must be laid in place with a particular purpose in mind. Linen-backed tape is not sufficiently elastic to bend around acute angles but must be allowed "to fall as it may," fitting naturally to the body contours. Failing to allow this fit creates wrinkles and gaps that can result in skin irritations.

7. Start taping with an "anchor" piece and finish by applying a "lock" strip. Taping should commence, if possible, by sticking the tape to an anchor piece that has encircled the part. This placement affords a good medium for the stabilization of succeeding tape strips, so that they will not be affected by the movement of the part.

8. Where maximum support is desired, tape directly over skin surfaces. In cases of sensitive skin, other mediums may be used as tape bases. With the use of artificial bases, some movement can be expected between the skin and the base.

3.2.2 Taping procedures

3.2.2.1 The foot

This taping method is used to support the longitudinal arch.

Position of the subject: The subject lay face downward on a table, with the affected foot extending approximately 6 inches (15 cm) over the edge of the table. To ensure proper position, allow the foot to hang in relaxed natural position.
Procedure

1. Lightly place an anchor strip around the ball of the foot, making certain not to constrict the action of the toes.

2. Start the next strip of tape from the medial edge of the anchor, moving it upward at an acute angle, crossing the center of the longitudinal arch, encircling the heel, and descending; then, crossing the arch again, end at the later aspect of the anchor.

3. Lock the first "cross" and each subsequent cross individually by using a single piece of tape placed around the ball of the foot.
Figure 3.1 Foot taping (a) Place an anchor strip around the ball of foot. (b) Cross a single piece of tape to the arch of foot. (c) Lock the first cross and each subsequent cross by using a single piece of tape placed around the ball of foot.
3.2.2.2 The ankle

Closed basketweave (Gibney) technique

The closed basketweave technique offered strong tape support and was primarily used in athletic training for newly sprained or chronically weak ankles.

Position of the subject: the subject sat on a table with the leg extended and the foot at a 90-degree angle.

Procedure

1. One anchor piece is placed around the ankle, approximately 5 or 6 inches (12.7 to 15.2 cm) above the malleolus, and a second anchor is placed around the arch and instep.

2. The first stirrup is then applied posteriorly to the malleolus and attached to the ankle stirrup.

3. The first Gibney is started directly under the malleolus and is attached to the foot anchor.

4. In an alternating series, three stirrups and three Gibneys are placed on the ankle, with each piece of tape overlapping at least one half of the preceding strip.

5. After the basketweave series has been applied, the Gibney strips are continued up the ankle, thus giving circular support.

6. For arch support, two or three circular strips are applied.

7. After the conventional basket weave has been completed, a heel lock should be applied to ensure maximum stability.
Figure 3.2 Ankle taping procedure (a) Place an anchor piece above ankle and around arch of foot. (b) Apply the first stirrup to ankle. (c) Apply the first Gibney under malleolus. (d) Alternate series of three stirrups and three Gibneys on the ankle. (e) Apply circular support and then apply heel lock to maximum stability. (f) Finish ankle taping.
3.2.2.3 The knee

Hyperextension

Hyperextension taping was designed to prevent the knee from hyperextending and also may be used for strained hamstring muscles or slackened cruciate ligaments.

Position of the subject: The subject's leg should be completely shaved above midthigh and below midcalf. The athlete stood on a 3-foot (90 cm) table the another knee flexed by a 2-inch (5 cm) heel lift.

Procedure

1. Place two anchor strips at the hairlines, two around the thigh, and two around the leg. They were applied loosely to allow for muscle expansion during exercise.

2. A gauze pad was placed at the popliteal space to protect the popliteal nerves and blood vessels from constriction by the tape.

3. Start the supporting tape strips by forming an x over the popliteal space.

4. Cross the tape again with two more strips and one up the middle of the leg.

5. Complete the technique by applying four or five locking strips around the thigh and calf.

6. Lock the supporting strips in place by applying two or three overlapping circles around the thigh and leg.
Figure 3.3 Knee taping procedures. (a) Place two anchor strips, two around the thigh, and two around the leg. (b) Apply tape strips by forming an X over the popliteal space. (c) Cross tape again with two more strips and one up the middle of leg. (d) Lock the strips by applying three circles around thigh and leg.

3.3 Vertical jump and reach test

Vertical jump and reach test was used to assess vertical jump performance by other investigator (16). Support for its reliability as a jumping assessment tool is inferred from its widespread use in the literature as a performance test.

Preparing the jumping board

A measuring tape with red lined attached to a black color paper 2 feet 3 5 feet (60.96 cm. by 152.40 cm.) at the center of this paper and numbered from 0 to 150 cm, bottom to top. A scale of a measuring tape was cm. Each red line was apart extending across the width of the black board. The black board was attached firmly to the wall with the lines parallel to the floor and the bottom edge of the board exactly 150 cm. above the floor. Chalk dust for the fingertips was required.

The tests were done during:

1. No taping
2. Taping of both feet
3. Taping of both ankles
4. Taping of both knees

These tests were done before and after partial fixing at each joint in the lower extremity.
Subjects stood facing sideways to the jump board. The subject's preferred hand was coated with chalk. With the feet remaining flat on the floor, subject then reached and placed his palm on the scale as high as possible while keeping both legs together in a straight position. The highest point was marked with chalk dust applied on his palm. This point was referred to the starting zero rest. Subjects were asked to plant both feet approximately shoulder width apart and bend his legs in a jumping position. The degree of knee-bend utilized by the subjects is self-determine, with the primary goal to jump as high as possible. The subject then jumped as high as possible which touch the scale with the palm at the maximum extension of the arms when reach the peak. The distance between the initial chalk making and the highest chalking lift on the wall was then recorded. Total arm swing and depth of preparatory squat were not controlled in this study. Before testing, the subjects were allowed three practice jumps at submaximal effort. Subsequently, subjects performed three trials of each condition of taping at maximal effort, with the highest jump being used in statistical analysis. The subjects rest between jumps until the feel no residual fatigue, usually between 1-3 minute. The total of vertical jump test of each subject is 12 jumps.

4. WARM UP PROTOCOL

An active warm-up should facilitate muscular performance by increasing blood flow, muscular and core temperature, oxygen utilization, nervous system transmission, and by decreasing muscular viscosity. (75) A good warm up will also decrease chance of muscle or joint injury and reduce the amount of muscle and joint soreness. (76) The subject started to warm up with stretching hamstrings muscle, quadriceps muscle,
gastrocnemius muscle, and follow it with 5 min of light jogging or jogging in place and practice vertical jumping.

PROCEDURE FLOW CHART

Explanation of the testing procedures in detail

- Informed consent and subjects history
- Hip, knee and ankle measurements
- Anthropometric measurements (body weight and height, legs length and circumference)
- Muscle strength measurements by Back and leg dynamometer
- Warm-up 5 min
- ROM measurement (knees and ankles)
- Strap each joint before experimental testing
- ROM measurement after taping by goniometer
Vertical jump test during four conditions:

1) no tape, 2) tape both feet, 3) tape both ankles, 4) tape both knees

Subject instruction

Three practice jumps at submaximal effort

1-3 minute rest interval

Subject performs three trials vertical jump at maximal effort,

With 1-3 minute rest interval between trial
5. DATA ANALYSIS

Paired sample t-test was used to detect ROM differences between before and after taping.

Paired sample t-test was used to detect differences among conditions (no taping, taping of feet, ankles, and knees)

Pearson correlation was used to reveal the relationships among leg strength, height of subjects, and the length of lower limb, and vertical jumping performance.
CHAPTER IV

RESULTS

1. PHYSICAL CHARACTERISTICS

Physical assessment of ankles and knees, which included knee ligament stability and ankle ligament stability were done in all subject as the screening tests. Tests for ankle and knee joint stability have been shown in Table 4.1. The results show that 10 subjects have negative assessments of all ankle stability tests. That evaluations of ankle stability present negative results mean the subjects have normal condition of the anterior talofibular, posterior talofibular, calcaneofibular, and deltoid ligaments. From evaluations of integrity of right ankle joint, one subject present positive result of inversion test which indicate sprain of right ankle. The ligamentous damage may occur in the calcaneofibular ligament. Therefore, one subject was excluded from this experiment. Assessments of knee joint stability consisted of abduction test, adduction test, anterior drawer test, posterior drawer test, and McMurray test. Ten subjects present negative results of these tests. They have normal strength and integrity of knee joint capsule, collateral ligaments, cruciate ligaments, and surrounding muscles and tendons. Therefore, 10 volleyball players were participated in this study.
### Table 4.1 Assessment of knee and ankle functions by tests (see below)

<table>
<thead>
<tr>
<th>Physical assessment</th>
<th>Negative (Number of Subject)</th>
<th>Positive (Number of Subject)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
</tr>
<tr>
<td><strong>Knee ligament stability assessment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abduction test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Adduction test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Anterior drawer test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Posterior drawer test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>McMurray test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Ankle ligament stability test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior drawer test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Posterior drawer test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Inversion test</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Eversion test</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>
### Table 4.2 Characteristics of subjects (n =10)

<table>
<thead>
<tr>
<th>Subject's characteristics</th>
<th>Mean±SEM</th>
<th>SD</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>20.10±0.59</td>
<td>1.85</td>
<td>3.43</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>63.85±2.41</td>
<td>7.61</td>
<td>58.00</td>
</tr>
<tr>
<td><strong>Height (m)</strong></td>
<td>1.75±0.02</td>
<td>0.05</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>BMI (kg/m^2)</strong></td>
<td>20.81±0.49</td>
<td>1.54</td>
<td>2.36</td>
</tr>
<tr>
<td><strong>Right lower extremity length (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg length</td>
<td>90.50±1.11</td>
<td>3.50</td>
<td>12.28</td>
</tr>
<tr>
<td>Thigh length</td>
<td>45.40±0.83</td>
<td>2.62</td>
<td>6.88</td>
</tr>
<tr>
<td>Lower leg length</td>
<td>40.10±0.66</td>
<td>2.08</td>
<td>4.32</td>
</tr>
<tr>
<td>Foot length</td>
<td>24.90±0.43</td>
<td>1.37</td>
<td>1.88</td>
</tr>
<tr>
<td><strong>Left lower extremity length (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg length</td>
<td>90.50±1.11</td>
<td>3.50</td>
<td>12.28</td>
</tr>
<tr>
<td>Thigh length</td>
<td>45.40±0.83</td>
<td>2.62</td>
<td>6.88</td>
</tr>
<tr>
<td>Lower leg length</td>
<td>40.10±0.66</td>
<td>2.08</td>
<td>4.32</td>
</tr>
<tr>
<td>Foot length</td>
<td>24.85±0.45</td>
<td>1.43</td>
<td>2.06</td>
</tr>
</tbody>
</table>
Table 4.3 Leg strength (quadriceps muscle strength) of subjects (n=10) and circumference.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean±SEM</th>
<th>SD</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg strength (kg)</td>
<td>155.40±6.35</td>
<td>20.08</td>
<td>403.16</td>
</tr>
<tr>
<td><strong>Right lower extremity circumference (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At joint line</td>
<td>36.60±0.61</td>
<td>1.93</td>
<td>3.71</td>
</tr>
<tr>
<td>5 cm superior to the joint line</td>
<td>38.65±0.75</td>
<td>2.36</td>
<td>5.56</td>
</tr>
<tr>
<td>15 cm superior to the joint line</td>
<td>46.60±0.95</td>
<td>2.99</td>
<td>8.93</td>
</tr>
<tr>
<td>15 cm distal to the joint line</td>
<td>35.70±0.85</td>
<td>2.69</td>
<td>7.23</td>
</tr>
<tr>
<td><strong>Left lower extremity circumference (cm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At joint line</td>
<td>36.53±0.64</td>
<td>2.04</td>
<td>4.14</td>
</tr>
<tr>
<td>5 cm superior to the joint line</td>
<td>37.95±0.71</td>
<td>2.25</td>
<td>5.08</td>
</tr>
<tr>
<td>15 cm superior to the joint line</td>
<td>45.80±1.06</td>
<td>3.35</td>
<td>11.23</td>
</tr>
<tr>
<td>15 cm distal to the joint line</td>
<td>35.20±0.81</td>
<td>2.57</td>
<td>6.62</td>
</tr>
</tbody>
</table>

The data in Table 4.2 show the general characteristics of subjects used. Age of subjects ranged from 19 to 25 years and the mean of age of subjects is 20.10±0.59 years. The means of weight, height, and BMI (body mass index) of subjects are 63.85±2.41 kg, 1.75±0.02 m, and 20.81±0.49 kg/m², respectively. The ranges of weight,
height, and BMI of subjects were 53-76 kg, 1.68-1.83 cm, and 18.78-23.15 kg/m², respectively.

The length of various body segments were mostly similar within the following ranges; right lower limb 86.5-96.0 cm, left lower limb 86.5-96.0 cm, right thigh 42.0-51.0 cm, left thigh 42.0-51.0 cm, right lower leg 37.0-43.0 cm, left lower leg 37.0-43.0 cm, right foot 23.0-27.0 cm, and left foot 23.0-27.0 cm.

The subjects had the similar means of the lower extremity segment length within the following orders; right lower limb (90.5±1.11 cm), left lower limb (90.5±1.11 cm), right thigh (45.4±0.83), left thigh (45.4±0.83), right lower leg (40.1±0.66), left lower leg (40.1±0.66 cm), right foot (24.9±0.43 cm), and left foot (24.85±0.45 cm).

Table 4.3 summarizes leg muscle strength and leg circumference. Leg strength, especially quadriceps muscles, was measured from each subject by a leg and back dynamometer. The strength of the leg extensor musculature of subjects ranged from 114.0 to 182.0 kg. The mean of leg extensor muscle strength was 155.4±6.35 kg.

The means of right lower extremity circumferences of subjects were greater than left lower extremity circumferences of all sites which were at the knee joint line, above the knee joint line 5 cm, above the knee joint line 15 cm, and below the knee joint line 15 cm. The site of circumference measurement that was above the knee joint 15 cm represented the thigh circumference, while the site of circumference measurement that below the knee joint 15 cm represented the calf circumference. The means of right and left thigh circumferences were 46.60±0.95 and 45.80±1.06 cm, respectively. The means of right and left calf circumferences were 35.70±0.85 and 35.2±0.81 cm, respectively. The ranges of circumference of right and left thigh, and
right and left calf were 42.0-51.0 cm, 41.5-51.0 cm, 32.0-41.0 cm, and 32.0-40.0 cm, respectively.

2. ROM BEFORE AND AFTER TAPING

Mean and standard error mean of ankle and knee active range of motion before taping appeared in Table 4.4. The range of motion of all movements of ankle and knee joints before taping ranged in the following; right ankle dorsiflexion [20-30 degree], left ankle dorsiflexion [20-30 degree], right ankle plantarflexion [40-70 degree], left ankle plantarflexion [40-70 degree], right ankle inversion [17-35 degree], left ankle inversion [17-35 degree], right ankle eversion [20-35 degree], left ankle eversion [20-35 degree], right knee flexion [120-140 degree], left knee flexion [120-140 degree], right knee extension [0-0 degree], and left knee extension [0-0 degree].

Taping technique significantly reduced all movements, which consisted of dorsiflexion, plantarflexion, inversion, and eversion of ankle joint, flexion and extension of knee joint following application compared with preapplication measurement (p<0.05).

The mean and standard error mean measurements for active range of motion of ankle and knee joint for postapplication of taping are given in Table 4.5.

The range of motion of all movements of ankle and knee joints after taping procedure ranged in the following; right ankle dorsiflexion [10-20 degree], left ankle dorsiflexion [10-20 degree], right ankle plantarflexion [20-42 degree], left ankle
Table 4.4 The range of motion of knee and ankle joints before taping.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Mean±SEM</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Left</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>26.70±1.20</td>
<td>26.00±1.00</td>
<td></td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>47.50±2.81</td>
<td>46.20±2.87</td>
<td></td>
</tr>
<tr>
<td>Ankle inversion</td>
<td>28.70±2.36</td>
<td>28.70±2.24</td>
<td></td>
</tr>
<tr>
<td>Ankle eversion</td>
<td>25.80±1.48</td>
<td>26.00±1.63</td>
<td></td>
</tr>
<tr>
<td>Knee flexion</td>
<td>132.50±2.27</td>
<td>132.50±2.27</td>
<td></td>
</tr>
<tr>
<td>Knee extension</td>
<td>0±0</td>
<td>0±0</td>
<td>0±0</td>
</tr>
</tbody>
</table>

Table 4.5 The range of motion of knee and ankle joints after taping.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Mean±SEM</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Left</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>14.40±1.30</td>
<td>16.00±1.45</td>
<td></td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>28.20±2.16</td>
<td>24.90±3.38</td>
<td></td>
</tr>
<tr>
<td>Ankle inversion</td>
<td>21.60±2.39</td>
<td>19.50±2.52</td>
<td></td>
</tr>
<tr>
<td>Ankle eversion</td>
<td>17.40±1.56</td>
<td>15.00±1.49</td>
<td></td>
</tr>
<tr>
<td>Knee flexion</td>
<td>122.00±1.70</td>
<td>121.20±1.25</td>
<td></td>
</tr>
<tr>
<td>Knee extension</td>
<td>-21.50±1.28</td>
<td>-21.40±1.03</td>
<td></td>
</tr>
</tbody>
</table>
plantarflexion [10-42 degree], right ankle inversion [10-30 degree], left ankle inversion [10-30 degree], right ankle eversion [10-25 degree], left ankle eversion [10-20 degree], right knee flexion [115-130 degree], left knee flexion [115-130 degree], right knee extension [(-30) - (-15) degree], and left knee extension [(-30) - (-18) degree].

Figure 4.1-4.12 were plotted in aspect of raw data of active range of motion for each movement of pre- and postapplication of ankle and knee taping of each subject.

Figure 4.13, 4.15, 4.17, 4.19, 4.21, and 4.23 represented graphically mean and standard error mean range of motion for each movement before and after taping application both side of ankle and knee joints. These graphs were converted as percentage of no taping or normal range of motion in Figure 4.14, 4.16, 4.18, 4.20, 4.22, and 4.24.

Ankle and knee taping applications demonstrated significant loss in the ability to perform active movement of ankle dorsiflexion, ankle plantarflexion, ankle inversion, ankle eversion, knee flexion, and knee extension (p<0.05). Ankle taping affected on a decreasing in range of motion of right ankle dorsiflexion 46.39%, left ankle dorsiflexion 38%, right ankle plantarflexion 40.44%, left ankle plantarflexion 46.65%, right ankle inversion 26.35%, left ankle inversion 34.12%, right ankle eversion 32.20%, and left ankle eversion 42.62% in Figure 4.14, 4.16, 4.18, and 4.20 (p<0.05). Knee taping application caused a decreasing in range of motion of right knee flexion 7.79%, left knee flexion 8.38%, right knee extension 16.34%, and left knee extension 16.26% in Figure 4.22 and 4.24.
Figure 4.1 ROM of right ankle dorsiflexion before and after ankle taping of each subject in 10 Thai male subjects.

Figure 4.2 ROM of left ankle dorsiflexion before and after ankle taping of each subject in 10 Thai male subjects.
Figure 4.3 ROM of right ankle plantarflexion before and after ankle taping of each subject in 10 Thai male subjects.

Figure 4.4 ROM of left ankle plantarflexion before and after ankle taping of each subject in 10 Thai male subjects.
Figure 4.5 ROM of right ankle inversion before and after ankle taping of each subject in 10 Thai male subjects.

Figure 4.6 ROM of left ankle inversion before and after ankle taping of each subject in 10 Thai male subjects.
Figure 4.7 ROM of right ankle eversion before and after ankle taping of each subject in 10 Thai male subjects.

Figure 4.8 ROM of left ankle eversion before and after ankle taping of each subject in 10 Thai male subjects.
Figure 4.9 ROM of right knee flexion before and after knee taping of each subject in 10 Thai male subjects.

Figure 4.10 ROM of left knee flexion before and after knee taping of each subject in 10 Thai male subjects.
Figure 4.11 ROM of right knee extension before and after knee taping of each subject in 10 Thai male subjects.

Figure 4.12 ROM of left knee extension before and after knee taping of each subject in 10 Thai male subjects.
Figure 4.1-4.12 show range of motion of both knees and ankles before and after taping treatment. When using paired sample t-test, there were statistically significant difference of range of motion (ROM) before and after taping in all movement.

1) Right ankle dorsiflexion active range of motion before and after taping (p<0.05)
2) Left ankle dorsiflexion active range of motion before and after taping (p<0.05)
3) Right ankle plantarflexion active range of motion before and after taping (p<0.05)
4) Left ankle plantarflexion active range of motion before and after taping (p<0.05)
5) Right ankle inversion active range of motion before and after taping (p<0.05)
6) Left ankle inversion active range of motion before and after taping (p<0.05)
7) Right ankle eversion active range of motion before and after taping (p<0.05)
8) Left ankle eversion active range of motion before and after taping (p<0.05)
9) Right knee flexion active range of motion before and after taping (p<0.05)
10) Left knee flexion active range of motion before and after taping (p<0.05)
11) Right knee extension active range of motion before and after taping (p<0.05)
12) Left knee extension active range of motion before and after taping (p<0.05)
Figure 4.13 ROM of right and left ankle dorsiflexion before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.14 Data from the same subjects and treatment in Figure 4.13. Paired t-test compared between before and after ankle taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by using raw data.
Figure 4.15 ROM of right of left ankle plantar flexion before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.16 Data from the same subjects and treatment in Figure 4.15. Paired t-test compared between ankle taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by using raw data.
Figure 4.17 ROM of right and left ankle inversion before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.18 Data from the same subjects and treatment in Figure 4.17. Paired t-test compared between ankle taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by using raw data.
Figure 4.19 ROM of right and left ankle eversion before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.20 Data from the same subjects and treatment in Figure 4.19. Paired t-test compared between ankle taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by using raw data.
Figure 4.21 ROM of right and left knee flexion before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.22 Data from the same subjects and treatment in Figure 4.21. Paired t-test compared between before and after knee taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by raw data.
Figure 4.23 ROM of right and left knee extension before and after taping of 10 Thai male subjects. Data are mean±SEM (n = 10 subjects). Paired t-test compared between before and after taping. * p<0.05.

Figure 4.24 Data from the same subjects and treatment in Figure 4.23. Paired t-test compared between before and after knee taping, but ROM of each subject were calculated as a percent of no taping or normal ROM. Data are mean±SEM (n = 10 subjects). Comparison was made by using raw data.
3. THE EFFECTS OF JOINT PARTIAL FIXING ON VERTICAL JUMP

Figure 4.25 shows the different distance between the initial chalk marking and the highest chalk lift on the wall for the conditions of no taping or normal group, taping of both feet, taping of both ankles, and taping of both knees. It is clearly seen that the height of vertical jumping was significantly decreased by taping of both knees, ankles, and feet.

![Graph showing different distance between initial chalk marking and highest chalk lift in four conditions consisting of no taping of normal, plantar taping, ankle taping and knee taping in each subject (10 Thai male subjects).]

Figure 4.26 shows the means of vertical jumping height of each treatment. The means of vertical jumping height of no taping, feet taping, ankle taping, and knee taping were 65.01, 63.65, 59.05, and 57.8 cm, respectively. Taping treatment of all
conditions (taping both feet; ankles, and knees) were statistically significant of vertical jumping performance compared to the control normal (no taping).

When using paired t-test:

1) there was a significant difference between no taping and taping both feet (p≤0.05)

2) there was a statistically significant difference between no taping and taping both ankles (p<0.05)

3) there was a statistically significant difference between no taping and taping both knees (p<0.05)
4. THE CONTRIBUTION OF EACH JOINT OF LOWER EXTREMITY ON VERTICAL JUMP PERFORMANCE.

From Figure 4.27-4.28, there was possible to reveal the effect of the lower extremities taping on vertical jump performance that the knee and ankle joint contributed in terms of power generation of vertical jumping when compared to the control normal (no taping). The percentages of vertical jumping height restricted lower limb movement by taping treatment of feet, ankles, and knees are 97.95%, 90.90%, and 88.84%, respectively, compared to no taping in Figure 4.28. Knee joint was the most contribution in term of power generation and ankle joint contributed greater than feet to vertical jumping.
Figure 4.27 Percentage of vertical jumping height of each subject in four conditions of vertical jump (normal or no taping, plantar taping or feet taping, ankle taping and knee taping treatment) comparing with no taping.
Figure 4.28 Data from the same subjects and conditions as in Figure 4.26, but the jump heights of each subject in each condition were calculated as a percent of no tape or normally vertical jump performance. Data are mean ± SEM (n = 10 subjects). The levels of significance are indicated by * (p<0.05) for the comparison of each taping treatment with normal or no taping group by using paired t-test. (Comparison made with raw data)
5. CORRELATION OF LEG STRENGTH, SUBJECT HEIGHT, AND LEG LENGTH WITH VERTICAL JUMPING PERFORMANCE.

Pearson correlation was used to analyze the relationships among the strength of the leg extensor musculature, subject height, and the lengths of lower limbs and performance in vertical jump. Figure 4.29-4.32 show that they did not statistically correlate with the vertical jumping distance. Therefore, these variables was relatively less important with vertical jumping performance.

![Graph showing correlation of vertical jumping height and leg strength](image)

**Figure 4.29** Correlation of vertical jumping height and leg strength of 10 Thai male subjects in no taping treatment.
Figure 4.30 Correlation of vertical jumping height and subject height of 10 Thai male subjects in no taping treatment.

Figure 4.31 Correlation of vertical jumping height and right leg length of 10 Thai male subjects in no taping treatment.
Figure 4.32 Correlation of vertical jumping height and left leg length of 10 Thai male subjects in no taping treatment.
CHAPTER V

DISCUSSION

Joint partial fixing can be considered as one factor to increase the joint stiffness. Therefore, it may have some effect on the vertical jump height. In this study, it was clearly seen that the vertical jump height was decreased by taping of plantar fascia, ankle and knee joints. The aim of the present study was to investigate the magnitude effects of partial fixing of each joint in vertical jump and evaluate degree of contribution of each joint of lower extremity on vertical jumping performance. There was found that the vertical jump height was significantly decreased due to the partial fixing of joint of lower extremity of the body. The vertical jump height performances of subject were decreased by 12%, 10% and 3% after strapping of knees, ankles and plantar fascia respectively. This agrees with many researchers. (25, 26, 27, 28, 29) Burks et al. (1991) who indicated that ankle taping significantly decreased performance in the vertical jump, shuttle run, and sprint for 4%, 4.6% and 3.2%, respectively. Juvenal (1972) and Mayhew (1972) similarly described a decrease in vertical jump ability with taping. (31, 32) Both Juvenal (1972) and Mayhew (1972) discovered that various running and jumping activities were significantly restricted by the use of adhesive strapping procedures. (31, 32) The knees was the most contribution in terms of power generation in vertical jumping, and the ankle contributed greater than the plantar fascia muscle to vertical jumping. This agree with the kinetic and kinematic data reported by Jaric et al. (1989). (3) The knee extensors
have the dominant effect on jumping height. Chentanez et al. (2001) used the method of partial fixing of joints (e.g. knee, ankle, and plantar flexors) on subjects performing horizontal jumps in order to evaluate contribution in jumping performance. (77) They found plantar flexion and knee extension contributed greatly to horizontal jumping. (77)

But this result is contrary with the previous studies. Robertson and Fleming (1987) pointed out that the contribution of the ankle muscles was more than the knee muscles by using similar body parts in generating force. (4) As well as, the conclusion of Stefanyshyn and Nigg (1998), they reported that the ankle was the largest energy generator but they investigated the energy contribution of the lower extremity to vertical jumping with a running approach. (78)

Another aim of the present study was to simulate an orthopedics abnormality of joints on jumping performance in normal and volleyball player. Applying adhesive tape strapping had an effect on the range of motion (ROM) in each joint. The present results show a decline of ROM in knee flexion 7.79%, 8.38%; knee extension 16.34%, 16.26%; ankle plantar flexion 40.44%, 46.65%, ankle dorsiflexion 46.39%, 38%; ankle inversion 26.35%, 34.12%; ankle eversion 32.20%, 42.62%; in right and left lower extremity respectively. This corresponded with a study of Verbrugge (1996). (26) They investigated the effect of adhesive taping on range of motion of ankles inversion and eversion, adhesive taping condition revealed maximal losses of ankle ROM restriction for both inversion and eversion.

In addition, joint partial fixing can be considered as one abnormality which can increase the joint stiffness. Thus, it might has some effects on the vertical jump performance. In the current study, it is clearly seen that the vertical jump height was
decreased by strapping of knees, ankles and plantar fascia respectively. This contradicts to a study by Kubo, Kawakami, and Fukunaga (1999), who studied on the elastic properties of tendon structures in vivo and to investigate the influence of the tendon properties on jumping performance. (79) Statistical analysis revealed that the stiffness was not significantly related to jump height. Work of Pienkowski et al. (1995) determined whether athletic performance (in four basketball-related activities which were vertical jumping, standing long jumping, and cone running) was affected by three ankle brace designs. (80) It was concluded that no brace affected athletic performance in one specific activity more than another, and athletic performance did not change with ankle bracing.

There were many factors that maybe related to the jump height performance. When consider the subject's characteristics of this study, there was no significant correlation between leg length, leg strength, and body height to jump height performance in this study. This coincides with a previous study by Young, Wilson and Byrne (1999), who investigated the relationships between the strength of the leg extensor musculature and performance in vertical jumps. (81) It was concluded that strength is relatively less important in vertical jump. In a vertical jump simulation study, Bobbert and van Soest (1994) demonstrated that although muscle strength determines the maximal jump height achievement, actual performance depends on the control of muscle coordination. (82) In that study neither increasing the muscle strength of the knee extensor muscles nor raising the strength of all muscles resulted in jump height improvement, until the muscle activation (control) was reorganized. These studies agree with the present study. On the other hand, a study by Fuster, Jerez, and Ortega (1998) determined whether the relationship of body typology to physical
performance. (83) The results were shown that vertical jump performance in men appeared to be more related to height of subject.

Fatigue can be considered as one of the factors related to the jump performance of subjects. Some evidences provided that compensatory mechanisms were used to counterbalance the loss of the muscle force-generating properties because of fatigue. This was in agreement with Rodacki, Fowler and Bennett (2002) who investigated the segmental coordination of vertical jumps under fatigue of the knee extensor and flexor muscles. (84) Fatiguing the knee flexor muscles did not reduce the height of the jumps or induce changes in the kinematic, kinetic, and electromyographic profiles. Knee extensor fatigue caused the subjects to adjust several variables of the movement, in which the peak joint angular velocity, peak joint net moment, and power around the knee were reduced and occurred earlier in comparison with the nonfatigued jumps. Besides the investigation by van Schenau et al. (1995) suggested that change in muscle activation timing should be accomplished to avoid deterioration of the performance when the properties of the musculoskeletal system are changed. (85) Thus, under fatigue, defined as the inability of the neuromuscular system to sustain the required or expected power output around a joint. (86) Thus, the present study provided the rest interval between each jump for 1-3 minutes. At this rest interval, considered long enough to vanish fatigue in subjects. Hence, Read and Cisar (2001) revealed that a 15-second rest interval was sufficient for recovery during the performance of jumps. (87) This conclusion came from their measurements of the effects of varied rest interval lengths on the vertical jump heights. The 3 rest intervals between jumps were 15, 30, and 60 seconds, the result revealed that rest interval length did not affect (p > 0.05) vertical jump height.
The present study used the Gibney techniques (74) as a method of taping application, and found that adhesive tape strapping had an effect on the vertical jump performance. In contrast, Verbrugge (1996) and Gross et al (1994) (26, 30) suggested application of adhesive tape did not significantly affect the performance of vertical jumping, while they applied the modified Gibney technique (26) with medial to lateral straps and continuous heel locks as a method of application.

The present experiment asked the subjects to plant both feet approximately shoulder width apart and bend their legs in a jumping position. The degree of knee-bend utilized by the subjects is self-determine, total arm swing and depth of preparatory squat was not controlled in this study, with the primary goal to jump as high as possible. For this reason, starting position may be considered as one factor related to jump performance as well. Selbie and Caldwell (1996) addressed the question of whether maximal vertical jump height depends on initial jumping posture in their work. (88) By using a computer simulation, a human body was modeled as four rigid segments connected by ideal hinge joints, with movement constrained to the sagittal plane and driven by three single-joint torque actuators. The model results revealed that maximal jump height is relatively insensitive to initial posture, and also suggested that similar vertical jump heights should be obtained using a wide range of initial starting positions. In the literature of Bobbert et al. (1996), it is well established that subjects are able to jump higher in a countermovement jump (CMJ) than in a squat jump (SJ). (89) The greater jump height in CMJ was attributed to the fact that the countermovement allowed the subjects to attain greater joint moments at the start of push-off. As a consequence, joint moments were greater over the first part of the range of joint extension in CMJ, so that more work could be produced than in SJ. To
explain this finding, measured and manipulated kinematics and electromyographic activity were used as input for a model of the musculoskeletal system. According to simulation results, storage and reutilization of elastic energy could be ruled out as explanation for the enhancement of performance in CMJ over that in SJ. The crucial contribution of the countermovement seemed to be that it allowed the muscles to build up a high level of active state (fraction of attached cross-bridges) and force before the start of shortening, so that they were able to produce more work over the first part of their shortening distance.

The simple method of jumping analysis such as that shown here can demonstrate the degree of contribution of knee, ankle, and foot to a vertical jumping action. This analysis may help in designing training methods and follow-up, which may give increased advantage in sports competition. Similar methods of partial immobilizing of joints by taping, if applied to other body parts, may permit functional changes to be detected objectively and systematically. This approach may permit analysis of greater detailed functions of the joints and muscles involved in specified movement of the body parts.
CHAPTER VI

CONCLUSION

On the basis of the results obtained in this study, the following conclusions seem warranted.

1) Taping of some joints of the leg had significant effect on the athletes' vertical jumping ability.

2) The data obtained indicated that the knee may give the most contribution in terms of power generation in vertical jumping, and the contribution of the ankle was more than the plantar fascia muscle.

3) Taping application was effective at providing significant restriction in active range of motion of ankle dorsiflexion, ankle plantarflexion, inversion, eversion, knee flexion, and knee extension.

4) Taping application demonstrated maximal losses in mechanical restriction for both ankle dorsiflexion and plantarflexion active range of motion.

5) There were not significantly related between leg muscles strength, height of subject, and leg length and vertical jump ability.
CHAPTER VII
RECOMMENDATION

1. Recommendation for useful of taping

Other sports such as boxing and weight lifting can use and choose the taping technique, which is appropriate for their sports in order to prevent and manage injury without the effect on their performance.

2. Recommendation for further research

A subject who got used to taping might able to adjust his skill to perform an optimal vertical jump. Therefore, further studies are needed to ask about the using frequency of taping treatment as knee and ankle supports over the period of volleyball practices and games.

In addition, increase sample size will helps the researcher to know more clearly about the relationship between the vertical jump performance and the leg strength, subject’s height, and leg length.
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APPENDIX A

PHYSICAL EXAMINATION FORM

NAME..............................................................................................................
AGE.................. WEIGHT.................... kg  HEIGHT..............................cm
EXPERIENCE............................
THE HIGHEST LEVEL..............................................................

Anthropometric measurements
- body weight...................... kg
- body height...................... cm

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<td>Leg length (ASIS - medial malleolus)</td>
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<tr>
<td>Thigh length</td>
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</tr>
<tr>
<td>Leg length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot length</td>
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<td></td>
</tr>
<tr>
<td>Circumference of knee joint</td>
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<td></td>
</tr>
<tr>
<td>5 cm above knee joint line</td>
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</tr>
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<tr>
<td>15 cm below knee joint line</td>
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### Leg strength (kg)

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### Assessment of the knees, and ankles

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<td>- Adduction test</td>
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<td>- Anterior drawer test</td>
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<td>- Posterior drawer test</td>
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<tr>
<td>- McMurray test</td>
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<tr>
<td>- Posterior drawer test</td>
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</tr>
<tr>
<td>- Inversion stress test</td>
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<td>- Eversion stress test</td>
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Range of motion measurement

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<tr>
<td></td>
<td>Rt</td>
<td>Lt</td>
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<tr>
<td>Knee flexion</td>
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</tr>
<tr>
<td>Ankle plantarflexion</td>
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</tr>
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<tr>
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<tr>
<td>Ankle eversion</td>
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Vertical jump test

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<tr>
<td>Knee taping</td>
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APPENDIX B

หนังสือยินยอม

ชื่อโครงการ การเปลี่ยนแปลงข้อถกประเด็นของการดำรงในนักวอลเลย์บอลหลังจากรุ่นชีวิต
ชื่อผู้พิจารณา นางสาว ณัฐธิกา นาคเพชร
ชื่อผู้รุ่งเรือง .................................................. อาญ..................................

ค่ายนักฟุตบอล

ข้าพเจ้า.............................................................ได้ทราบรายละเอียดของโครงการ การรักษาและ
ทดสอบผลพนักประชัย และข้อเสียที่จะเกิดขึ้นต่อผู้รุ่งเรืองจากผู้พิจารณาแล้ว และยินยอมให้
ทำการทดสอบในโครงการที่มีข้อจำกัดไว้ และข้าพเจ้ารู้ว่าไม่มีปัญหาหรือข้อสงสัยกิจขึ้น ข้าพเจ้า
สามารถยอมผู้รุ่งเรืองได้ และข้าพเจ้าสามารถไม่นำข้อมูลโครงการทดสอบนี้สื่อให้กันได้

ลงชื่อ...........................................................(ผู้รุ่งเรือง)
...........................................................(อาญ)
...........................................................(อาญ)
วันที่...........................................................

คำอธิบายของผู้พิจารณา

ข้าพเจ้าได้อธิบายรายละเอียดของโครงการ ทดสอบผลพนักประชัยของการทดสอบรวมทั้งข้อ
เสียที่อาจเกิดขึ้นต่อผู้รุ่งเรืองแล้ว

ลงชื่อ นางสาว ณัฐธิกา นาคเพชร (ผู้พิจารณา)
วันที่...........................................................
BIOGRAPHY

NAME
Miss. Nuttika Nakphet

DATE OF BIRTH
April 9, 1978

PLACE OF BIRTH
Suratthani, Thailand

INSTITUTIONS ATTENDED
Chulalongkorn University,
1995-1999 Bachelor of Science
(Physical Therapy)
Mahidol University, 1999-2002
Master of Science (Sport Science: Biomechanic)

ADDRESS
133/7 Moo 1 Watpho-Bangyai Road, Thumboon
Makhamtea, Muang, Suratthani, 84000.