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EFFECTS OF TENNIS SHOE TREAD PATTERNS ON PLANTAR PRESSURES DURING GROUNDSTROKE SHOTS

Miss Somruthai Poomsalood

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Sports Medicine
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By	Miss Somruthai Poomsalood
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Accepted by the Faculty of Medicine, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of the Faculty of Medicine

(Professor Adisorn Patradul, M.D.)

THESIS COMMITTEE

.... Chairman

(Associate Professor Pongsak Yuktanandana, M.D.)

.... Thesis Advisor

(Assistant Professor Pasakorn Watanatada, M.D., Ph.D.)

.... Examiner

(Associate Professor Sompol Sanguanrungsirikul, M.D., M.Sc.)

.... Examiner

(Songpoj Tanprasert, M.D.)

.... External Examiner

(Suwat Sidthilaw, Ph.D.)

สมฤทัย พุ่มสลุด : ผลของรูปแบบลายพื้นรองเท้าเทนนิสต่อแรงกดฝ่าเท้าขณะตีลูกท้ายคอร์ท. (EFFECTS OF TENNIS SHOE TREAD PATTERNS ON PLANTAR PRESSURES DURING GROUNDSTROKE SHOTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.นพ.ดร. ภาสกร วัธนธาดา, 98 หน้า.

การวิจัยนี้มีวัตถุประสงค์เพื่อเปรียบเทียบแรงกดฝ่าเท้าที่บริเวณจุดหมุนของรองเท้า (Pivot point area) ซึ่งเป็นบริเวณที่อยู่ตรงกับส่วนของกระดูก 1st metatarsal เป็นส่วนใหญ่ ระหว่างการใส่รองเท้าเทนนิสที่มีลายพื้นแบบฟันปลา (Herringbone pattern) และรองเท้าเทนนิสที่มีลายพื้นแบบฟันปลากับจุดหมุน (Herringbone pattern with pivot point) ในนักเทนนิสขณะวิ่งตีลูกท้ายคอร์ท นักเทนนิสชายไทยที่เข้าร่วมการวิจัยครั้งนี้มีจำนวน 5 คน มีทักษะการตีเทนนิสอยู่ที่ระดับ 5.0 โดยอาศัยเกณฑ์การจัดระดับของ National Tennis Rating Program (NTRP) โดยนักเทนนิสแต่ละคนต้องใส่รองเท้าทั้ง 2 แบบ แล้วทำการตีลูกท้ายคอร์ทตามรูปแบบที่กำหนดให้บนคอร์ทปูน (Hard court) แรงกดฝ่าเท้าถูกบันทึกโดยอุปกรณ์ F-Scan insole

ผลการศึกษาพบว่ามีความแตกต่างอย่างมีนัยสำคัญของแรงกดฝ่าเท้า (Peak pressure) ที่เป็นข้อมูลดิบ (Raw data) ของก้าวโฟร์แฮนด์ระหว่างการใส่รองเท้าทั้ง 2 แบบ นักเทนนิสตีโฟร์แฮนด์ทุกก้าวด้วยการยืนแบบเปิด (Open stance) โดยรองเท้าเทนนิสที่มีลายพื้นแบบฟันปลากับจุดหมุนทำให้เกิดแรงกดฝ่าเท้าที่บริเวณจุดหมุนของรองเท้าสูงกว่ารองเท้าเทนนิสที่มีลายพื้นแบบฟันปลา (760.54 ± 253.17 KPa (ฟันปลา); 866.82 ± 233.52 KPa (จุดหมุน), $p<0.05$) แต่พบว่าไม่มีความแตกต่างของแรงกดฝ่าเท้าของก้าวแบคแฮนด์ทั้งแบบ Square stance (117.80 ± 109.42 KPa (ฟันปลา); 115.61 ± 82.79 KPa (จุดหมุน)) และ Open stance (502.10 ± 173.01 KPa (ฟันปลา); 511.76 ± 174.22 KPa (จุดหมุน)) ระหว่างการใส่รองเท้าทั้ง 2 แบบ และเมื่อทำค่าแรงกดฝ่าเท้าให้เป็นมาตรฐานเดียวกันโดยหารด้วยน้ำหนักตัวของนักเทนนิสแต่ละคน พบว่าค่าทางสถิติที่ได้เป็นไปในทางเดียวกับค่าแรงกดฝ่าเท้าที่เป็นข้อมูลดิบ รองเท้าเทนนิสที่มีลายพื้นแบบฟันปลากับจุดหมุนทำให้เกิดแรงกดฝ่าเท้าที่บริเวณจุดหมุนของรองเท้าสูงกว่ารองเท้าเทนนิสที่มีลายพื้นแบบฟันปลาอย่างมีนัยสำคัญทางสถิติในส่วนของก้าวโฟร์แฮนด์ (11.24 ± 3.35 KPa/kg (ฟันปลา); 12.90 ± 3.39 KPa/kg (จุดหมุน), $p<0.05$) แต่พบว่าไม่มีความแตกต่างของแรงกดฝ่าเท้าของก้าวแบคแฮนด์ทั้งแบบ Square stance (1.72 ± 1.52 KPa/kg (ฟันปลา); 1.63 ± 1.14 KPa/kg (จุดหมุน)) และ Open stance (7.84 ± 2.72 KPa/kg (ฟันปลา); 8.15 ± 2.98 KPa/kg (จุดหมุน)) ระหว่างการใส่รองเท้าทั้ง 2 แบบ สรุปได้ว่ารองเท้าเทนนิสที่มีลายพื้นแบบฟันปลากับจุดหมุนทำให้เกิดแรงกดฝ่าเท้าที่บริเวณจุดหมุนของรองเท้ามากกว่ารองเท้าเทนนิสที่มีลายพื้นแบบฟันปลาเฉพาะก้าวโฟร์แฮนด์

สาขาวิชา เวชศาสตร์การกีฬา ลายมือชื่อนิสิต สมฤทัย ปุ่มสลุด
ปีการศึกษา 2552 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....

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SOMRUTHAI POOMSALOOD : EFFECTS OF TENNIS SHOE TREAD PATTERNS ON PLANTAR PRESSURES DURING GROUNDSTROKE SHOTS. THESIS ADVISOR : ASST. PROF. PASAKORN WATANATADA, M.D., Ph.D., 98 pp.

The objective of the study was to compare plantar pressures on the pivot point area between wearing tennis shoes with herringbone pattern and tennis shoes with herringbone pattern with pivot point when tennis players changed direction during groundstroke shots. The participants in this study were 5 Thai male tennis players whose skill levels were 5.0 classified by National Tennis Rating Program (NTRP) criteria. All the players wore 2 types of tennis shoes and performed groundstroke shots as designated patterns on the hard court surface. Peak pressures were recorded by the F-Scan insole.

The results demonstrated that there was statistically significant difference in peak pressures on the pivot point area of forehand steps between wearing 2 types of shoes. All forehand steps were performed with square stance pattern. The shoe type with pivot point caused higher plantar pressures than the one without pivot point did (760.54 ± 253.17 KPa (herringbone); 866.82 ± 233.52 KPa (pivot point), $p<0.05$). There were no differences in peak pressures on the pivot point area between wearing the tennis shoes with herringbone pattern and the ones with herringbone pattern with pivot point when performing square stance backhand steps (117.80 ± 109.42 KPa (herringbone); 115.61 ± 82.79 KPa (pivot point)) and open stance backhand steps (502.10 ± 173.01 KPa (herringbone); 511.76 ± 174.22 KPa (pivot point)). After normalizing peak pressures with the players' body weight, the results agreed to the results of peak pressures without normalization: forehand steps: 11.24 ± 3.35 KPa/kg (herringbone); 12.90 ± 3.39 KPa/kg (pivot point), $p<0.05$, square stance backhand steps: (1.72 ± 1.52 KPa/kg (herringbone); 1.63 ± 1.14 KPa/kg (pivot point), and open stance backhand steps: 7.84 ± 2.72 KPa/kg (herringbone); 8.15 ± 2.98 KPa/kg (pivot point). In conclusion, the tennis shoes with herringbone pattern with pivot point caused higher peak plantar pressures on the pivot point area when performing forehand steps.

Field of Study : Sports Medicine Student's Signature Somruthai Poomsalood

Academic Year : 2009 Advisor's Signature P. Watanatada

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CHAPTER I

INTRODUCTION

Background and Rationales

Tennis is one of the world's most popular and widely-played sports by people of all standards (สุธนะ ติงศภัทิย์, 2547; Girard et al., 2007; Pluim et al., 2008). There are rules that help players develop their performances and their minds. Tennis originated from the game "Le Jeu Du Paume" which was originally played with a player's palm on an indoor court. It was very popular in Paris during the 13^{th} century (สุธนะ ติงศภัทิย์, 2547).

During the last few decades, tennis has experienced a big growth. During the first half of this century, tennis was a recreational activity for wealthy people. At the present time, it is available to all and has a strong competitive component (Nigg, Luethi, and Bahlsen, 1989). The modern game of tennis is completely different from the past. Most tennis players recently play power and quick games because they have been influenced by equipment used, such as rackets, balls, surfaces, and shoes (Luethi et al., 1986). In the late 19^{th} century, tennis was played mainly on grass for many years until the introduction of acrylic in the 1940s and clay in the 1950s. These are the most common surfaces on which tennis is played today (Miller, 2006).

During a game of tennis, a player has to move in different directions, such as forward, backward, and side to side. Fast lateral movements occur very frequently so the player is often forced to stop this type of movement in one step in order to be prepared for the following stroke (Reid and Crespo, 2003; Pieper, Exler, and Weber, 2007). Tennis footwear plays an important role of the tennis game besides rackets, balls, and clothes. It has been designed to suit the recent playing styles. It consists of four basic components which are upper part, insole, midsole, and outsole. The upper part is an area that wraps over the foot. The insole is found directly under the foot. The midsole is a shoe's predominant cushion support. The outsole is where the rubber hits the court.

Furthermore, there is a tread pattern in the rubber of the outsole that is designed for distinct frictional needs of specific movements (Tennis shoe anatomy, n.d.).

Currently, there are several types of tennis shoe tread patterns available on the market depending on manufacturers but only two types are mainly used. The first one is herringbone pattern which is good on all court surfaces, especially on the hard one. The second one is herringbone pattern with pivot point. The pivot point is on the medial forefoot area to help abilities of changing direction without falling (Tennis shoe review, n.d.). It is not easy to decide which shoes are the best for tennis players because of several factors, such as foot types and court surfaces (Miller and Cross, 2003; Tennis shoes and court surface, n.d.). However, good tennis shoes should help to increase players' performances and their abilities of changing direction without causing high plantar pressures.

Controlling a ball from the baseline during groundstroke shots is a very important thing that affects tennis game results. If a player can hit a ball to various direction and barely hit it to the net then he gains advantages. The best ways to control the ball are to be ready to receive the ball, to move fast, to stop at the appropriate position, to transfer the body weight from the lower part to the upper part, and to change direction efficiently (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547). Tennis shoes are very beneficial for players to move, to stop, and to change direction.

Studying about plantar pressures while wearing tennis shoes that have different tread patterns will help tennis players choose appropriate tennis shoes that increase their performances and decrease plantar pressures which cause injuries (Girard et al., 2007). From this view, the researcher is interested in studying about different tennis shoe tread patterns on plantar pressures on the pivot point area during tennis groundstroke shots. The researcher expects that different tread patterns may cause different plantar pressures during the change of directions.

Research Question

Will different tennis shoe tread patterns result in different plantar pressures on the pivot point area in tennis players during groundstroke shots?

Objective

To compare plantar pressures on the pivot point area between wearing tennis shoes with herringbone pattern and tennis shoes with herringbone pattern with pivot point in tennis players during groundstroke shots.

Hypothesis

Tennis shoes with herringbone pattern and tennis shoes with herringbone pattern with pivot point result in different plantar pressures on the pivot point area during groundstroke shots.

Scope of Research

This study is an observational analytic research which examines plantar pressures between wearing tennis shoes with herringbone pattern and tennis shoes with herringbone pattern with pivot point in tennis players and compares those pressures on the pivot point area during groundstroke shots.

The study approval was obtained from the University Ethics Committee. Written informed consent was obtained from each subject prior to participation. On attendance, the subjects were given the details of the research procedure and risk involved, and reminded of their right to withdraw at any stage.

Assumptions

1. The participants were Thai male tennis players who had tennis skills (National Tennis Rating Program: NTRP) at level 5.0. All the players were classified by a tennis coach who had been trained from the International Tennis Federation (ITF).

2. If the players got injured during the study, the data would not be analyzed.

3. Only one tennis court was used so it did not affect different plantar pressures.

4. The tennis shoe sizes were 10.5 and 11.5 (US size).

5. If it rained in the testing day, the tennis court must be cleaned before starting the test.

6. The equipment in the study was accurate.

Limitations

1. This study required the cooperation from Thai male tennis players who had tennis skills (National Tennis Rating Program: NTRP) at level 5.0.

2. This study required the cooperation from the institutes that had the equipment.

3. The In-shoe system used in this study had no wireless so it required plugging in with a laptop computer. Wiring the system to a player might limit movements.

4. The tennis players must have shoe size 10.5 or 11.5 (US size).

Key Words

Tennis shoes, Tread pattern, Plantar pressure, Groundstroke

Operational Definitions

1. Tennis shoes are defined as footwear that the tennis players wear in the study. There are two types of tennis shoes used in this study. One is Adidas Barricade CLS which has herringbone tread pattern on the outsole. The other one is Adidas Tirand III which has herringbone pattern with pivot point. The two pairs were made from the same materials. Adiprene is in the heel part and Adiprene+ is in the forefoot part for shock absorption.

2. Tread pattern is defined as a part that hits the court. Most tennis shoes consist of two types of tread patterns which are herringbone pattern and herringbone pattern with pivot point.

3. Plantar pressure is defined as pressure that is produced when tennis players move, stop, and change direction. The unit Kilopascal (kPa) is used in this study.

4. National Tennis Rating Program (NTRP) is defined as a system that is used to rate skills of tennis players. It was established in 1978 by the USTA (United States Tennis Association). It is designed to be easily administered, non-exclusive, and provide better on-court compatibility. This rating is from 1.0 - 7.0 with increments of 0.5. Level 1.0 is for beginners and level 7.0 is for world-class players. In this study, all tennis players must be at level 5.0. This means the players have good shot anticipation and regularly have excellent shots or attribute around which a game may be structured. They can hit winners or force errors off of short balls and put away volleys, successfully perform lobs, drop shots, half volleys, overhead smashes, and have good depth and spin on most second serves (National Tennis Rating Program [NTRP] Guidebook, 2005).

5. Open stance forehand is defined as a tennis hitting pattern. It has become one of the game biggest changes in the past 4 years. Most professional tennis

players hit most of their forehands with the legs in an open stance (legs and hips parallel to the baseline) in these days (Bahamonde and Knudson, 2003; Hofer, 2004).

6. Groundstroke is defined as a forehand or a backhand shot that is executed after the ball has bounced once on the court. It is generally hit from the back of the tennis court, around the baseline (Groundstroke, 2009).

7. Quadriceps angle (Q-angle) is defined as an angle formed by a line drawn from the Anterior Superior Iliac Spine (ASIS) to the central patella and a second line drawn from the central patella to the tibial tubercle. The normal range is between 18-22 degrees in the standing position (Biedert and Warnke, 2001).

8. Footprint is defined as a method that distinguishes a normal foot and an abnormal foot. The method is called "The Chippaux-Smiruk Index (CSI)". CSI values of 0% indicate a high arch foot, between 0.1 and 29.9% a normal arch, 30 to 39.9% an intermediary arch, 40 to 44.9% a low arch, and more than 45% indicate a morphological flat arch foot (Shiang et al., 1998; Nikolaidou and Boudolos, 2006; Villarroya et al., 2008).

9. Leg length difference is defined as when one leg is shorter than the other. It is measured from the Anterior Superior Iliac Spine (ASIS) to the medial malleolus in the lying position (Ashford and Shippen, 2003). In this study, the tennis players must not have more than 5 mm of the difference.

10. Ankle Range of Motion (ROM) is defined as a distance and a direction that the joint can move to its full potential. The normal active range of ankle plantarflexion is 0-50° and the normal active range of ankle dorsiflexion is 0-20° (Thoms and Rome, 1997). The normal active range of ankle inversion and eversion is 0-5° (subtalar joint) (Menadue et al., 2006).

Expected Benefits and Applications

1. To help tennis players decide what are the best shoes for increasing performances and decreasing plantar pressures.

2. To indicate the tennis players' performances while completing the test. The protocol requires them to run very fast. If the tennis players can not complete the entire test because of fatigue, it shows that they need more training.

3. To gain the tennis players' experiences from participating the study.

4. To start biomechanical studies about tennis shoe tread patterns.

5. To develop future researches.

CHAPTER II

REVIEW LITERATURES

Basic Movements in Tennis

Playing tennis requires several kinds of movements of the body. Tennis players need to have good movement skills to perform their highest performances. The movement skills that tennis players should have are running, jumping, sliding, and changing direction (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547; Reid and Crespo, 2003).

There are some basic skills that help tennis players move very well on the court as follows:

1. Footwork

Footwork is a huge part of the game of tennis. The better a tennis player's footwork the better he can play (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547). The player does not need to be quick to have good footwork. Although speed can help, the player can still be very effective and cover a lot of the court without being extremely fast as long as he has good footwork. Correct footwork can help the player to cover more court, recover quicker after shots and help him prepare for the next shot (Baker, n.d.).

2. Balance (static and dynamic)

One of the most important things in becoming a good tennis player is to be in the correct position to hit the ball and control it to the right direction (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547). Not only does a tennis player's footwork have to be good to be able to get to the ball, but that player also has to be balanced. Therefore, the player really needs to learn to master and control his body so that he can hit the best shot (Hassan, n.d.).

Ball Control

Ball control is the root of every successful tennis game. Learning how to control a ball step by step helps tennis players hit the ball effectively (Bowden, n.d.).

There are five steps that tennis players should pay attention as follows:

1. Keep the ball in play

The first thing that every tennis player has to learn when they start hitting a ball for the first time is how to control the ball into the court (Elderton, 2002). To do that, the player needs to know how to control the racket including trying to move to the right position before hitting the ball (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

2. Direct the ball

Knowing how to control a ball very well helps tennis players control the ball to every direction they want. It is useful for them to apply this technique to competition matches (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

3. Maintain good depth

When a player can control the direction and the depth of a ball, it means that he puts pressure on his opponent and makes the opponent hit the ball when he is far away from the baseline. The further he is far from the baseline, the more mistakes he makes. Moreover, the ball speed will be slower so it gives the hitter more time to prepare for the next shot (Elderton, 2002; วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

4. Spin

The spin makes a ball hit the court faster so it is easy for a player to control the ball by using the spin. There are two kind of spin which are topspin and backspin in the tennis game. Tennis players usually hit the ball with topspin when they play offensive points. If they want to play defensive points, they will use backspin (Elderton, 2002; วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

5. Power

The modern tennis game is very fast and hard. A player who hits harder and more accurate will have advantages over an opponent because he gives the opponent less time to get ready for the next shot and can't control the ball so well (Elderton, 2002; วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

Playing Surfaces

Tennis was developed as an outdoor game played on natural surfaces which were grass and clay (Nigg and Yeadon, 1987; Miller, 2006). Two of the principal reasons for the development of artificial playing surfaces were the desire to make tennis independent from external influences, for example the weather, and the need to reduce operating and maintenance costs. On the other hand, there is evidence pointing to change in the type and frequency of injuries with the introduction of new surface materials (Nigg and Yeadon, 1987).

Today, tennis is played on a variety of surfaces from concrete and asphalt to clay, indoor carpet, synthetic materials, and grass. The four major tournaments around the world are played on different surfaces: Australian Open – Rebound Ace, French Open – clay, Wimbledon – lawn, and the US Open – Deco Turf and Plexipave. The uppermost playing surface is the hard court (Cassell and McGrath, 1999).

Open Stance Forehand Groundstroke

About 80% in the tennis game, most tennis players hit the ball with forehand because they can move fast and hit the ball hard (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547). Recent alteration in the weight, size, and stiffness of the racket has started to change the dominant forehand technique used during the tennis game (Bahamonde and Knudson, 2003). Most players recently hit the open stance forehand shot because it creates harder shots and helps the players change direction faster than the square stance forehand technique (Hofer, 2004).

The open stance forehand is like the greatest symbol of modern tennis. It has become one of the game's biggest changes in the past 4 years. Most professional tennis players usually hit most of their forehands with the legs in an open stance (legs and hips parallel to the baseline) (Bahamonde and Knudson, 2003; Hofer, 2004).

There are several benefits for this. The first one is that the open stance permits more power. The hips and the shoulders rotate back with the racket, the legs must bend and flex. This flexing of the body creates a dynamic loading of leg muscles and body (Elliott and Alderson, 2003; Elliott, 2006). This loading is like a rubber band that is stretched then it creates a quick and powerful action. When these loaded muscles begin to contract in order, they create a kinetic chain that unleashed offers a strong power source (Elliott and Alderson, 2003; Hofer, 2004). Unlike the closed or neutral stance (feet and hips turn sideways with the body), there is very little loading or stretching of the muscles. This neutral stance should have some leg flex but the main power comes from shifting the weight from the back leg to the front leg during the swing (Hofer, 2004). Although it is good and does not overstress the player's upper extremity, it is become archaic or old. Today's game demands more strength and power (Elliott and Alderson, 2003).

The second benefit comes from a quicker recover from the open stance. Even before the swing is completed, the body weight is transferred from the right leg to the left leg. This shifting is lateral or sideways and has the body moving back towards the center of the court even before the finish of the swing. Once the swing is completed, the body is already moving back into position because the legs are still parallel to the baseline. Today's players must react and recover more quickly because of the power involved in the game (Hofer, 2004).

This is how to hit the open stance forehand groundstroke.

1. Place the outside leg almost directly in the path of the oncoming ball. The body weight is placed on this leg while the legs bend and the trunk turns sideways (Figure 2.1) (Elliott and Alderson, 2003; Hofer, 2004).

Figure 2.1 The open stance forehand step one (Hofer, 2004)

2. During the swing, the legs begin the motion by straightening as the hips turn forward followed by the shoulder rotation (Elliott and Alderson, 2003). The arm and the racket are the last components to be brought into the sequence of the swing (Figure 2.2) (Hofer, 2004).

Figure 2.2 The open stance forehand step two (Hofer, 2004)

This sequencing is called the kinetic chain. It is very important that the timing of each of the body segments is happening one right after the other (Hofer, 2004).

Square Stance and Open Stance Two-Handed Backhand Groundstroke

Two-handed backhand is very useful for players whose arms' muscles are not so strong because the two hands help each other to control the racket. Moreover, players who play two-handed backhand can hit the highly bouncing ball better than those players who play one-handed backhand. This is the reason why most tennis players play two-handed backhand. One more important thing is playing two-handed backhand is much easier than one-handed backhand (วิทยาศาสตร์การกีฬาสำหรับกีฬาเทนนิส, 2547).

Tennis players still play backhand shots with both square and open stance techniques depending on an oncoming ball. A ball that is hit hard around a player's body should be played with the open stance backhand that requires the player to stand with legs and hips parallel to the baseline, whereas a low bouncing ball in front of the player should be played with the square stance backhand that requires the player to step the right leg forward and across the left leg (Key, 2007).

This is how to hit the two-handed backhand groundstroke.

1. Turn the shoulders towards the ball. Use the wrists and arms to bring the racket head back. Keep turning until the racket is pointing backward at about waist high (Figure 2.3) (Elliott and Alderson, 2003; Master the two-handed backhand, n.d.).

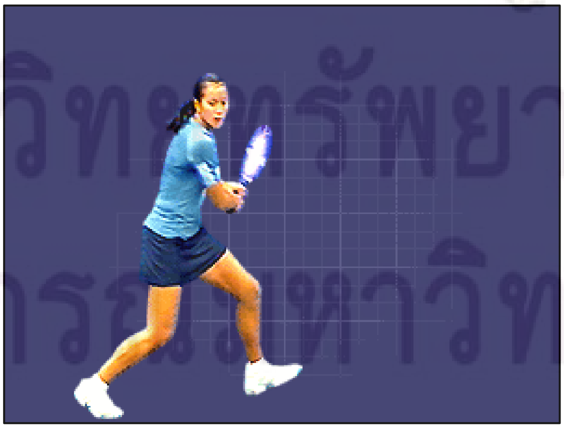


Figure 2.3 The two-handed backhand step one (Master the two-handed backhand, n.d.)

2. The key from here is to stay relaxed. The role of the arms is largely to transfer the power stored in the legs, shoulders, and torso to the racket (Figure 2.4) (Master the two-handed backhand, n.d.).

Figure 2.4 The two-handed backhand step two (Master the two-handed backhand, n.d.)

3. The footwork is now crucial. As a player gets to the ball, looks to load up on the left foot, and then transfers the body weight forward to the right before hitting the ball (Figure 2.5) (Elliott and Alderson, 2003; Master the two-handed backhand, n.d.).

Figure 2.5 The two-handed backhand step three (Master the two-handed backhand, n.d.)

4. Rotate the left side of the body through the ball and then combine this with a low-to-high swing with the arms. The rotation that is created will be so great that a player can start to spin around the follow through (Figure 2.6) (Elliott and Alderson, 2003; Master the two-handed backhand, n.d.).

Figure 2.6 The two-handed backhand step four (Master the two-handed backhand, n.d.)

Tennis Shoe History

The tennis shoe also known as the "sneaker" has its roots in the industrial revolution of the 19th century. The word "sneakers" was used to refer to boys' tennis shoes (Sebastian, 2008; Augustine, n.d.). American lexicographers described sneakers as "shoes with canvas tops and rubber soles," the local language meaning has come to include any shoes with natural or synthetic rubber soles (Figure 2.7). Uppers can be made of leather, nylon, canvas, plastic, or combinations of these (Coronado, 2002).

Figure 2.7 The sneakers (Coronado, 2002)

With new materials like vulcanized rubber and new production methods like assembly lines, manufacturers could make shoes more cheaply and more efficiently (previously, each shoe had to be produced by hand by a shoemaker). While some of the brands we know today which are Keds, Converse, and Adidas were introduced in the early 20th Century (Coronado, 2002; Sebastian, 2008; Augustine, n.d.).

Early tennis shoes timeline (Coronado, 2002)

Late 1800s	The first inexpensive British upper-class footwear was manufactured in England used for lawn tennis, cricket, croquet, and at the beach.
1917	The perfect sneaker “Converse All Star” was introduced.
1931	Dassler’s new company, Adidas, produced its first tennis shoe.
1960s	Adidas made shoes with nylon uppers and velcro started to be used as a fastener.
1970s	Geoffery Beene, Calvin Klein, and other designers changed sneakers into fashion.
1980s	Many shoe brands had become household words, such as Reebok, Nike, and Adidas.

Plantar Pressure Distribution Measurements

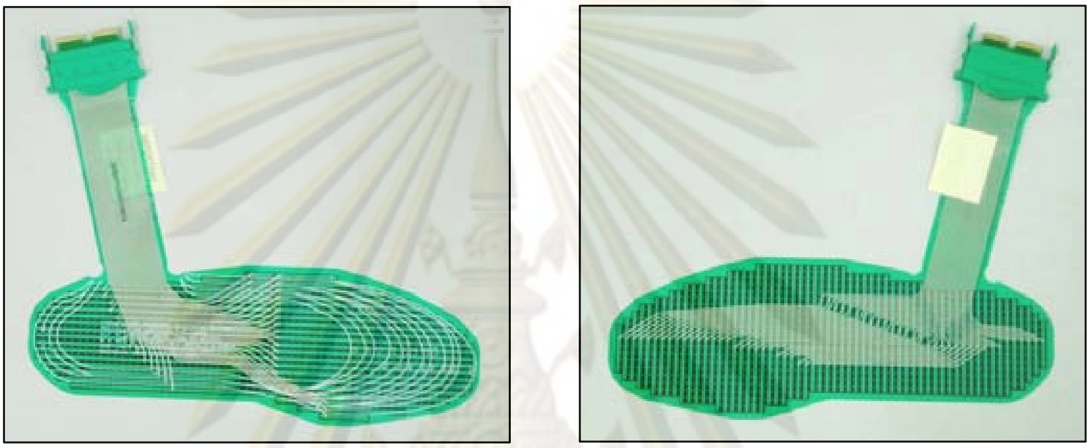
Early examinations of foot pressure patterns have used the imprint in soft materials, such as plaster of Paris comparable to the foot prints seen in the sand on the beach. These qualitative devices were only able to capture the shape of the foot and the deepest impressions in the surface. The first quantitative measurements using an air filed chamber were introduced by Marey and Carlet in the last century (Rosenbaum and Becker, 1997).

Today's pressure measurement systems depend on specialized electromechanical sensors. In fact, the pressure sensors are force transducers that measure the force acting on a known surface. They provide the necessary information to determine the pressure by dividing force by area. In the "SI" naming system, the pressure values should be reported in units of Pascal (Pa) which equals a force of 1 Newton on 1 square meter (1 $N \cdot m^{-2}$). For foot pressures, the values generally reach the kilopascal (KPa) or megapascal (MPa) range (Rosenbaum and Becker, 1997).

The In-Shoe Systems

These systems are useful tools to detect the plantar pressures between the foot and the shoe and can also be used to measure the effect of different shoe constructions or modifications during dynamic movements (Woodburn and Helliwell, 1996; Hsiao, Guan, and Weatherly, 2002; Cordero, Koopman, and Helm, 2003; Kong and Heer, 2009). A general advantage of these systems is that repeated steps can be recorded in one measurement (Rosenbaum and Becker, 1997). Another advantage is some of the available systems are combined with a portable data logger that allows field measurements outside the laboratory so that the subject can move freely (Kong and Heer, 2009).

The F-Scan system (Tekscan Inc., Boston, USA) is one of the most commonly used to determine the in-shoe pressures (Kong and Heer, 2009). The F-Scan insole (Figure 2.8) is a matrix system (Woodburn and Helliwell, 1996) using resistance-based technology and the insole is composed of 2 polyester sheets that inner surfaces are printed with electrical circuits (Hsiao, Guan, and Weatherly, 2002). The total number of sensors per insole is 960 and 4 cells per 1 cm^2. Each cell plays a role as a force measuring device and the system software calculates the average pressure on the measured vertical load and the cell area (Woodburn and Helliwell, 1996).



(a) (b)

Figure 2.8 (a) The F-Scan insole front view (b) The F-Scan insole back view

Related Studies

Although the tennis game is now very popular for all around the world to play and the modern equipments have been introduced including tennis shoes, there are not many studies about the influence of tennis shoes on plantar pressures. It can only be seen one. Bloch, Potthast, and Bruggemann (1999) studied about plantar pressures during the sliding on clay. Seventeen tennis players were instructed to hit alternating forehand and backhand baseline shots while wearing 3 types of tennis shoes. The ball machine shot tennis balls widely so that the players could slide side to side to hit the balls. The plantar pressures were measured by an insole with 99 sensors. The result demonstrated that there were significant differences ($p<0.05$) among the shoes. A pressure shift occurred from the back and middle foot to the forefoot during sliding when dividing the foot into 3 areas. This was seen in all 3 test shoes. The analysis of the pressure distribution when the foot was divided into 12 areas showed that in addition to the forward pressure shift that there was also a pressure shift from lateral to medial. It can be concluded that the shoes may play an important role in the learning and control of sliding in tennis.

Research studies about plantar pressure measurements in tennis players with the use of in-shoe systems can be seen some but not considered as much. Most of the studies focus on court surfaces. Girard et al. (2007) examined the influence of different playing surfaces on in-shoe loading patterns during tennis specific movements. Ten experienced male players performed two types of tennis-specific displacements (serve and volley (SV) and baseline play (BA)) on two different playing surfaces which were clay and acrylic. Plantar pressure information was recorded by an insole with 99 sensors. The results showed that mean force of the whole foot (SV: 615 ± 91 vs. 724 ± 151 N, BA: 614 ±73 vs. 717 ± 133 N) decreased on clay. When dividing the foot into 9 areas, it showed that playing on acrylic produced higher loading in the hullux (SV: 115 ± 39 vs. 85 ± 35 N, BA: 108 ± 38 vs. 84 ± 37 N) and lesser toes areas (SV: 121 ± 36 vs. 91 ± 28 N, BA: 116 ± 25 vs. 84 ± 31 N). In contrast, the relative load in the medial (SV: 56 ± 24 vs. 60 ± 30 N, BA: 61 ± 21 vs. 63 ± 29 N) and lateral midfoot (SV: 56 ± 17 vs. 62 ± 32 N, BA: 50 ± 18 vs. 58 ± 33 N) was higher on clay. This study demonstrates that playing surfaces affect plantar loading in tennis players.

Girard et al. (2007) also studied the influence of difference playing surfaces on in-shoe loading patterns during tennis specific movements. Ten experienced male players performed two types of tennis-specific displacements (serve and volley (SV) and baseline play (BA)) on two different playing surfaces which were clay and greenset. Maximum force, mean force, mean pressure, contact time, contact area, and relative load were recorded by an insole with 99 sensors. The results showed that mean force of the whole foot (SV: 615 (91) vs. 724 (151) N; -12.4%, $p<0.05$ and BA: 614 (73) vs. 717 (133) N; -11.6%, $p<0.05$) was higher on clay than on greenset.

The studies above present that there are not many plantar pressure researches in tennis players, especially about tennis shoe tread patterns on the pivot point area. The researcher is interested in studying about different tennis shoe tread patterns on plantar pressures on the pivot point area during tennis groundstroke shots as tennis is a very popular sport in Thailand and many other countries around the world. Moreover, the study could guide tennis players to choose the appropriate tennis shoes for themselves.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

This study is an observational analytic research which aims to examine effects of different tennis shoe tread patterns on plantar pressures on the pivot point area in five tennis players when changing direction during groundstroke shots. The study was approved by the Institutional Review Board, Faculty of Medicine, Chulalongkorn University.

Study Population

The target population was steps of Thai male tennis players whose skills were at level 5.0 rated by National Tennis Rating Program criteria.

The study samples were steps of qualified Thai male tennis players whose skills were at level 5.0 rated by National Tennis Rating Program criteria.

Screening

Tennis players were qualified for the study if they were at level 5.0 and had no documented diseases or conditions listed on the exclusion criteria. All the players were initially contacted by telephone to determine their qualification before the study.

<u>Inclusion criteria</u>

Steps that were produced from:

1. Thai male tennis players who were at level 5.0.
2. Tennis players who played tennis at least 3 times a week for the past 3 months.

3. Tennis players who had a normal arch on both feet (Figure 3.1).

4. Tennis players who had normal range of motion (ROM) with both ankles (Figure 3.2).

5. Tennis players who had a normal Q-angle of both legs (Figure 3.3).

6. Tennis players who had leg length difference of no more than 5 mm (Figure 3.4).

7. Tennis players who had two-handed backhand pattern.

8. Tennis players who were willing to participate in the study.

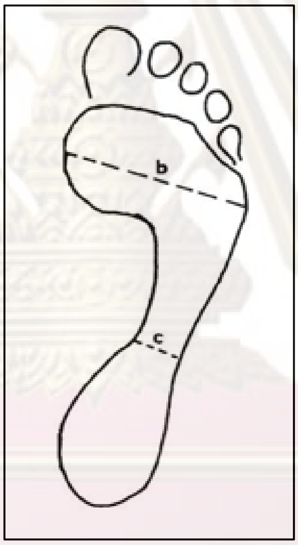
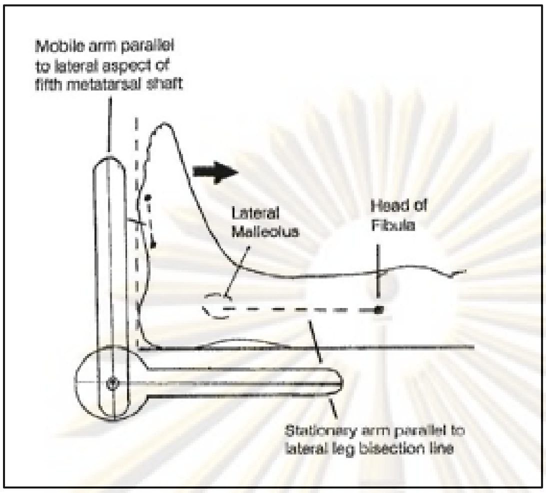
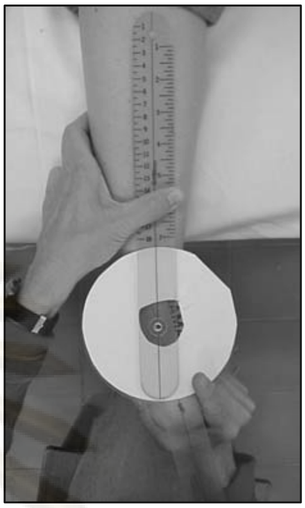


Figure 3.1 The Chippaux-Smirak Index (c/b %) (Villarroya et al., 2008)





(a) (b)

Figure 3.2 (a) Ankle plantarflexion and dorsiflexion measurements (Thoms and Rome, 1997) (b) Ankle inversion and inversion measurements (Menadue et al., 2006)

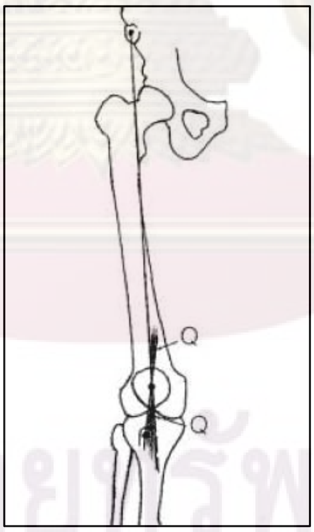


Figure 3.3 Q-angle measurement (Biedert and Warnke, 2001)

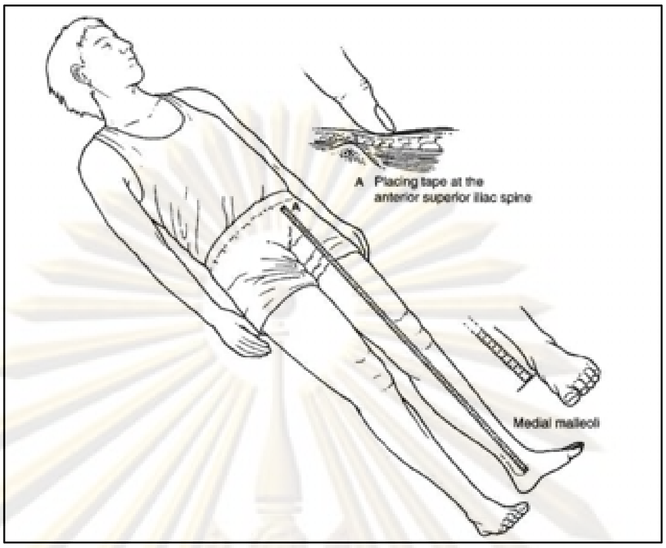


Figure 3.4 Leg length difference measurement (Ashford and Shippen, 2003)

Exclusion criteria

Steps that were produced from:

1. Tennis players who had lower extremity injuries for the past 3 months (Bloch et al., 1999; Girard et al., 2007).
2. Tennis players who had previous lower extremity surgery (Girard et al., 2007).
3. Tennis players who were left-handed.
4. Tennis players whose shoe sizes were not 10.5 or 11.5 (US size).

Sample

Sampling technique

This study used purposive sampling technique and voluntariness for selecting tennis players.

Sample size determination

In this study, the sample size determination was not calculated because this model was the starting of biomechanical research about tennis shoe tread patterns so it was not possible to use any past researches for the calculation. The researcher instead used Central Limit Theorem for the study. To make the data normal distribution, the number of sample size (n) must be at least 30 and to make the data reliable, the sample size should be more than 100.

Five Thai male tennis players who were at level 5.0 hit forehand and backhand groundstroke shots behind the baseline. Every player had to make 20 successful trials to collect a turning step in every trial wearing each type of shoes according to the station below:

- Start with a forehand hitting on the right side10 trials (to collect 10 backhand turning steps).
- Start with a backhand hitting on the left side 10 trials (to collect 10 forehand turning steps).

It was shown that all the tennis players must make 40 successful trials each to collect 40 turning steps and "n" would be totally 200 turning steps for 5 players.

Instruments

1. In-Shoe System (Tekscan Pressure Measurement System, Tekscan, Inc., Boston, USA)

2. F-Scan Research 6.31 Software (Tekscan, Inc., Boston, USA)

3. Ball machine (Shot Maker Standard Model by Sports Tutor, USA)

4. Video camera (Sony Handycam DCR-HC46, Sony Corporation, Tokyo, Japan) with tripod legs

5. Laptop computer

6. Tennis balls (Dunlop Fort, Dunlop Sport, UK)

7. Tennis shoes (Adidas Barricade CLS and Adidas Tirand III, Adidas®, Germany)

8. Masking tapes

9. Measuring tapes

10. Plastic ropes

11. Wood columns

12. Scissors

13. Electric cables

Procedures

<u>Standard measurements</u>

Height: The tennis player stood with the heels next to each other and stretched upward to the fullest extend. The heels, buttock, and upper back touched a wall. The measurement was recorded in centimeters.

Weight: The player's weight was recorded with individual tennis clothes without shoes in kilograms.

Body Mass Index (BMI): BMI is used to assess weight that is relative to height. It is calculated by dividing weight in kilogram and height in square meters ($kg \cdot m^{-2}$) (ACSM's guidelines, 2006).

Subject preparation

1. All the tennis players wore tennis clothes and brought their own rackets.

2. The researcher explained the protocol to each player.

3. The tennis players warmed up for 10 minutes (Girard et al., 2007).

4. The tennis players wore the tennis shoes that were prepared for the study and were allowed to repeat the course until they felt comfortable with the two different shoes and the condition (Girard et al., 2007).

Methods

Experimental set-up

Five Thai male tennis players who were qualified for the study wore both tennis shoes (Figure 3.5), which had the same materials of upper, insole, midsole, and outsole (Table 3.1) (Tennis shoe review, n.d.), in a random sequence (Eils et al., 2004; Girard, 2007) and warmed up for 10 minutes before the test. Tennis players ran and hit tennis balls behind the baseline under the condition that the researcher created. A player hit a ball until he completed 20 successful trials wearing each type of the tennis shoes. Plantar pressures were measured by putting a sensor in the right shoe. A video camera was set up on the opposite side to the players to record movements of the players and ball directions and to count their steps.

(a) (b)

Figure 3.5 (a) Tennis shoes Adidas Barricade CLS (the herringbone) and (b) Tennis shoes Adidas Tirand III (the pivot point)

Table 3.1 Materials of the tennis shoes (see in appendix E)

	Adidas Barricade CLS	Adidas Tirand III
Upper	Leather	Synthetic leather
Insole	Molded EVA	EVA
Midsole	Torsion system, Adiprene, Adiprene plus	3-D Torsion system, Adiprene, Adiprene plus
Outsole	Adiwear	Adiwear

The tennis player stood at the starting point behind the baseline then ran to hit a tennis ball that was produced from a ball machine travelling at a speed of approximately 90 km/h (Mavvidis et al., 2005). Diagram of movement trial was shown in figure 3.6. The balls that were produced from the ball machine (Figure 3.7) must drop in the 6 ft x 4.5 ft box. The player must try to control every shot to the backcourt. When the ball machine shot a ball to the right side of the player then he had to hit the ball with a forehand topspin and when a ball was shot to the left side he had to hit it with a backhand topspin. The duration between each ball was 2.8 seconds. A rope was stretched out 8 ft above the court surface (Figure 3.8) to help the player decide how high he should hit the groundstroke. The player must try to control the ball not higher than 8 ft from the court surface (Cross and Lindsey, 2005). Criteria of a successful trial were the ball passing between the net and the rope and through the backcourt. The player had to change direction to the right or left to hit the ball 3 consecutive shots. It was concluded that one trial consisted of 3 groundstroke shots. One successful trial meant that the ball machine shot at least the second and third balls into the box and the player hit those balls passing between the net and the rope to the backcourt.

The tennis player was allowed to rest 20 seconds every trial and drink water and sports drink 90 seconds every 10 trials. When the player finished the first shoes then he had 120 seconds to rest before starting the second shoes.

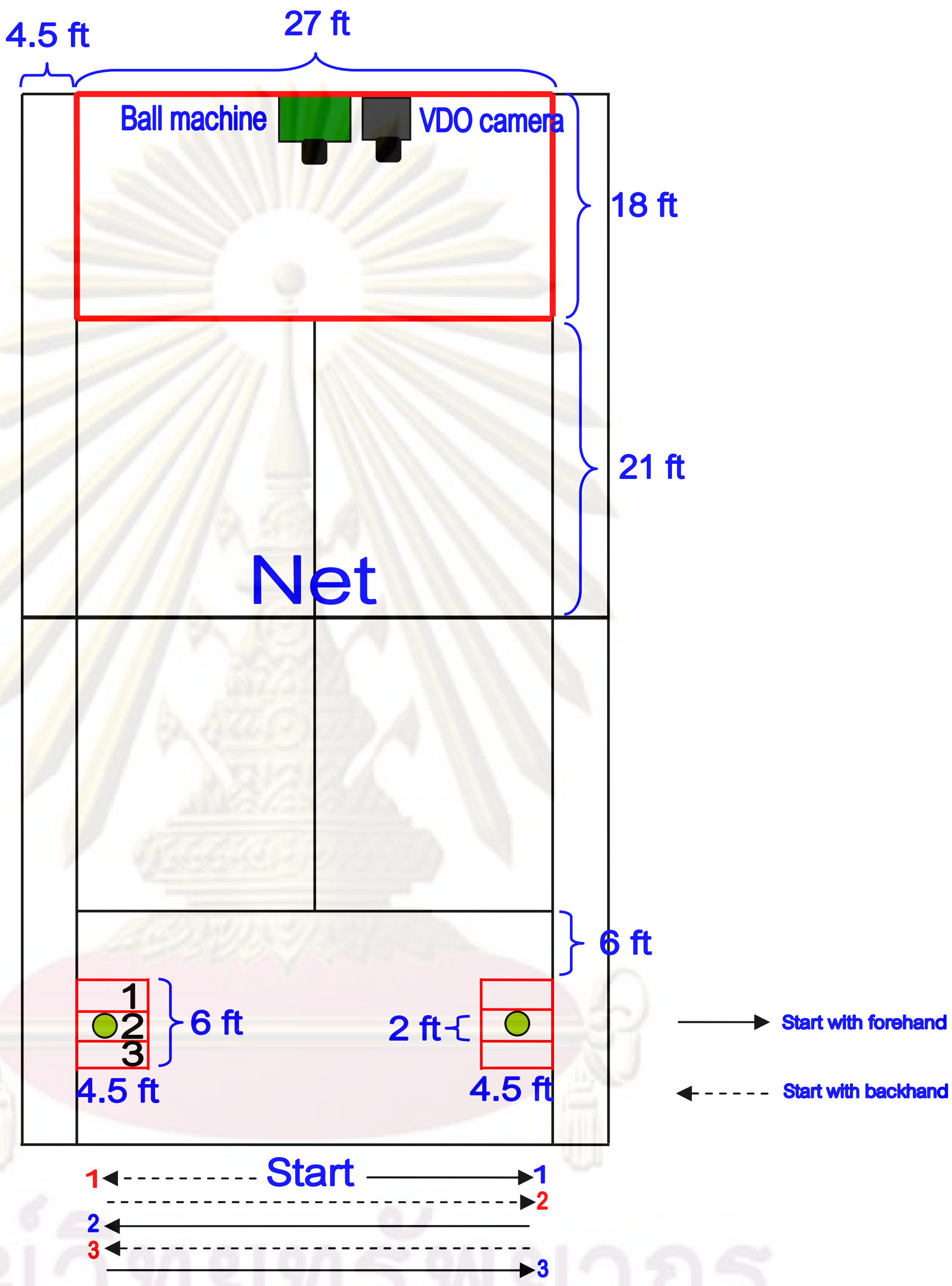


Figure 3.6 Diagram of movement trial

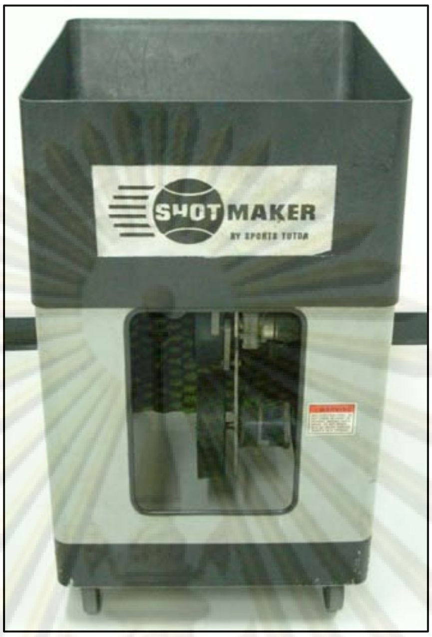


Figure 3.7 Ball machine

Figure 3.8 Eight-foot high rope above the court surface

Plantar pressure data

Insole plantar pressure distribution was recorded using the In-Shoe System (Tekscan, Inc., Boston, USA) (Figure 3.9). A sensor was placed in the right shoe (Figure 3.10) and the system was calibrated for each player before starting data collection. The data were sent by a cuff cable to a laptop computer (Figure 3.11). Plantar pressures were recorded at 50 Hz (Eils et al., 2004; Girard, 2007; Chuckpaiwong, 2008). Only the last step (the turning step) of the second shot of every successful trial was analyzed.

Figure 3.9 Tekscan Pressure Measurement System

Figure 3.10 Sensor in the right shoe

Figure 3.11 Set-up cuff cable for data transferring

A regional analysis of the foot was performed utilizing the objects dialog box section on the F-Scan Research 6.31 Software (Tekscan, Inc., Boston, USA) (Figure 3.12). Only peak pressures on the pivot point area was calculated (Figure 3.13). The pivot point area box was assigned by a number of 2 (left), 8 (right), 16 (top), and 22 (bottom) on the software program.

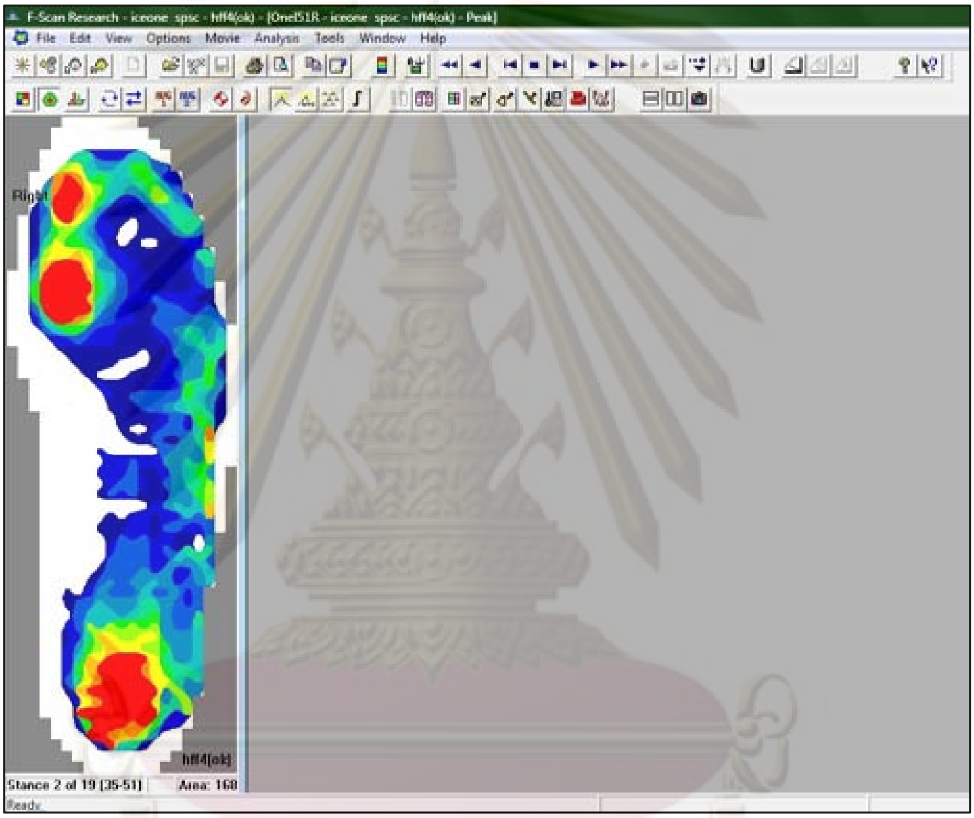


Figure 3.12 F-Scan Research 6.31 Software main window

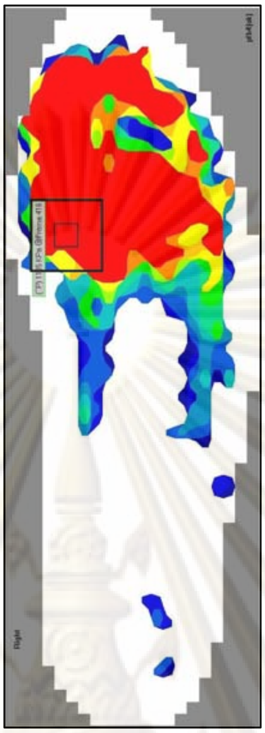


Figure 3.13 Pivot point area

Data analysis

1. Plantar pressures (Peak pressures) on the pivot area were expressed as mean ± SD.

2. The differences in peak pressures on the pivot point area between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point were determined by the unpaired t-test.

Normality of distribution was investigated using the Kolmogorov-Smirnov test. An Alpha level of 0.05 was used to determine statistical significant. All analyses were performed on the Statistical Package for the Social Sciences version 10.0 (SPSS, Chicago, IL, USA).

CHAPTER IV

RESULTS

Characteristics of Subjects

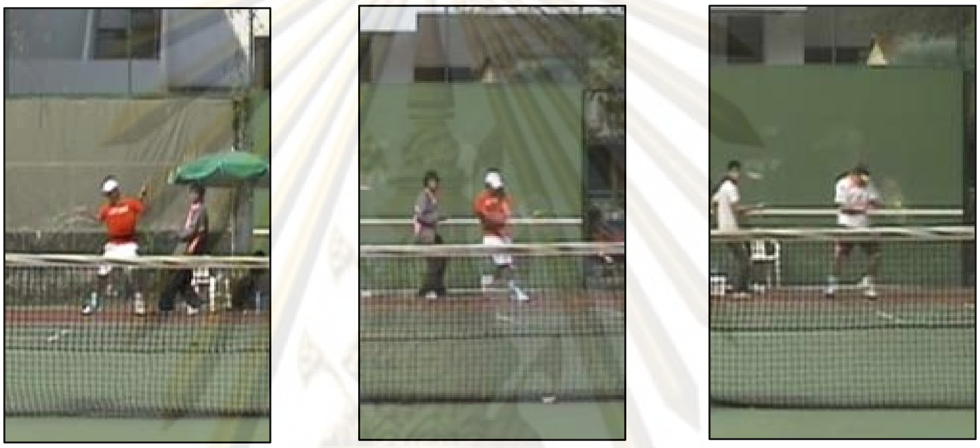
A total of 5 tennis players, who were at level 5.0 rated by NTRP criteria, were in the study. The successful 200 trials were collected from all the players. Table 4.1 provides the baseline characteristics of the subjects (5 male tennis players), such as age, weight, height, and shoe size.

Table 4.1 Baseline characteristics of the subjects

	Age (years)	Weight (kg.)	Height (cm.)	Shoe size (US)
Player 1	21	68	171	10.5
Player 2	25	72	177	10.5
Player 3	23	65	178	10.5
Player 4	19	61	168	10.5
Player 5	19	70	170	10.5

Plantar Pressures without Normalization

All plantar pressures on the pivot point area were collected from the tennis players wearing both types of tennis shoes. There were 2 strokes of turning steps: forehand and backhand strokes. All forehand strokes were performed with open stance (Figure 4.1a). The backhand strokes were divided into 2 types which were square stance backhand (Figure 4.1b) and open stance backhand (Figure 4.1c).



(a) (b) (c)

Figure 4.1 (a) The open stance forehand (b) The square stance backhand (c) The open stance backhand (Captured from video camera)

Mean and standard deviation of peak pressures, which were raw data, on the pivot point area of the forehand steps, the square stance backhand steps, and the open stance backhand steps from wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point is presented in table 4.2.

Table 4.2 Mean ± SD of peak pressures on the pivot point area

	Herringbone	Herringbone with pivot point
Forehand (KPa)	760.54 ± 253.17	866.82 ± 233.52
Backhand square (KPa)	117.80 ± 109.42	115.61 ± 82.79
Backhand open (KPa)	502.10 ± 173.01	511.76 ± 174.22

Table 4.3 shows that there was statistically significant difference ($p<0.05$) in peak pressures on the pivot point area of the forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point.

Table 4.3 Mean differences of peak pressures on the pivot point area of forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

	Herringbone (n=50)	Herringbone with pivot point (n=50)	p-value
Forehand (KPa)	760.54 ± 253.17	866.82 ± 233.52	0.032*

Compared peak pressures on the pivot point area between the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point using Unpaired t- test Statistics.

* Significant difference between both types of shoes, $p<0.05$

Table 4.4 presents that there was no statistically significant difference (p>0.05) in peak pressures on the pivot point area of the square stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point.

Table 4.4 Mean differences of peak pressures on the pivot point area of square stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

	Herringbone (n=40)	Herringbone with pivot point (n=33)	p-value
Backhand Square (KPa)	117.80 ± 109.42	115.61 ± 82.79	0.925

Compared peak pressures on the pivot point area between the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point using Unpaired t- test Statistics.

* Significant difference between both types of shoes, p<0.05

Table 4.5 demonstrates that there was no statistically significant difference (p>0.05) in peak pressures on the pivot point area of the open stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point.

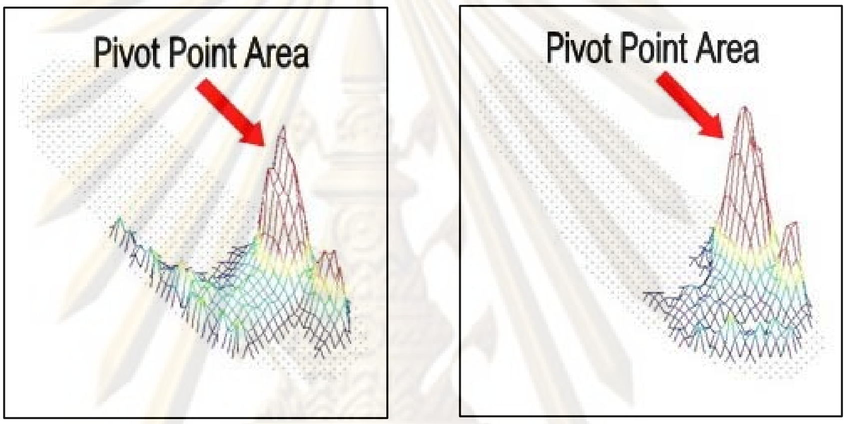
Table 4.5 Mean differences of peak pressures on the pivot point area of open stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

	Herringbone (n=10)	Herringbone with pivot point (n=17)	p-value
Backhand Open (KPa)	502.10 ± 173.01	511.76 ± 174.22	0.890

Compared peak pressures on the pivot point area between the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point using Unpaired t- test Statistics.

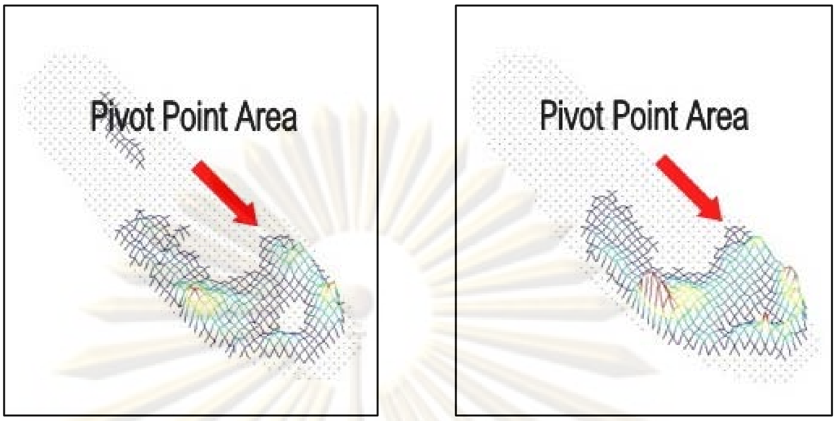
* Significant difference between both types of shoes, p<0.05

The 3D view of plantar pressure measurement shows that there was statistically significant difference in peak pressures on the pivot point area of forehand steps (Figure 4.2). The tennis shoes with herringbone pattern with pivot point produced higher plantar pressures than the tennis shoes with herringbone pattern did. On the other hand, there were no statistically significant differences in peak pressures on the pivot point area of square stance backhand steps (Figure 4.3) and open stance backhand steps between 2 types of the tennis shoes (Figure 4.4).



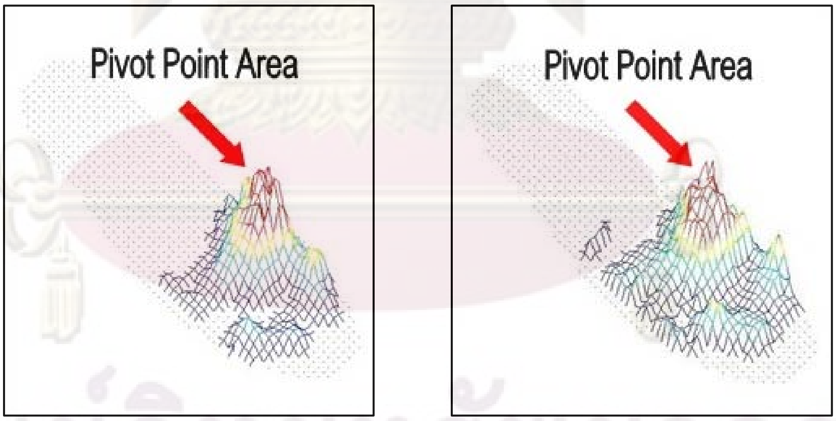
(a) (b)

Figure 4.2 (a) Peak pressure on the pivot point area of forehand step from wearing the tennis shoes with herringbone pattern (b) Peak pressure on the pivot point area of forehand step from wearing the tennis shoes with herringbone pattern with pivot point



(a) (b)

Figure 4.3 (a) Peak pressure on the pivot point area of square stance backhand step from wearing the tennis shoes with herringbone pattern (b) Peak pressure on the pivot point area of square stance backhand step from wearing the tennis shoes with herringbone pattern with pivot point



(a) (b)

Figure 4.4 (a) Peak pressure on the pivot point area of open stance backhand step from wearing the tennis shoes with herringbone pattern (b) Peak pressure on the pivot point area of open stance backhand step from wearing the tennis shoes with herringbone pattern with pivot point

Plantar Pressures with Normalization

When dividing peak plantar pressures on the pivot point area with the player's body weight, mean and standard deviation of peak pressures of the forehand steps, the square stance backhand steps, and the open stance backhand steps from wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point after normalization is presented in table 4.6. Due to limitations of the F-Scan Research 3.61 Software, the 3D view of plantar pressure measurement could not be proceeded by the software.

Table 4.6 Mean ± SD of peak pressures on the pivot point area after normalization with the players' body weight

	Herringbone	Herringbone with pivot point
Forehand (KPa/kg)	11.24 ± 3.35	12.90 ± 3.39
Backhand square (KPa/kg)	1.72 ± 1.52	1.63 ± 1.14
Backhand open (KPa/kg)	7.84 ± 2.72	8.15 ± 2.98

Table 4.7 shows that there was statistically significant difference ($p<0.05$) in peak pressures on the pivot point area after normalization with the players' body weight of the forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point. There were no statistically significant differences ($p>0.05$) in peak pressures on the pivot point area after normalization with the players' body weight between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point when performing the square stance backhand steps and the open stance backhand steps.

Table 4.7 Mean differences of peak pressures on the pivot point area after normalization with the players' body weight of forehand steps, square stance backhand steps, and open stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

	Herringbone	Herringbone with pivot point	p-value
Forehand (KPa/kg)	11.24 ± 3.35 (n=50)	12.90 ± 3.39 (n=50)	0.015*
Backhand square (KPa/kg)	1.72 ± 1.52 (n=40)	1.63 ± 1.14 (n=33)	0.770
Backhand open (KPa/kg)	7.84 ± 2.72 (n=10)	8.15 ± 2.98 (n=17)	0.788

Compared peak pressures on the pivot point area after normalization with the player's body weight between the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point using Unpaired t- test Statistics.

* Significant difference between both types of shoes, $p<0.05$

CHAPTER V

DISCUSSION AND CONCLUSION

Conclusion

This study is an observational analytic research which aims to examine effects of different tennis shoe tread patterns on plantar pressures on the pivot point area in five Thai male tennis players when changing direction during groundstroke shots. All the tennis players were at the level 5.0 classified by National Tennis Rating Program (NTRP) criteria and had two-handed backhand. The players hit forehand and two-handed backhand groundstroke topspin shots behind the baseline. Every player had to collect 20 successful trials wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point.

The results demonstrate that there was statistically significant difference in the peak pressures on the pivot point area of the forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point. The tennis shoes with the herringbone pattern with pivot point produced higher plantar pressures than the tennis shoes with herringbone pattern did (760.54 ± 253.17 KPa (herringbone); 866.82 ±233.52 KPa (pivot point)). On the other hand, there were no differences in the pressures on the pivot point area between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point when performing the square stance backhand steps (117.80 ± 109.42 KPa (herringbone); 115.61 ± 82.79 KPa (pivot point)) and the open stance backhand steps (502.10 ± 173.01 KPa (herringbone); 511.76 ± 174.22 KPa (pivot point)).

After normalizing peak pressures with the players' body weight, there was statistically significant difference in the peak pressures on the pivot point area of the forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point. The tennis shoes with the herringbone pattern with pivot point produced higher plantar pressures than the tennis shoes with herringbone pattern did (11.24 ± 3.35 KPa/kg (herringbone); 12.90 ± 3.39 KPa/kg (pivot point)). There were no differences in the pressures on the pivot point area between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point when performing the square stance backhand steps (1.72 ± 1.52 KPa/kg (herringbone); 1.63 ± 1.14 KPa/kg (pivot point)) and the open stance backhand steps (7.84 ± 2.72 KPa/kg (herringbone); 8.15 ± 2.98 KPa/kg (pivot point)).

Discussion

Tennis is a game that is played on many different surface types (grass, clay, acrylic, and many more) (Miller, 2006) each of these has different characteristics not only in terms of interaction with the ball, but also the player. As the way in which a tennis court feels to a player is dependent on the nature of the interaction between the two surfaces in contact, it is clear that footwear plays an important role in tennis (Miller and Cross, 2003). Shoes influence two distinct aspects of tennis performance and injury. Tennis movement patterns are relatively complex, involving forward, backward, sideways, and rotational movement at a variety of speeds (Stussi, Stacoff, and Tiegermann, 1989). Tennis is therefore demanding on footwear and tennis shoe tread patterns must be considered.

Due to limitations of the F-Scan Research 3.61 Software, average plantar pressures can not be calculated by the software. Only peak plantar pressures were reported. Performing forehand steps, players applied higher peak pressures on the pivot point area when they wore the tennis shoes with herringbone pattern with pivot point. From this point of view, the pivot point might act like the center of rotation. Peak plantar pressures were applied mostly under the 1st metatarsal area while peak pressures at the other metatarsal areas were reduced (table 26, see in Appendix F). Further investigations are required to prove the effort of pivot point on foot motion.

There were no significant differences in peak pressures on the pivot point area between wearing both of the shoes when the players performed the square stance backhand steps and the open stance backhand steps. Performing the square stance backhand, the players tended to stand on the lateral part of the foot so it did not affect the pivot point area which is on the medial forefoot area and mostly under the 1st metatarsal (Miller and Cross, 2003) on both types of shoes. When comparing peak pressures of the square stance backhand steps and the open stance backhand steps, it was found that the peak pressures on the pivot point area of the open stance backhand steps were higher. Open stance steps require the player to stand mostly on the forefoot. Standing on the forefoot produces higher plantar pressures on the pivot point area than standing on the lateral side of the foot. Movement characteristics and peak plantar pressures of these players might not be generalized to those of players with different NTRP levels.

This study provides tennis players information to select appropriate tennis shoes. The researcher suggests that players who perform strokes with the open stance should consider the tennis shoes with herringbone pattern with pivot point. Gheluwe and Deporte (1992) found that the friction rises when the plantar pressure increases. This means that tennis shoes with herringbone pattern with pivot point help to increase the pressures on the pivot point area so it helps the players change direction well without slipping or falling from turning so fast during groundstroke shots.

However, the players need to pay attention to injuries that might occur during the game while wearing both types of shoes. It is believed that a high peak pressure, together with a number of repetitions, could lead to chronic injury (Wong et al., 2007), especially playing on the hard court surface. It produces more injuries in tendons and joints of foot comparing to other surfaces (Pieper et al., 2007). Foot injuries in tennis players may include stress fractures, plantar fasciitis, blisters, and abrasions or “tennis toe”. Stress fractures result from failure of the microstructure of bone in an area of active remodeling occurring secondary to repetitive stress (Bylak and Hutchinson, 1998). Moreover, it is believed that too much friction while turning can transfer rotational forces from the shoe-surface interface to the menisci and collateral ligaments of the knee (Miller and Cross, 2003).

Maquirriain and Ghisi (2006) found that tennis players had an overall stress fracture incidence of 12.9% with stress fractures at the foot 5.76%. The incidence of metatarsal stress fractures was 2.16%, 0.72% at each 1^{st} metatarsal, 2^{nd} metatarsal, and 4^{th} metatarsal. Due to force and injury relationship, players who have an injury at 1^{st} metatarsal area should avoid wearing the shoes with herringbone pattern with pivot point. On the other hand, they should be worn by players with an injury at other metatarsal areas. Without those conditions, players can select shoes by their preferences.

Nevertheless, all of the suggestions above can only be considered when using these 2 types of tennis shoes. Other types of tennis shoes should have different materials that may cause different plantar pressures. In this study, the researcher attempted to find shoes that had same materials, especially upper, insole, midsole, and outsole parts but most manufacturers focused on the midsole. The 2 types of tennis shoes in the study had the closest materials that the researcher could find at that time.

Further studies may focus on the difference of tennis shoe tread patterns on another surface besides the hard surface, such as clay. Ball speed is slower on the clay surface. The frictional coefficient between shoes and clay is lower than the one between shoes and other surfaces. Players frequently perform sliding across the clay court (Miller, 2006). When examining the two different tennis shoe tread patterns on plantar pressures on the clay court, different plantar pressure characteristics might be expected.

Female tennis players should be included in the future studies. The plantar pressures of female players from wearing tennis shoes might be different from the ones of male players because of gender differences, such as physical performance, playing style, movement pattern, and power (Paserman, 2007). Other models of tread patterns should be included in the future studies. Currently, other tread patterns were invented, such as modified herringbone pattern and versatile pattern. These tread patterns might cause different plantar pressure characteristics.

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APPENDICES

APPENDIX A

เอกสารชี้แจงข้อมูล/คำแนะนำแก่ผู้เข้าร่วมโครงการ
(Patient Information Sheet)

ชื่อโครงการ ผลของรูปแบบลายพื้นรองเท้าเทนนิสต่อแรงกดฝ่าเท้าขณะตีลูกท้ายคอร์ท

Effects of tennis shoe tread patterns on plantar pressures during groundstroke shots

ผู้ทำการวิจัย นางสาวสมฤทัย พุ่มสลุด
นิสิตหลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาเวชศาสตร์การกีฬา

อาจารย์ที่ปรึกษาโครงการ ผศ.นพ.ดร. ภาสกร วัธนธาดา

ผู้ดูแลที่ติดต่อได้

1. ผศ.นพ.ดร. ภาสกร วัธนธาดา ภาควิชาสรีรวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัยโทรศัพท์ 02-256-4000 ต่อภาควิชาสรีรวิทยา (ที่ทำงาน)
2. นางสาวสมฤทัย พุ่มสลุด ภาควิชาสรีรวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย โทรศัพท์ 083-771-4789 (มือถือ)

สถานที่วิจัย

1. สนามเทนนิส คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ความเป็นมาของโครงการ

รองเท้าเทนนิส (Tennis shoes) เป็นหนึ่งในอุปกรณ์ที่มีความสำคัญอย่างมากต่อการเล่นเทนนิสนอกเหนือไปจากไม้เทนนิส (Racquet) ลูกเทนนิส (Tennis ball) และเสื้อผ้า (Clothes) ถูกออกแบบมาเพื่อให้มีความเหมาะสมกับรูปแบบการเล่นเทนนิสในปัจจุบัน มีส่วนประกอบแยกออกเป็น ส่วนบน (Upper) คือส่วนที่ห่อหุ้มบริเวณหลังเท้าทั้งหมด ส่วนพื้นรองเท้าชั้นใน (Insole) คือชั้นที่สัมผัสกับฝ่าเท้า ส่วนพื้นรองเท้าชั้นกลาง (Midsole) คือชั้นที่ช่วยรับและกระจายแรงกระแทกจากหลัง ขา และเท้า ลงสู่พื้น นอกจากนี้ยังช่วยเพิ่มความมั่นคงในการเดินและวิ่งขณะเล่นเทนนิส และส่วนพื้นรองเท้าชั้นนอก (Outsole) คือชั้นนอกสุดที่สัมผัสกับพื้นดิน นอกจากคุณสมบัติที่เหมือนกับชั้นกลางแล้ว สิ่งที่ต้องให้ความสนใจคือลวดลายรูปแบบของพื้น (Tread pattern) ซึ่งจะมีผลต่อความยืดหยุ่น ความลื่น และเป็นจุดหมุนของรองเท้า

ลายของพื้นรองเท้าเทนนิสมีอยู่หลายลักษณะแตกต่างกันไปขึ้นอยู่กับบริษัทผู้ผลิตจะคิดค้น แต่สามารถแบ่งออกเป็น 2 รูปแบบหลัก คือ แบบฟันปลา (Herringbone pattern) มีคุณสมบัติทำงานได้ดีบนสนามเทนนิสทุกประเภท โดยเฉพาะสนามปูน (Hard court) อีกรูปแบบหนึ่งได้แก่ แบบฟันปลากับจุดหมุน (Herringbone pattern with pivot point) จุดหมุนที่พื้นรองเท้าซึ่งเป็นบริเวณที่อยู่ตรงกับส่วนของกระดูก 1st metatarsal เป็นส่วนใหญ่ มีคุณสมบัติในการช่วยเปลี่ยนทิศทางอย่างรวดเร็วโดยไม่ทำให้เกิดการลื่นล้ม การเลือกซื้อรองเท้าเทนนิสให้เหมาะสมกับนักเทนนิสแต่ละคนนั้นถือเป็นเรื่องยากเพราะมีหลายปัจจัยที่ต้องคำนึงถึง เช่น ประเภทเท้า (Foot type) รูปแบบการเล่น รวมไปถึงสภาพพื้นสนาม อย่างไรก็ตามการเลือกรองเท้าเทนนิสควรจะเลือกประเภทที่ใส่แล้วเพิ่มศักยภาพในการเล่น สามารถวิ่ง เบรก และเปลี่ยนทิศทางได้อย่างรวดเร็วโดยไม่ทำให้เกิดแรงกดต่อฝ่าเท้า (Plantar pressure) ที่มากเกินไป

การควบคุมทิศทางของลูกเทนนิสขณะตีลูกจากท้ายคอร์ท (Groundstroke) เป็นส่วนสำคัญส่วนหนึ่งที่มีผลต่อการแพ้และชนะในการเล่นเทนนิส ถ้านักเทนนิสสามารถตีลูกเทนนิสไปลง ณ ตำแหน่งที่ต้องการได้อย่างแม่นยำ มีการตีติดเน็ตหรือตีออกน้อย ก็จะได้เปรียบในการแข่งขัน การที่จะตีลูกเทนนิสได้ดีนั้น จำเป็นต้องมีพื้นฐานมาจากการเตรียมพร้อมในการรับลูก การเคลื่อนที่อย่างรวดเร็ว การไปหยุดอยู่ในตำแหน่งที่เหมาะสม รวมถึงการถ่ายน้ำหนักตัวในการตีลูกจากร่างกายส่วนร่างไปสู่ส่วนบน ตามลำดับ และ การกลับตัวอย่างมีประสิทธิภาพ ซึ่งจะทำให้สามารถวิ่งไปตีลูกเทนนิสทางด้านซ้ายและขวาได้ด้วย ซึ่งรองเท้าเทนนิสจะมีส่วนสำคัญในการช่วยให้นักเทนนิสสามารถเคลื่อนที่ หยุด และกลับตัว

การศึกษาเรื่องแรงกดฝ่าเท้าที่เกิดขึ้นในขณะใส่รองเท้าเทนนิสที่มีความแตกต่างของลายพื้นรองเท้าจะช่วยให้นักเทนนิสเลือกรองเท้าเทนนิสได้อย่างเหมาะสม ใส่แล้วทำให้ศักยภาพในการ

เล่นเทนนิสเพิ่มขึ้น เกิดแรงกดต่อฝ่าเท้าน้อยซึ่งจะช่วยลดปัญหาการบาดเจ็บของเท้าในนักเทนนิส นอกจากนี้อาจมีผลทำให้การส่งแรงจากเท้าไปสู่การตีลูกเทนนิสได้ดี ตีลูกได้ความเร็วสูงขึ้น ซึ่งเป็นการเพิ่มประสิทธิภาพในการแข่งขัน

จากความสำคัญดังกล่าวผู้วิจัยจึงสนใจที่จะศึกษาถึงความแตกต่างของลายพื้นรองเท้าเทนนิสที่มีต่อแรงกดฝ่าเท้าบริเวณจุดหมุนขณะวิ่งตีลูกเทนนิส และคาดว่าความแตกต่างของลายพื้นรองเท้าเทนนิสน่าจะมีผลต่อการกลับตัวเพื่อวิ่งตีโต้ลูกเทนนิสซึ่งอาจทำให้แรงกดฝ่าเท้าที่เกิดขึ้นแตกต่างกัน โดยจะมีการนำผลที่ได้ไปเป็นข้อมูลในการเลือกซื้อรองเท้าเทนนิสที่เหมาะสมต่อไป

วัตถุประสงค์ของการวิจัย (Objectives)

1. เพื่อเปรียบเทียบแรงกดฝ่าเท้าที่บริเวณจุดหมุน จากการใส่รองเท้าเทนนิสที่มีพื้นแบบฟันปลาและแบบฟันปลากับจุดหมุนในนักเทนนิสขณะวิ่งเข้าตีลูกท้ายคอร์ท

รายละเอียดที่จะปฏิบัติต่อผู้เข้าร่วมการวิจัย

1. ผู้เข้าร่วมการวิจัยจะได้รับการชี้แจงรายละเอียดเกี่ยวกับงานวิจัยโดยย่อ และได้รับการแจ้งให้ทราบว่าการเข้าร่วมโครงการศึกษาวิจัยในครั้งนี้ผู้เข้าร่วมการวิจัยไม่ต้องเสียค่าใช้จ่ายใดๆ ทั้งสิ้น เมื่อผู้เข้าร่วมการวิจัยตัดสินใจเข้าร่วมการวิจัย จะต้องลงนามยินยอมเข้าร่วมในการวิจัย ซึ่งผู้ที่ผ่านเกณฑ์เข้ามาร่วมการวิจัยจำนวน 5 คนนั้นจะมีระยะเวลาที่อยู่ในโครงการคนละไม่เกิน 1 สัปดาห์
2. อธิบายจุดประสงค์ของการวิจัยให้ผู้เข้าร่วมการวิจัยทราบ แล้วให้กรอกแบบยินยอมเข้าร่วมการวิจัย
3. อธิบายวิธีการทดสอบให้ผู้เข้าร่วมการวิจัยทราบ
4. ทำการทดสอบ

ผลหรือประโยชน์ที่คาดว่าจะได้รับจากการวิจัย (Expected Benefit and Application)

1. เป็นข้อมูลในการตัดสินใจเลือกซื้อรองเท้าที่เหมาะสมแก่นักเทนนิส เพื่อเพิ่มศักยภาพในการเล่นเทนนิส
2. เป็นตัวบ่งบอกถึงสมรรถภาพร่างกายของนักเทนนิสที่เข้าร่วมการวิจัย เนื่องจากจะต้องมีการวิ่งตีลูกเทนนิสด้วยความเร็วสูง และต้องวิ่งหลายรอบตามรูปแบบที่กำหนดให้ ซึ่งเป็นรูปแบบที่ประยุกต์มาจากเกมการแข่งขันจริง ดังนั้นถ้านักเทนนิสเกิดอาการเหนื่อยล้าก่อนที่จะวิ่งตี

ลูกเทนนิสครบตามกำหนด ก็แสดงว่านักเทนนิสไม่มีความทนทานและแข็งแรงเพียงพอในการแข่งขัน ซึ่งเป็นสิ่งที่ทำให้ตัวนักเทนนิสเองจะต้องนำไปปรับปรุงแก้ไข

3. นักเทนนิสที่เข้าร่วมการวิจัยได้รับประสบการณ์เกี่ยวกับการทำวิจัย และได้ทดลองใช้เครื่องมือที่ทันสมัยซึ่งมีความสามารถในการวัดแรงกดฝ่าเท้าของนักเทนนิสเอง

4. เป็นการริเริ่มรูปแบบการศึกษาด้านชีวกลศาสตร์เกี่ยวกับลายพื้นรองเท้าเทนนิส

5. เป็นข้อมูลในการพัฒนางานวิจัยในอนาคต

ผลข้างเคียงที่อาจเกิดขึ้นแก่ผู้เข้าร่วมการวิจัย

ผู้เข้าร่วมการวิจัยจะไม่ได้รับความเสี่ยงใดๆ จากการวิจัย เนื่องจากได้มีการซักซ้อมใช้อุปกรณ์ต่างๆ และทำ Pilot study มาเป็นที่เรียบร้อยแล้ว แต่อาจเป็นไปได้ที่ผู้เข้าร่วมการวิจัยสะดุดขาตัวเองแล้วหกล้มหรือข้อเท้าพลิกในขณะทำการทดสอบ เพราะต้องวิ่งด้วยความเร็วที่ค่อนข้างสูง ในกรณีที่เกิดการบาดเจ็บ ผู้วิจัยได้มีการเตรียมอุปกรณ์ในการปฐมพยาบาลไว้ ได้แก่ ยาใส่แผลสด ผ้าปิดแผล น้ำแข็งประคบ เจลบรรเทาปวด ผ้าเทปแถบกาว ซึ่งผู้เข้าร่วมการวิจัยจะได้รับการดูแลจากนักกายภาพบำบัด แต่ถ้าเกินความสามารถของนักกายภาพบำบัดและต้องส่งตัวไปรักษาต่อ ผู้วิจัยก็จะจ่ายเงินเป็นค่ารักษาพยาบาลให้ แต่อย่างไรก็ตาม ผู้วิจัยได้มีการอธิบายให้ผู้เข้าร่วมการวิจัยทราบแต่แรกแล้วว่า ให้ผู้เข้าร่วมการวิจัยถอนตัวได้ทุกเมื่อ ผู้เข้าร่วมการวิจัยซึ่งเป็นนักเทนนิสระดับ 5 จะรู้ตัวเองดีอยู่แล้วว่าถ้ารู้สึกตัวว่าจะเกิดการบาดเจ็บ ก็จะไม่เล่นต่อ หรือถ้ากำลังจะหกล้ม ก็จะมีการป้องกันตัวเองโดยการล้มลงในท่าที่จะไม่ทำให้เกิดการบาดเจ็บหรือเจ็บน้อยที่สุด ดังนั้นคาดว่าถ้ามีการบาดเจ็บเกิดขึ้นก็จะเป็นการบาดเจ็บที่ไม่รุนแรง สามารถอยู่ในความดูแลของนักกายภาพบำบัดได้

การเก็บข้อมูลเป็นความลับ

ผู้วิจัยขอยืนยันว่า ข้อมูลเกี่ยวกับตัวผู้เข้าร่วมงานวิจัยจะถูกเก็บไว้เป็นความลับ และจะใช้สำหรับงานวิจัยนี้เท่านั้น และชื่อของผู้เข้าร่วมงานวิจัยจะไม่ปรากฏในแบบฟอร์มการเก็บข้อมูลและในฐานข้อมูลทั่วไป โดยมีผู้ทำวิจัยเพียงคนเดียวเท่านั้นที่ทราบรายละเอียดของข้อมูลนี้ ผู้ทำวิจัยขอขอบพระคุณผู้เข้าร่วมงานวิจัยที่ให้ความร่วมมือในการทำวิจัยครั้งนี้

ท่านสามารถขอถอนตัวออกจากโครงการวิจัยได้ทุกเวลา

หากท่านมีข้อสงสัยใดๆ สามารถสอบถามได้ที่ น.ส.สมฤทัย พุ่มสลุด โทรศัพท์ 083-771-4789 ซึ่งยินดีตอบคำถามทุกเวลา

ทั้งนี้ หากท่านมีปัญหาทางด้านจริยธรรมการวิจัย ท่านสามารถร้องเรียนได้ต่อคณะกรรมการจริยธรรมการวิจัย ณ สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน ตึกอานันทมหิดล ชั้น 3 คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย เบอร์ติดต่อ (02) 256-4455 ต่อ 14, 15

APPENDIX B

ใบยินยอมเข้าร่วมการวิจัย

(Consent Form)

การวิจัยเรื่อง ผลของรูปแบบลายพื้นรองเท้าเทนนิสต่อแรงกดฝ่าเท้าขณะตีลูกท้ายคอร์ท

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

ข้าพเจ้า นาย/นาง/นางสาว.. ได้อ่านรายละเอียดจากเอกสารข้อมูลสำหรับผู้เข้าร่วมโครงการวิจัยวิจัยที่แนบมาฉบับวันที่...................................... และข้าพเจ้ายินยอมเข้าร่วมโครงการวิจัยโดยสมัครใจ

ข้าพเจ้าได้รับสำเนาเอกสารแสดงความยินยอมเข้าร่วมในโครงการวิจัยที่ข้าพเจ้าได้ลงนาม และ วันที่ พร้อมด้วยเอกสารข้อมูลสำหรับผู้เข้าร่วมโครงการวิจัย ทั้งนี้ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย ระยะเวลาของการทำวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย หรือจากยาที่ใช้ รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัย และแนวทางรักษาโดยวิธีอื่นอย่างละเอียด ข้าพเจ้ามีเวลาและโอกาสเพียงพอในการซักถามข้อสงสัยจนมีความเข้าใจอย่างดีแล้ว โดยผู้วิจัยได้ตอบคำถามต่าง ๆ ด้วยความเต็มใจไม่ปิดบังซ่อนเร้นจนข้าพเจ้าพอใจ

ข้าพเจ้ารับทราบจากผู้วิจัยว่าหากเกิดอันตรายใด ๆ จากการวิจัยดังกล่าว ผู้เข้าร่วมวิจัยจะได้รับการรักษาพยาบาลโดยไม่เสียค่าใช้จ่าย(และจะได้รับการชดเชยจาก.................................)

ข้าพเจ้ามีสิทธิที่จะบอกเลิกเข้าร่วมในโครงการวิจัยเมื่อใดก็ได้ โดยไม่จำเป็นต้องแจ้งเหตุผล และการบอกเลิกการเข้าร่วมการวิจัยนี้ จะไม่มีผลต่อการรักษาโรคหรือสิทธิอื่น ๆ ที่ข้าพเจ้าจะพึงได้รับต่อไป

ผู้วิจัยรับรองว่าจะเก็บข้อมูลส่วนตัวของข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะเมื่อได้รับการยินยอมจากข้าพเจ้าเท่านั้น บุคคลอื่นในนามของบริษัทผู้สนับสนุนการวิจัย คณะกรรมการพิจารณาจริยธรรมการวิจัยหรือผู้ได้รับอำนาจมอบหมายให้เข้ามาตรวจและประมวลข้อมูลของผู้เข้าร่วมวิจัย ทั้งนี้จะต้องกระทำไปเพื่อวัตถุประสงค์เพื่อตรวจสอบความถูกต้องของข้อมูลเท่านั้น โดยการตกลงที่จะเข้าร่วมการศึกษานี้ข้าพเจ้าได้ให้คำยินยอมที่จะให้มีการตรวจสอบข้อมูลประวัติทางการแพทย์ของผู้เข้าร่วมวิจัยได้

ผู้วิจัยรับรองว่าจะไม่มีการเก็บข้อมูลใด ๆ ของผู้เข้าร่วมวิจัย เพิ่มเติม หลังจากที่ข้าพเจ้าขอยกเลิกการเข้าร่วมโครงการวิจัยและต้องการให้ทำลายเอกสารและ/หรือ ตัวอย่างที่ใช้ตรวจสอบทั้งหมดที่สามารถสืบค้นถึงตัวข้าพเจ้าได้

ข้าพเจ้าเข้าใจว่า ข้าพเจ้ามีสิทธิ์ที่จะตรวจสอบหรือแก้ไขข้อมูลส่วนตัวของข้าพเจ้าและสามารถเลิกการให้สิทธิในการใช้ข้อมูลส่วนตัวของข้าพเจ้าได้ โดยต้องแจ้งให้ผู้วิจัยรับทราบ

ข้าพเจ้าได้ตระหนักว่าข้อมูลในการวิจัยรวมถึงข้อมูลทางการแพทย์ที่ไม่มีการเปิดเผยชื่อจะผ่านกระบวนการต่าง ๆ เช่น การเก็บข้อมูล การบันทึกข้อมูลในคอมพิวเตอร์ การตรวจสอบ การวิเคราะห์ และการรายงานเพื่อวัตถุประสงค์ทางวิทยาศาสตร์ รวมทั้งการใช้ข้อมูลทางการแพทย์ในอนาคตหรือการวิจัยทางด้านเภสัชภัณฑ์ เท่านั้น

ข้าพเจ้ายินดีลงนามในเอกสารยินยอมนี้เพื่อเข้าร่วมการวิจัยด้วยความเต็มใจ

....ลงนามผู้ยินยอม

(..) ชื่อผู้ยินยอมตัวบรรจง

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

ข้าพเจ้าได้อธิบายถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย หรือจากยาที่ใช้ รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียด ให้ผู้เข้าร่วมในโครงการวิจัยตามนามข้างต้นได้ทราบและมีความเข้าใจดีแล้ว พร้อมลงนามลงในเอกสารแสดงความยินยอมด้วยความเต็มใจ

....ลงนามผู้ทำวิจัย

(...) ชื่อผู้ทำวิจัยตัวบรรจง

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

....ลงนามพยาน

(...) ชื่อพยานตัวบรรจง

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

APPENDIX C

แบบบันทึกข้อมูลส่วนบุคคล

(Data Record Form)

การวิจัยเรื่อง ผลของรูปแบบลายพื้นรองเท้าเทนนิสต่อแรงกดฝ่าเท้าขณะตีลูกท้ายคอร์ท

ข้อมูลพื้นฐาน

เลขที่...........................

เพศ……………………. อายุ……………………ปี

น้ำหนัก…………กิโลกรัม ส่วนสูง…………เซนติเมตร

เบอร์รองเท้าเทนนิส..................

Ankle ROM:	Plantarflexion	Right…………องศา	Left…………องศา
	Dorsiflexion	Right…………องศา	Left…………องศา
	Inversion	Right…………องศา	Left…………องศา
	Eversion	Right…………องศา	Left…………องศา

Q-angle: Right knee…………องศา Left knee……………องศา

The Chippaux-Smirak index: Right foot………เปอร์เซ็นต์ Left foot………เปอร์เซ็นต์

Leg length difference…………………มิลลิเมตร

APPENDIX D

Screening Visit

Date……………….

Subject number…………………

Inclusion Criteria	Yes	No
1. ผู้เข้าร่วมการวิจัยเป็นนักเทนนิสชายไทยที่มีทักษะในการตีเทนนิสระดับ 5	☐	☐
2. ผู้เข้าร่วมการวิจัยเล่นเทนนิสอย่างน้อยสัปดาห์ละ 3 ครั้ง ในช่วง 3 เดือนที่ผ่านมา	☐	☐
3. ผู้เข้าร่วมการวิจัยมีฝ่าเท้าจัดอยู่ในประเภทปกติ (Normal arch)	☐	☐
4. ผู้เข้าร่วมการวิจัยมี ROM ของข้อเท้าปกติ	☐	☐
5. ผู้เข้าร่วมการวิจัยมี Q-angle ปกติ	☐	☐
6. ผู้เข้าร่วมการวิจัยมีความยาวขา 2 ข้างต่างกันไม่เกิน 5 มิลลิเมตร	☐	☐
7. ผู้เข้าร่วมการวิจัยมีแบบแผนการตีโฟร์แฮนด์ท็อปสปินแบบเปิด (Open stance forehand)	☐	☐
8. ผู้เข้าร่วมการวิจัยมีแบบแผนการตีแบ็คแฮนด์ท็อปสปินแบบ 2 มือ (Two-handed backhand)	☐	☐
9. ผู้เข้าร่วมการวิจัยยินยอมเข้าร่วมการวิจัยอย่างเต็มใจ	☐	☐

Exclusion Criteria	Yes	No
1. ผู้เข้าร่วมการวิจัยมีปัญหาเกี่ยวกับอาการบาดเจ็บของระยางค์ส่วนล่างในช่วง 3 เดือนที่ผ่านมาจนถึงเวลาเข้าร่วมการวิจัย	☐	☐
2. ผู้เข้าร่วมการวิจัยมีประวัติเข้ารับการผ่าตัดที่ระยางค์ส่วนล่างมาก่อน	☐	☐
3. ผู้เข้าร่วมการวิจัยถนัดซ้าย	☐	☐
4. ผู้เข้าร่วมการวิจัยไม่ได้ใส่รองเท้าเทนนิสเบอร์ 10.5 และ 11.5 (US size)	☐	☐

APPENDIX E

Tennis Shoe Materials

adidas Barricade CLS Men's Shoes Wh/Black

Price: 79.95

The original Barricade that started the legend continues in the CLS. Offering the same fit and feel, this version has more comfort engineered into it. The famous Barricade Claw support system on the lateral side of the forefoot is gone, but the classic, glove-like supportive fit means this shoe is still well-suited to high level tennis. A leather upper offers classic feel and comfort.

- **Upper:** Leather Upper for comfort and a classic tennis shoe feel.
- **Lining:** Textile. Protects the foot from upper seams for increased blister protection.
- **Inlay:** Molded EVA insole for anatomical support.
- **Midsole:** Torsion System for increased support during aggressive court movement. adiPRENE insert in the heel for comfort and shock absorption on tough landings. adiPRENE + in the forefoot maintains forefoot propulsion and efficiency.
- **Outsole:** adiWEAR 6 tough rubber durable compound in a herringbone pattern. Offers traction on all court surfaces.
- **Colors:** White / Black
- **Weight:** 15 ounces (Size 10.5)

adidas Tirand III Men's Shoes Wh/Bk/Blue

Price: 49.95

Offering the look of the Barricade V, the **Tirand III** comes in at a more affordable price. Though the Tirand III may not offer the stability or durability guarantee of the Barricade V, it provides excellent comfort focusing on midfoot support and requires no break-in.

- **Fit:** True to size for length fit. Width fit is medium with a medium height arch support.
- **Upper:** adiTUFF for superior abrasion resistance in the toe area. adiTUFF for abrasion resistance in the toe area. Synthetic leather upper for light weight and durability.
- **Lining:** Textile.
- **Inlay:** EVA insole for anatomical support and comfort.
- **Midsole:** 3-D TORSION SYSTEM for midfoot integrity. adiPRENE for high shock absorbency to cushion and protect the heel upon impact. adiPRENE+ insert for forefoot propulsion and efficiency.
- **Outsole:** adiWEAR outsole for increased durability in high wear areas. Herringbone pattern with pivot point for nonmarking traction on all court surfaces.
- **Weight:** 14.0 ounces (size 10.5)
- **Color:** White / Black / Blue

Source: www.tenniswarehouse.com

APPENDIX F

Baseline Data

Table 1 Ankle range of motion data

Tennis Player	Ankle Range of Motion (degree)							
	Plantarflexion		Dorsiflexion		Inversion		Eversion	
	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.
1	45	44	17	16	4	3	3	3
2	48	48	20	18	4	4	4	3
3	50	47	17	15	5	3	3	4
4	43	44	16	16	3	4	3	4
5	48	46	18	19	4	4	4	5

Table 2 Quadriceps angle, footprint, and leg length difference data

Tennis Player	Q-Ankle (degree)		The Chippaux-Smirak Index (%)		Leg Length Differenc (mm)
	Rt.	Lt.	Rt.	Lt.	
1	20	21	30.2	30.6	5
2	19	18	38.4	39.3	3
3	19	20	37.6	35.9	4
4	18	18	39.1	39.8	4
5	19	19	35.2	38.3	3

APPENDIX G

Collected Trial Data

The first tennis player

Table 3 The collected trial data of forehand steps of the 1st tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	2	2	1	X (out)	O	O
2	1	1	1	O	X (out)	X (out)
3	2	2	1	O	X (out)	X (out)
4	2	2	1	O	O	O
5	X (short)	2	1	X (out)	O	O
6	1	1	X (short)	O	X (out)	X (out)
7	X (short)	1	1	O	O	X (out)
8	X (short)	X (short)	X (short)	X (short)	X (short)	X (short)
9	X (short)	1	1	X (short)	O	O
10	2	1	1	X (net)	O	O
11	1	1	1	O	O	O
12	1	2	1	O	X (short)	X (short)
13	1	3	1	O	O	O
14	1	X (out)	2	O	O	X (out)
15	X (out)	X (out)	X (short)	X (net)	O	O
16	1	2	1	O	O	O
17	2	X (out)	1	O	X (out)	X (out)
18	2	3	2	O	O	O
19	1	1	1	X (out)	O	O

Table 4 The collected trial data of backhand steps of the 1st tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	X (long)	3	2	O	O	O
2	1	2	2	X (net)	O	O
3	X (long)	2	2	X (out)	X (out)	X (lob)
4	X (long)	2	2	O	O	X (lob)
5	X (long)	2	3	O	O	O
6	1	2	1	O	O	O
7	3	2	3	O	O	X (short)
8	X (long)	2	1	X (lob)	O	O
9	1	3	3	O	X (out)	O
10	2	1	1	O	X (net)	O
11	2	2	2	O	O	O
12	2	X (out)	2	O	O	X (out)
13	X (long)	X (long)	2	X (lob)	O	O
14	X (short)	1	1	O	O	O
15	1	X (short)	X (short)	O	O	O
16	3	2	2	O	O	O
17	1	1	1	O	O	O
18	2	2	1	X (short)	O	O
19	2	1	X (out)	O	O	O
20	X (long)	2	2	X (short)	O	O

Table 5 The collected trial data of forehand steps of the 1st tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	2	3	2	O	O	X (short)
2	2	2	2	X (out)	O	X (out)
3	3	3	2	X (out)	O	O
4	3	3	2	O	O	X (out)
5	2	2	2	O	O	O
6	X (long)	2	2	X (lob)	O	O
7	2	2	1	O	X (net)	X (out)
8	2	2	1	O	O	X (out)
9	3	X (long)	1	X (out)	X (lob)	-
10	1	2	1	O	O	O
11	2	2	1	O	O	O
12	1	X (long)	2	O	O	O
13	2	1	1	O	X (short)	O
14	2	1	1	X (net)	O	O
15	2	2	2	O	O	O
16	X (long)	2	1	X (short)	O	O
17	1	1	1	O	O	O
18	1	2	1	O	O	O
19	1	1	1	O	O	O
20	1	X (long)	2	O	X (out)	X (lob)
21	2	1	1	O	O	X (net)

Table 6 The collected trial data of backhand steps of the 1st tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	2	2	2	X (out)	O	O
2	2	2	X (long)	X (net)	O	X (net)
3	3	X (out)	2	O	X (out)	X (short)
4	2	2	2	O	O	O
5	3	1	2	X (lob)	X (net)	O
6	X (long)	1	2	X (out)	O	O
7	3	1	3	X (short)	O	O
8	3	2	2	O	O	O
9	3	2	2	O	X (short)	O
10	3	2	2	X (lob)	X (net)	X (out)
11	2	2	1	X (out)	O	O
12	2	2	1	O	X (out)	X (short)
13	2	2	2	O	O	O
14	X (out)	3	1	O	X (net)	O
15	3	1	2	O	O	X (net)
16	2	1	3	O	O	O
17	2	3	2	O	O	O
18	X (short)	1	1	X (out)	X (out)	O
19	2	1	1	O	O	O
20	1	1	1	O	O	X (net)
21	X (long)	1	1	O	O	O

<u>The second tennis player</u>

Table 7 The collected trial data of forehand steps of the 2nd tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	1	1	1	X (net)	O	O
2	1	2	2	X (net)	X (net)	X (net)
3	2	1	3	X (lob)	O	X (lob)
4	2	1	1	O	O	O
5	2	1	1	X (short)	O	X (net)
6	2	1	2	O	O	O
7	2	2	2	O	O	X (net)
8	X (short)	1	1	O	O	X (lob)
9	2	2	X (short)	O	O	X (net)
10	2	1	1	X (out)	O	O
11	1	1	1	X (out)	O	O
12	1	X (short)	1	X (short)	O	X (lob)
13	2	X (short)	X (short)	X (net)	O	X (net)
14	2	X	1	X (out)	O	X (net)
15	1	1	1	O	O	O
16	1	X (out)	1	X (net)	O	O
17	1	X (short)	X (short)	O	O	X (net)
18	1	1	1	O	O	O
19	2	2	2	O	O	O
20	X (short)	1	1	X (net)	X (net)	X (out)
21	2	1	1	X (net)	X (net)	X (out)
22	3	X (out)	X (short)	O	O	O
23	3	X (out)	1	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
24	2	2	1	O	O	O
25	2	1	2	O	O	O

Table 8 The collected trial data of backhand steps of the 2nd tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	2	X (short)	1	O	x (net)	O
2	3	1	2	X (net)	O	O
3	3	1	X (short)	O	X (lob)	O
4	2	2	3	X (net)	O	O
5	2	X (out)	3	O	O	X (net)
6	3	1	1	O	X (lob)	O
7	3	1	2	X (net)	O	O
8	X (short)	1	X (short)	X (out)	X (net)	X (net)
9	X (short)	1	1	O	x (net)	O
10	1	3	2	O	O	O
11	1	1	1	O	X (lob)	O
12	2	1	1	X (out)	O	O
13	2	1	1	O	O	O
14	1	2	1	O	O	O
15	2	X (out)	1	O	X (out)	O
16	2	2	1	X (short)	O	O
17	2	1	2	X (out)	X (short)	X (out)
18	2	2	X (short)	X (out)	X (lob)	O
19	2	1	1	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
20	3	1	2	O	O	O

Table 9 The collected trial data of forehand steps of the 2nd tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	X (out)	1	1	O	O	O
2	1	1	1	O	O	O
3	1	1	X (short)	X (net)	O	X (net)
4	1	1	2	X (lob)	O	X (net)
5	3	1	1	X (lob)	O	O
6	X (long)	X (long)	3	X (out)	X (short)	X (net)
7	3	3	2	X (net)	O	X (out)
8	X (long)	3	3	X (out)	O	X (net)
9	2	2	1	X (short)	O	X (net)
10	3	2	2	O	O	X (net)
11	X (long)	3	2	X (lob)	O	O
12	X (long)	X (long)	3	X (short)	X (net)	X (out)
13	2	2	2	O	O	X (lob)
14	3	2	2	X (lob)	O	O
15	3	2	1	O	O	X (lob)
16	3	2	2	O	O	X (net)
17	2	2	1	X (lob)	O	O
18	2	X (short)	1	X (out)	O	X (net)
19	X (short)	1	1	X (out)	O	O
20	3	3	2	X (lob)	O	O

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
21	1	1	1	O	O	O
22	1	1	1	O	O	O

Table 10 The collected trial data of backhand steps of the 2nd tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	3	2	1	O	X (net)	X (net)
2	1	2	1	O	O	X (net)
3	X (short)	X (out)	X (short)	O	X (net)	O
4	2	X (short)	1	O	X (out)	O
5	1	1	1	O	O	O
6	3	1	1	O	X (short)	O
7	2	1	1	O	X (net)	O
8	2	3	2	X (out)	X (lob)	O
9	2	X (out)	3	O	O	X (net)
10	2	2	X (short)	X (out)	X (out)	X (net)
11	1	1	1	O	O	X (net)
12	1	2	2	O	O	O
13	X (long)	2	1	O	O	O
14	1	1	1	O	O	O
15	2	3	X (out)	X (out)	X (net)	O
16	1	1	X (short)	O	X (lob)	O
17	1	1	1	O	O	O
18	2	1	1	O	X (lob)	O
19	1	1	1	O	O	O

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
20	2	2	2	O	O	O
21	3	1	1	X (net)	O	O
22	2	1	1	O	O	O
23	1	1	1	O	O	O

<u>The third tennis player</u>

Table 11 The collected trial data of forehand steps of the 3rd tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	1	2	2	O	O	O
2	2	1	1	O	O	X (net)
3	3	2	2	O	O	O
4	X (long)	2	1	-	O	O
5	2	X (short)	X (short)	X (lob)	X (short)	X (net)
6	X (short)	1	X (short)	X (net)	X (net)	O
7	3	1	1	O	X (short)	O
8	1	2	1	O	O	O
9	2	1	2	-	O	X (short)
10	1	1	1	O	O	X (net)
11	1	1	2	X (net)	X (short)	O
12	2	1	1	X (short)	O	O
13	1	1	1	X (short)	O	O
14	1	2	1	O	X (net)	O
15	2	1	2	X (net)	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
16	1	X (long)	2	O	X (lob)	O
17	2	1	1	X (net)	X (net)	O
18	1	1	1	X (net)	X (lob)	X (lob)
19	1	2	1	X (short)	X (short)	X (net)
20	1	1	1	O	X (net)	X (net)
21	2	1	1	X (net)	O	O
22	1	1	1	X (net)	O	O
23	1	1	1	X (lob)	O	O

Table 12 The collected trial data of backhand steps of the 3rd tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	3	2	3	O	X (lob)	O
2	2	2	1	O	O	O
3	X (long)	2	3	O	X (net)	O
4	2	1	3	O	O	O
5	1	1	2	O	X (net)	O
6	X (long)	2	1	O	O	O
7	X (long)	3	3	O	X (lob)	X (net)
8	2	2	2	O	O	O
9	2	3	2	O	O	O
10	X (long)	2	2	X (lob)	X (out)	O
11	2	2	2	O	O	O
12	X (long)	2	2	X (short)	O	O
13	2	X (long)	3	O	X (net)	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
14	2	1	1	X (out)	X (out)	X (out)
15	3	1	X (short)	X (net)	X (net)	X (net)
16	2	1	1	O	O	O
17	1	1	1	O	X (short)	X (net)
18	2	2	2	O	X (lob)	O
19	1	1	1	O	X (net)	X (net)
20	3	1	1	O	O	X (net)
21	2	1	1	O	X (short)	X (net)
22	X (short)	1	1	O	O	X (net)
23	2	1	X (short)	X (out)	X (out)	X (net)
24	2	1	1	O	O	X (net)
25	1	1	1	O	O	O
26	X (long)	X (short)	1	O	X (net)	O
27	3	2	3	O	O	O

Table 13 The collected trial data of forehand steps of the 3rd tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	1	1	X (out)	O	O	X (net)
2	1	1	1	X (out)	O	X (net)
3	X (short)	X (short)	X (short)	O	O	X (short)
4	3	1	1	X (short)	O	O
5	2	1	1	O	O	O
6	3	1	1	O	O	O
7	3	2	X (out)	O	X (net)	O

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
8	3	1	1	O	O	X (short)
9	1	1	1	O	O	X (net)
10	1	1	2	O	X (short)	O
11	X (out)	1	1	X (net)	O	X (short)
12	1	1	2	O	X (short)	O
13	3	2	2	X (out)	O	X (short)
14	2	1	1	O	O	X (short)
15	1	1	1	O	O	O
16	1	1	2	O	O	O
17	2	X (out)	1	X (lob)	O	O
18	1	2	1	X (net)	O	O
19	2	1	X (short)	O	O	X (lob)
20	2	3	1	O	O	X (short)
21	2	1	1	X (short)	O	O
22	2	1	1	O	X (short)	X (short)
23	1	1	1	O	O	O
24	1	1	1	O	O	O
25	1	1	X (out)	O	O	O
26	2	1	1	O	O	O

Table 14 The collected trial data of backhand steps of the 3rd tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	1	1	X (short)	X (out)	X (short)	X (net)
2	3	1	X (short)	O	X (out)	X (net)
3	1	1	1	X (out)	O	O
4	1	X (short)	X (short)	X (short)	O	O
5	2	2	2	O	X (net)	O
6	2	2	2	X (lob)	O	X (short)
7	2	1	X (short)	O	O	O
8	2	1	2	O	O	X (out)
9	3	1	2	X (net)	O	X (out)
10	3	1	1	X (short)	X (net)	X (net)
11	X (long)	1	1	X (lob)	O	O
12	X (long)	1	1	X (lob)	O	O
13	2	2	1	X (out)	X (short)	O
14	1	3	1	X (net)	O	O
15	X (long)	2	1	X (net)	O	X (short)
16	X (long)	1	2	X (lob)	O	O
17	3	1	1	O	O	O
18	3	1	1	X (out)	X (net)	X (net)
19	3	1	1	X (short)	X (short)	X (lob)
20	2	1	1	O	O	X (short)
21	1	1	1	O	O	O
22	2	2	1	X (out)	O	O
23	1	1	1	O	O	O

<u>The fourth tennis player</u>

Table 15 The collected trial data of forehand steps of the 4th tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	X (out)	2	3	O	X (net)	X (slice)
2	X (short)	1	2	O	O	O
3	2	1	1	O	O	O
4	3	2	2	X (out)	O	X (net)
5	3	2	2	O	X (net)	O
6	2	2	1	O	O	X (net)
7	2	1	X (short)	O	O	O
8	1	3	1	X (net)	O	X (short)
9	3	2	3	X (short)	O	O
10	1	1	1	X (short)	O	O
11	1	3	1	O	O	O
12	X (short)	2	X (out)	X (short)	X (out)	O
13	2	2	2	O	X (net)	-
14	2	3	X (long)	O	O	X (short)
15	X (out)	2	2	O	O	O
16	3	X (long)	X (long)	X (out)	O	X (net)
17	3	2	1	O	O	O
18	2	1	2	O	O	X (net)
19	3	2	1	X (out)	O	X (net)
20	X (out)	X (short)	X (out)	O	X (out)	O
21	X (out)	2	X (out)	O	O	O
22	3	2	2	O	O	O
23	X (out)	3	2	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
24	1	X (out)	1	X (out)	O	O
25	X (short)	2	1	O	O	O

Table 16 The collected trial data of backhand steps of the 4th tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	1	2	1	X (out)	O	O
2	2	1	2	X (short)	X (net)	O
3	2	1	1	O	X (out)	O
4	X (long)	1	1	X (net)	O	X (net)
5	3	1	1	X (net)	O	O
6	X (long)	1	2	O	O	X (short)
7	3	3	3	X (net)	O	O
8	2	X (short)	2	O	O	X (short)
9	2	1	1	O	X (net)	O
10	2	1	1	X (net)	O	O
11	2	2	1	O	O	O
12	3	X (out)	2	O	X (short)	O
13	X (long)	X (long)	1	O	X (out)	O
14	3	2	1	O	X (short)	O
15	3	1	1	X (net)	O	O
16	X (short)	1	X (short)	O	X (short)	O
17	2	2	2	X (short)	O	O
18	X (long)	2	X (long)	X (net)	O	X (short)
19	X (long)	1	2	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
20	X (short)	X (out)	2	X (out)	X (net)	O
21	2	2	2	O	O	O
22	2	1	2	O	O	O

Table 17 The collected trial data of forehand steps of the 4th tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	1	3	3	X (net)	O	O
2	2	X (short)	1	X (out)	X (net)	X (short)
3	1	2	2	O	O	O
4	X (out)	1	1	O	O	O
5	1	1	X (short)	O	O	X (short)
6	X (long)	X (long)	X (out)	O	O	X (net)
7	1	2	X (short)	O	O	O
8	3	2	2	O	O	O
9	X (long)	2	2	X (out)	O	O
10	3	X (long)	3	O	X (short)	O
11	2	3	2	O	X (lob)	X (short)
12	3	3	2	O	O	O
13	3	2	2	X (out)	X (out)	O
14	3	X (long)	2	O	O	X (net)
15	X (long)	2	X (long)	O	O	X (short)
16	2	2	2	X (out)	O	O
17	X (long)	3	3	X (short)	O	X (short)
18	X (long)	X (long)	2	X (out)	X (net)	X (out)

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
19	X (long)	X (long)	X (long)	X (out)	O	O
20	X (out)	2	2	X (net)	O	O
21	X (out)	2	1	O	X (short)	O
22	3	X (long)	2	O	O	X (short)
23	1	1	2	O	O	O
24	3	X (long)	2	O	X (short)	O
25	2	2	1	O	X (out)	X (out)
26	2	2	X (long)	X (net)	O	O
27	X (long)	1	1	X (net)	O	O

Table 18 The collected trial data of backhand steps of the 4th tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	2	2	2	O	O	O
2	X (long)	2	2	X (short)	O	X (short)
3	3	X (long)	X (long)	X (net)	X (lob)	X (out)
4	1	2	1	O	O	O
5	1	X (out)	1	O	X (net)	O
6	2	1	2	X (short)	O	O
7	2	X (out)	2	X (short)	X (net)	X (short)
8	X (long)	2	1	O	O	O
9	X (long)	1	2	X (lob)	O	O
10	3	3	2	O	O	O
11	X (long)	1	X (long)	X (net)	X(out)	O
12	3	2	2	O	X (net)	O

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
13	2	2	2	O	O	O
14	2	X (out)	2	X (net)	X (short)	O
15	2	2	2	O	O	O
16	3	3	1	O	O	O
17	2	2	1	O	O	O

<u>The fifth tennis player</u>

Table 19 The collected trial data of forehand steps of the 5th tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	X (long)	3	2	O	X (net)	X (out)
2	3	2	2	O	O	O
3	2	2	1	O	X (net)	O
4	X (long)	2	2	O	O	O
5	X (long)	3	1	X (net)	X (out)	O
6	3	3	2	O	O	O
7	X (long)	X (long)	2	O	O	X (net)
8	2	2	1	O	X (net)	O
9	2	2	1	X (short)	O	O
10	X (long)	1	X (short)	X (slice)	X (net)	X (net)
11	2	1	X (short)	O	O	O
12	3	2	1	O	O	O
13	3	1	1	O	O	O
14	2	3	2	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
15	1	3	1	O	O	O
16	1	1	2	O	O	O
17	1	2	1	O	O	O

Table 20 The collected trial data of backhand steps of the 5th tennis player from wearing the tennis shoes with herringbone pattern

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	X (long)	2	1	X (short)	O	X (out)
2	2	2	2	O	O	X (short)
3	2	1	1	O	O	X (net)
4	3	2	2	O	O	O
5	1	1	1	X (short)	X (net)	O
6	2	1	1	X (short)	O	O
7	1	2	1	O	O	O
8	X (long)	2	1	X (short)	X (net)	X (net)
9	3	2	1	O	O	O
10	X (long)	2	1	O	O	O
11	2	2	2	O	O	X (net)
12	2	X (out)	1	O	X (net)	O
13	2	1	1	O	O	O
14	2	1	1	O	O	O
15	X (long)	2	1	X (short)	X (slice)	O
16	3	3	1	X (out)	X (out)	O
17	3	X (long)	X (long)	O	O	O

Trial Herringbone	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
18	3	1	X (short)	X (out)	X (out)	X (net)
19	1	1	2	X (out)	O	O
20	3	1	1	O	O	X (short)
21	X (long)	2	2	O	O	O
22	X (long)	2	3	X (short)	O	O

Table 21 The collected trial data of forehand steps of the 5th tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Lt.	Rt.	Lt.	1	2	3
1	3	3	2	O	O	O
2	X (long)	X (long)	X (long)	X (short)	X (out)	X (out)
3	X (short)	2	1	O	O	O
4	1	2	3	O	O	O
5	3	1	2	O	O	O
6	3	3	3	O	O	O
7	X (long)	3	1	O	O	O
8	3	2	2	O	O	O
9	X (long)	2	2	X (lob)	O	O
10	3	2	3	O	O	X (out)
11	X (long)	3	3	X (short)	O	O
12	X (long)	3	3	X (net)	O	X (net)
13	3	2	3	O	O	O

Table 22 The collected trial data of backhand steps of the 5th tennis player from wearing the tennis shoes with herringbone pattern with pivot point

Trial Pivot Point	Ball Machine Shooting Area			Tennis Player Hitting Area		
	Rt.	Lt.	Rt.	1	2	3
1	1	2	3	X (short)	O	O
2	X (long)	3	2	O	O	O
3	X (long)	3	3	O	X (net)	X (net)
4	X (long)	3	2	-	O	O
5	3	3	2	X (lob)	X (out)	X (out)
6	2	1	2	O	O	O
7	3	1	2	O	X (short)	X (net)
8	3	2	3	O	X (net)	X (net)
9	X (long)	X (long)	3	O	O	O
10	3	1	1	O	O	O
11	3	1	3	X (out)	O	O
12	1	2	2	O	O	O
13	X (long)	2	2	X (lob)	O	O
14	2	1	2	X (out)	O	O
15	3	1	1	O	O	X (net)
16	3	2	1	O	O	O

Trials under the shading are successful trials.

"-" means that the player couldn't reach a ball.

"x (lob)" means that the player hit a ball over the rope.

"x (long)" means that the player hit a ball out of the baseline.

"x (net)" means that the player hit a ball to the net.

"x (out)" means that the player hit a ball out of the single sidelines.

"x (short)" means that the player hit a ball to the service box.

"x (slice)" means that the player hit a ball with an underspin shot.

APPENDIX H

Peak Pressure Data on The Pivot Point Area

Table 23 Peak pressures on the pivot area from forehand steps

Trial	Herringbone (KPa)	Pivot Point (KPa)
1	660	881
2	684	1210
3	379	929
4	302	783
5	696	405
6	854	974
7	461	1080
8	641	569
9	785	1117
10	548	1261
11	1377	621
12	711	634
13	1046	1122
14	1185	1027
15	1000	1272
16	1240	1249
17	824	963
18	634	1080
19	1381	1296
20	997	1148
21	438	655
22	735	881
23	614	953

Trial	Herringbone (KPa)	Pivot Point (KPa)
24	690	581
25	554	533
26	442	539
27	748	455
28	381	571
29	570	741
30	605	579
31	653	758
32	635	769
33	564	1135
34	701	800
35	536	747
36	691	943
37	542	1021
38	732	1148
39	547	970
40	931	777
41	760	629
42	895	835
43	1131	763
44	788	899
45	776	1051
46	1127	854
47	812	633
48	932	807
49	1033	742
50	1059	951

Table 24 Peak pressures on the pivot area from square stance backhand steps

Trial	Herringbone (KPa)	Pivot Point (KPa)
1	46	146
2	0	31
3	91	71
4	54	50
5	91	32
6	73	30
7	30	89
8	0	114
9	24	0
10	28	54
11	100	210
12	112	121
13	0	252
14	308	162
15	361	206
16	75	59
17	474	136
18	74	402
19	447	111
20	106	204
21	160	155
22	242	0
23	165	74
24	80	177
25	86	129
26	123	214
27	51	87

Trial	Herringbone (KPa)	Pivot Point (KPa)
28	50	69
29	68	82
30	51	107
31	112	95
32	87	35
33	120	111
34	98	-
35	112	-
36	48	-
37	107	-
38	134	-
39	211	-
40	113	-

Table 25 Peak pressures on the pivot area from open stance backhand steps

Trial	Herringbone (KPa)	Pivot Point (KPa)
1	893	479
2	549	441
3	264	461
4	570	145
5	374	506
6	409	413
7	383	494
8	455	434
9	609	344
10	515	281

Trial	Herringbone (KPa)	Pivot Point (KPa)
11	-	793
12	-	723
13	-	579
14	-	581
15	-	571
16	-	640
17	-	815

APPENDIX I

Statistics of Peak Pressures on 12 Regions of The Foot

Table 26 Mean differences of the peak pressures of forehand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone M1	50	686.28	312.91	98	-1.329	0.187
Pivot point M1	50	762.20	255.51			
Herringbone M2	50	821.60	297.89	98	2.750	0.007†
Pivot point M2	50	667.22	262.43			
Herringbone M3	50	548.00	352.38	90.38	3.767	0.000#
Pivot point M3	50	314.30	261.34			
Herringbone M4	50	305.06	216.47	98	2.384	0.019*
Pivot point M4	50	211.46	173.88			
Herringbone M5	50	198.68	186.85	98	1.328	0.187
Pivot point M5	50	158.04	109.26			
Herringbone T1	50	681.36	446.69	98	0.281	0.780
Pivot point T1	50	657.40	405.88			
Herringbone T2	50	392.62	321.45	89.28	2.493	0.015*
Pivot point T2	50	252.74	232.62			
Herringbone T3	50	168.64	163.46	85.29	-1.351	0.180
Pivot point T3	50	225.02	245.61			
Herringbone T45	50	132.64	120.49	98	-0.809	0.420
Pivot point T45	50	151.66	114.44			
Herringbone MH	50	48.06	132.56	70.73	-3.148	0.002‡
Pivot point MH	50	183.64	274.13			

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone LH	50	17.66	39.07	82.96	-6.427	0.000#
Pivot point LH	50	83.94	61.57			
Herringbone MF	50	107.72	102.50	98	-1.552	0.124
Pivot point MF	50	138.48	95.52			

Compared between the 2 types of tennis shoes using Unpaired t- test Statistics.

* Significant difference between both shoes, $p<0.05$

† Significant difference between both shoes, $p<0.01$

‡ Significant difference between both shoes, $p<0.005$

Significant difference between both shoes, $p<0.001$

Table 27 Mean differences of the peak pressures of square stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone M1	40	129.23	109.93	71	-0.244	0.808
Pivot point M1	33	134.97	86.22			
Herringbone M2	40	108.38	65.55	71	-0.844	0.402
Pivot point M2	33	120.61	56.54			
Herringbone M3	40	143.63	66.55	71	-3.135	0.002‡
Pivot point M3	33	198.21	82.24			
Herringbone M4	40	319.80	233.00	47.33	0.842	0.404
Pivot point M4	33	287.12	70.08			
Herringbone M5	40	412.00	257.06	71	-0.885	0.379
Pivot point M5	33	459.85	191.49			
Herringbone T1	40	468.55	244.48	71	2.173	0.033*
Pivot point T1	33	351.88	206.85			
Herringbone T2	40	175.40	160.45	71	0.123	0.903
Pivot point T2	33	171.33	112.31			

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone T3	40	140.45	78.29	71	-0.295	0.769
Pivot point T3	33	145.79	75.14			
Herringbone T45	40	97.80	44.25	71	-2.163	0.034*
Pivot point T45	33	126.64	68.87			
Herringbone MH	40	379.38	236.86	71	0.552	0.583
Pivot point MH	33	345.58	286.53			
Herringbone LH	40	319.55	212.44	71	0.136	0.892
Pivot point LH	33	311.85	270.25			
Herringbone MF	40	299.08	211.54	68.39	0.771	0.443
Pivot point MF	33	267.00	142.11			

Compared between the 2 types of tennis shoes using Unpaired t- test Statistics.

* Significant difference between both shoes, $p<0.05$

‡ Significant difference between both shoes, $p<0.005$

Table 28 Mean differences of the peak pressures of open stance backhand steps between wearing the tennis shoes with herringbone pattern and the tennis shoes with herringbone pattern with pivot point

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone M1	10	483.60	151.72	25	0.966	0.343
Pivot point M1	17	418.29	178.97			
Herringbone M2	10	534.00	257.45	25	0.210	0.836
Pivot point M2	17	513.12	245.45			
Herringbone M3	10	409.60	318.63	25	-0.052	0.959
Pivot point M3	17	416.59	346.37			
Herringbone M4	10	238.30	220.78	25	-0.992	0.331
Pivot point M4	17	341.59	281.48			

Foot Region	n	$\overline{X}$	S.D.	df	t	p
Herringbone M5 Pivot point M5	10 17	163.80 261.24	67.09 201.46	21.26	-1.829	0.081
Herringbone T1 Pivot point T1	10 17	258.50 347.59	199.38 309.14	25	-0.814	0.424
Herringbone T2 Pivot point T2	10 17	169.90 218.53	177.90 197.15	25	-0.641	0.528
Herringbone T3 Pivot point T3	10 17	140.90 231.47	74.30 169.40	23.68	-1.914	0.068
Herringbone T45 Pivot point T45	10 17	131.60 116.88	46.87 56.43	25	0.694	0.494
Herringbone MH Pivot point MH	10 17	3.20 30.76	10.12 58.03	17.61	-1.910	0.073
Herringbone LH Pivot point LH	10 17	10.80 51.35	11.43 57.60	18.07	-2.811	0.012*
Herringbone MF Pivot point MF	10 17	73.00 116.59	54.75 86.18	25	-1.432	0.164

Compared between the 2 types of tennis shoes using Unpaired t- test Statistics.

* Significant difference between both shoes, $p<0.05$

M1 to M5 are defined as the first metatarsal area to the fifth metatarsal area respectively.

T1 to T3 are defined as the first toe area to the third toe area respectively.

T45 is defined as the fourth and fifth toe areas.

MH is defined as the medial heel area.

LH is defined as the lateral heel area.

MF is defined as the midfoot area.

APPENDIX J

National Tennis Rating Program

The National Tennis Rating Program (NTRP) developed by The United States Tennis Association (USTA) describes the general characteristics that tennis players exhibit in each of thirteen skill levels depending on the competitive ability and other factors.

<u>General characteristics of NTRP playing levels</u>

1.0 This player is just starting to play tennis.

1.5 This player has limited experience and is still working primarily on getting the ball into play.

2.0 This player needs on-court experience. This player has obvious stroke weaknesses but is familiar with basic positions for singles and doubles play.

2.5 This player is learning to judge where the ball is going, although court coverage is weak and can sustain a ***short rally of slow pace*** with other players of the same ability.

3.0 This player is fairly consistent when hitting medium-paced shots, but is not comfortable with all strokes and lacks execution when trying for directional control, depth, or power. Most common doubles formation is one up, one back.

3.5 This player has achieved improved stroke dependability with directional control on moderate shots, but still lacks depth and variety. This player exhibits more aggressive net play, has improved court coverage, and is developing teamwork in doubles.

4.0 This player has dependable strokes, including directional control and depth on both forehand and backhand sides on moderate shots, plus the ability to use lobs, overheads, approach shots, and volleys with some success. This player occasionally forces errors when serving. Rallies may be lost due to impatience. Teamwork in doubles is evident.

4.5 This player has begun to master the use of power and spins and is beginning to handle pace, has sound footwork, can control depth of shots, and is beginning to vary game plan according to opponents. This player can hit first serves with power and accuracy and place the second serve. This player tends to overhit on difficult shots. Aggressive net play is common in doubles.

5.0 This player has good shot anticipation and frequently has an outstanding shot or attribute around which a game may be structured. This player can regularly hit winners or force errors off of short balls and can put away volleys, can successfully execute lobs, drop shots, half volleys, overhead smashes, and has good depth and spin on most second serves.

5.5 This player has developed power and/or consistency as a major weapon. This player can vary strategies and styles of play in a competitive situation and hits dependable shots in a stress situation.

6.0 - 7.0 The 6.0 player typically has had intensive training for national tournament competition at the junior and collegiate levels and has obtained a sectional and/or national ranking. The 6.5 and 7.0 are world-class players.

Source: National Tennis Rating Program (NTRP) Guidebook

APPENDIX K

Men's Shoe Size Chart

Table 29 Us men's shoe sizing chart

US Men's Shoe Size	Foot Length	Foot Width		
		C (narrow)	D (standard)	E (wide)
6	9.31	3.3"	3.5"	3.7"
6.5	9.5	3.3"	3.6"	3.8"
7	9.69	3.4"	3.6"	3.8"
7.5	9.81	3.4"	3.7"	3.9"
8	10	3.5"	3.8"	3.9"
8.5	10.19	3.6"	3.8"`	4.0"
9	10.31	3.6"	3.9"	4.1"
9.5	10.5	3.7"	3.9"	4.1"
10	10.69	3.8"	4.0"	4.2"
10.5	10.81	3.8"	4.1"	4.3"
11	11	3.9"	4.1"	4.3"
11.5	11.19	3.9"	4.2"	4.4"
12	11.31	4.0"	4.3"	4.4"
12.5	11.5	4.1"	4.3"	4.5"
13	11.69	4.1"	4.4"	4.6"
13.5	11.81	4.2"	4.4"	4.8"
14	12	4.2"	4.5"	4.9"
14.5	12.19	4.3"	4.6"	4.9"
15	12.31	4.3"	4.6"	5"

Source: About.com Guide

BIOGRAPHY

Name	Miss Somruthai Poomsalood
Date of birth	16th November 1981
Place of birth	Phitsanulok, Thailand
Instruction attended	Faculty of Allied Health Science
	Thammasat University (2000 – 2003)
	Bachelor of Science (Physical Therapy)