

T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF SPORTS PHYSIOTHERAPY

**EVALUATION OF THE RELATIONSHIP
BETWEEN FOOT ANTHROPOMETRY
VARIABLES AND PERFORMANCE IN
ADOLESCENT TENNIS PLAYERS**

MASTER THESIS

HALİL İBRAHİM DURMUŞ, PT.

İSTANBUL-2022

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HALİL İBRAHİM DURMUŞ, PT.

ADVISER
PROF. DR. FERYAL SUBAŞI

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THESIS APPROVAL FORM

Institute : Yeditepe University Institute of Health Sciences
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This study have approved as a Master Thesis in regard to content and quality by the Jury.

	Title, Name-Surname (Instit
Chair of the Jury:	Prof. Dr. Feryal SUBAŞI (Yeditepe University)
Supervisor:	Prof. Dr. Feryal SUBAŞI (Yeditepe University)
Member/Examiner:	Dr. Öğr. Üyesi Zuhal Didem TAKİ (Sağlık Bilimleri University)
Member/Examiner:	Dr. Öğr. Üyesi Elif Tuğçe ÇİL (Yeditepe University)

APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated and numbered

Prof. Dr. Bayram YILMAZ
Director of Institute of Health Sciences

DECLARATION

I hereby declare that this thesis is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Halil İbrahim DURMUŞ

DEDICATION

I dedicated my thesis to my parents Mehmet Ali and Saniye DURMUŞ, who have always supported me throughout my education life.

Halil İbrahim DURMUŞ



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I would like to thank to Prof. Dr. Feryal SUBAŞI for providing all kinds of support and guidance that made this project possible.

Also, to my friends who were with me throughout my graduate education, to Ali GÖREÇ, the coach of Optimum Tennis Club, who supported and helped me in the provision of a working environment,

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LIST OF SYMBOLS AND ABBREVIATIONS

AITF	: Anteroinferior Tibiofibular
AJ	: Ankle Joint
ATFL	: Anterior Talofibular Ligament
BMI	: Body Mass Index
CFL	: Calcaneofibular Ligament
Cm	: Unit of Length in Centimeters
CN	: Calcaneonavicular
FDL	: Flexor Digitorum Longus
FHL	: Flexor Hallucis Longus
FL	: Foot Length
FW	: Foot Width
HW	: Heel Width
Kg	: Unit of Mass in Kilograms
LCL	: Lateral Collateral Ligaments
LL	: Leg Length
LLA	: Lateral Longitudinal Arch
LLL	: Lower Leg Length
LMH	: Lateral Malleolar Height
MCL	: Medial Collateral Ligaments
MLA	: Medial Longitudinal Arch
MMH	: Medial Malleolar Height
PITF	: Posteroinferior Tibiofibular
PTFL	: Posterior Talofibular Ligament
ROM	: Range of Motion
SD	: Standard Deviation
SPSS	: Statistical Package Analyze for Social Sciences
ST	: Subtalar
TC	: Talocrural
TN	: Tibionavicular
1st ML	: 1st Metatarsophalangeal Length,

ABSTRACT

Durmuş, H.İ. (2022). Evaluation Of The Relationship Between Foot Anthropometry Variables And Performance In Adolescent Tennis Players, Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, Master Thesis. Istanbul.

The aim of this study is to evaluate the foot anthropometric values of adolescent tennis players and to investigate their effects on performance parameters. Adolescent age group 48(19M, 29F) volunteer tennis players with an average age of $11,02 \pm 1,792$ who play active tennis in optimum tennis academy were included in the study. The sociodemographic characteristics of the participants were evaluated using a structured questionnaire. Bilateral anthropometric measurements of all participants with bare foot were measured with tape measure and digital caliper. Measured anthropometric values are medial malleolar height, lateral malleolar height, heel width, foot length, foot width, 1st metatarsophalangeal bone length. Performance tests, which are frequently used in tennis players, were applied to the participants. The hexagon agility test was used to determine the agility of the athlete, the y balance test to determine the dynamic balance, the vertical jump test to determine the lower extremity strength, and the navicular drop test to determine the foot arch height. As a result of our statistical analyzes, it was observed that there was a negative relationship ($r=-0.322$; $p=0.026$) between the length of the right foot and the hexagon agility test (clockwise). A statistically significant correlation was observed between left medial height and hexagon test (clockwise and counterclockwise) ($p<0.05$). A statistically significant correlation was observed between the Y balance test and the foot width and the length of the 1st metatarsophalangeal bone. Significant correlations were found between foot length ($p<0.001$), heel width ($p<0.05$), foot width ($p<0.05$), medial and lateral malleolus height ($p<0.05$) and vertical jump test. It was observed that there was a significant correlation between the height of the medial malleolus of the left foot and the navicular drop test, and between the height of the lateral malleolus and the navicular drop test ($p<0.05$). It has been found that the foot structure compatible with the hypothesis affects the performance of the athlete. According to the results of this study, we suggest examining the foot structure while evaluating the performance of tennis players and preparing the training program. After evaluating the player's foot, we can say that the performance can be optimized by using supported

insoles according to the player's foot, myofascial relaxation techniques, strengthening the foot extensor muscles or strengthening the foot flexor muscles in order to achieve the desired increase in performance.

Key Words: anthropometry; y balance; hexagon ; navicular drop test; vertical jump; performance; tennis



ÖZET

Durmuş, H.İ. (2022). Adolesan Tenis Oyuncularında Ayak Antropometrisi Değişkenleri ile Performans Arasındaki İlişkinin Değerlendirilmesi, Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Anabilim Dalı, Yüksek Lisans Tezi. İstanbul.

Bu çalışmanın amacı ergen tenisçilerin ayak antropometrik değerlerinin değerlendirilmesi ve performans parametreleri üzerine olan etkilerinin araştırılmasıdır. Çalışmaya optimum tenis akademisinde aktif tenis oynayan yaş ortalaması $11,02 \pm 1,792$ olan adolesan yaş grubu 48(19E, 29K) gönüllü tenis oyuncusu dahil edilmiştir. Katılımcıların sosyodemografik özellikleri yapılandırılmış bir anket kullanılarak değerlendirilmiştir. Tüm katılımcıların çıplak ayakla bilateral antropometrik ölçümleri mesura ve dijital kumpas ile ölçülmüştür. Ölçülen antropometrik değerler medial malleol yüksekliği, lateral malleol yüksekliği, topuk genişliği, ayak uzunluğu, ayak genişliği, 1. Metatarsofalangeal kemik uzunluğudur. Katılımcılara tenis oyuncularında sıklıkla kullanılan performans testleri uygulanmıştır. Sporcunun çevikliğini belirlemek için hexagon çeviklik testi, dinamik dengeyi belirlemek için y denge testi, alt ekstremitte kuvvetini belirlemek için vertical zıplama testi ve ayak ark yüksekliğini belirlemek için navikular düşme testi kullanılmıştır. Yaptığımız istatistiksel analizler sonucunda sağ ayak uzunluğu ile hexagon çeviklik testi (saat yönünde) arasında negatif bir ilişki olduğu ($r=-0,322$; $p=0,026$) gözlemlendi. Sol medial yükseklik ile hexagon testi (saat yönünde ve saat yönünün tersine) arasında istatistiksel olarak anlamlı bir ilişki gözlemlendi ($p<0.05$). Y denge testi ile ayak genişliği ve 1. metatarsofalangeal kemik uzunluk arasında istatistiksel olarak anlamlı bir ilişki gözlemlendi. Ayak uzunluğu ($p<0,001$), ayak topuk genişliği ($p<0,05$), ayak genişliği ($p<0,05$), medial ve lateral malleol yükseklik ($p<0,05$) ile dikey sıçrama testi arasında anlamlı korelasyon bulundu. Sol ayağın medial malleol yüksekliği ile navikular düşme testi arasında, lateral malleol yüksekliği ile navikular düşme testi arasında anlamlı bir ilişki olduğunu gözlemlendi ($p<0.05$). Hipotez ile uyumlu ayak yapısının sporcunun performansını etkilediği bulunmuştur. Bu çalışmanın sonuçlarına göre tenisçilerin performansını değerlendirirken ve antrenman programını hazırlarken ayak yapısının incelenmesini önermekteyiz. Oyuncunun ayağı değerlendirildikten sonra performansta istenilen artışın sağlanabilmesi için oyuncunun ayağına göre destekli tabanlık kullanımı, miyofasyal gevşeme teknikleri, ayak ekstansör

kaslarının güçlendirilmesi veya ayak fleksör kaslarının güçlendirilmesi ile performansın optimize edilebileceğini söyleyebiliriz.

Anahtar Kelimeler: antropometri; y denge; hexagon testi ; navikular düşme testi; dikey sıçrama ; performans; tenis



1. INTRODUCTION AND PURPOSE

In the last century, the number of tennis players has increased and tennis has become one of the most popular sports [1]. Around sixty million players at different levels play this popular sport worldwide [2]. Individuals of all ages can play this sport. Especially children show interest in this sport. In addition, this sport is beneficial for physical and mental health. For example, the risk of cardiovascular and diabetes diseases and stress decreases, balance coordination and proprioception increase in individuals who play tennis regularly [3]. This game includes runs at different speeds, turns, slides, and kicks, as well as low-intensity activities such as short bursts of high-intensity moves and serves. Tennis is a sport that can be played with different types of balls on different surfaces such as grass, dirt, and hard courts [4]. Unlike other sports, tennis matches do not have a predetermined playing time. Matches can usually last several hours [1]. It takes an average of 10 seconds to score in a tennis game, but there is a chance that matches will take more than 5 hours. Intermittent anaerobic energy systems of varying intensities are used in a tennis match. Break times allow aerobic energy systems to recover [5].

With the popularity of tennis lately, it has become a more dynamic and fast-paced game. Changes in speed, performance, and tempo depend on factors such as the player's muscle strength, body biomechanics, technique used, body mass index, height, and anthropometric characteristics [6]. The technical and biomechanical strokes used by the player affect the success in tennis. In other words, the physical characteristics of the tennis player are effective in this success [7]. The structure of the playing field and the material from which the ball is produced affect the performance of the players[4]. The game of tennis is a sport that requires multiple features of the players to be in harmony with each other. The player must have superior skills. These are tactical, technical, physical, and psychological elements [8]. Unlike many other sports, tennis players have to show high performance in every component. The force transferred to the tennis racket follows the path of the player's transmission of the force from the ground to the racquet via the ankle, lower extremity, trunk, and upper extremity. In other words, the force transferred to the tennis racket starts from the foot and proceeds in the form of leg-shoulder-arm. The player's biomechanical and anthropometric values gain importance at this point. A player's abilities are determined by making basic anthropometric and physiological measurements [5]. Anthropometry is not a qualitative measurement. The

fact that anthropometry is a quantitative measurement makes the research more reliable. Anthropometry is used to measure the human body [9]. Anthropometric measurement, which is used to quantitatively evaluate the human body, is an inexpensive, non-invasive, and universal method for evaluating body proportions [10].

Evaluation of body composition in players allows the player to optimize his performance and be more successful in training. Therefore, it is very important for the professional player [11]. Anthropometric values affect performance factors such as vertical jump height. For example, athletes with long lower limbs jump better. Arm length, finger length, lower limb length etc. Such anthropometric values are important in determining abilities such as jumping and running [12]. Players' speed, agility, muscle strength and game performance measures (for example, fighting and defensive skills, pulling and passing, ball playing speed) are closely related to their physical values [13]. Recent studies highlight the functional importance of foot structure in humans. Studies have shown that runners have shorter Achilles tendon moment arms than other players, and it turns out that runners have longer metatarsals. Another study was conducted on volleyball players. Studies have shown that volleyball players have shorter plantar flexor moment arms than non-players. The relationship between the anthropometric characteristics of the body and the metabolic status can be explained by the structure of the athletes. For example, athletes with shorter metatarsals consume less energy while producing muscle power. According to these studies, there is a link between differences in the structure of the human foot and various motor tasks. Therefore, if it is known how the structural differences in the athlete's body affect the functional capacity of the athlete, it is revealed how the athlete's performance can be improved [14].

Many studies have shown a causal link between foot structure and differences in lower extremity kinematics. However, there is little evidence of a possible relationship between foot structure and the physical activity and strength of the muscles that move the ankle. Foot length, foot width, and foot circumference have been proven to be associated with plantar flexion, dorsiflexion, eversion and inversion, and vertical jump. Thanks to these findings, it is seen that there is a connection between the foot structure and the muscle strength that provides these movements. It turns out that the physical performance of the individual changes with structural differences. For example, the athlete's weight, height and lower extremity length were evaluated with jump performance and a

significant relationship was found between them. However, there appears to be a gap in research investigating the relationship between performance and acute anthropometric measures such as heel width, toe length, and arch height.[12,15,16]

In tennis players, more studies have been done on the upper extremity strength, core strength and leg length value. It is seen that studies on anthropometric values in adolescent age group tennis players are limited. With this study, we will examine the foot structure of adolescent tennis players and show the way to increase their sports performance.

Purpose of the study:

In the literature, studies explaining the relationship between anthropometric measurements and performance values of tennis players are quite limited. In addition, there are few studies on body anthropometric values in adolescent tennis players. Studies have generally been conducted on height, body mass index, and extremity length. Therefore, the aim of this study is to examine the foot anthropometric values of tennis players and to investigate the effect on dynamic balance, agility and vertical jump performance. Dependent variables are hexagon agility test, vertical jump test. Independent variables are age, height, weight, navicular drop test, foot length, medial malleolus height, lateral malleolus height, foot width, heel width, 1st toe length, and Y balance test.

Our hypotheses for this study:

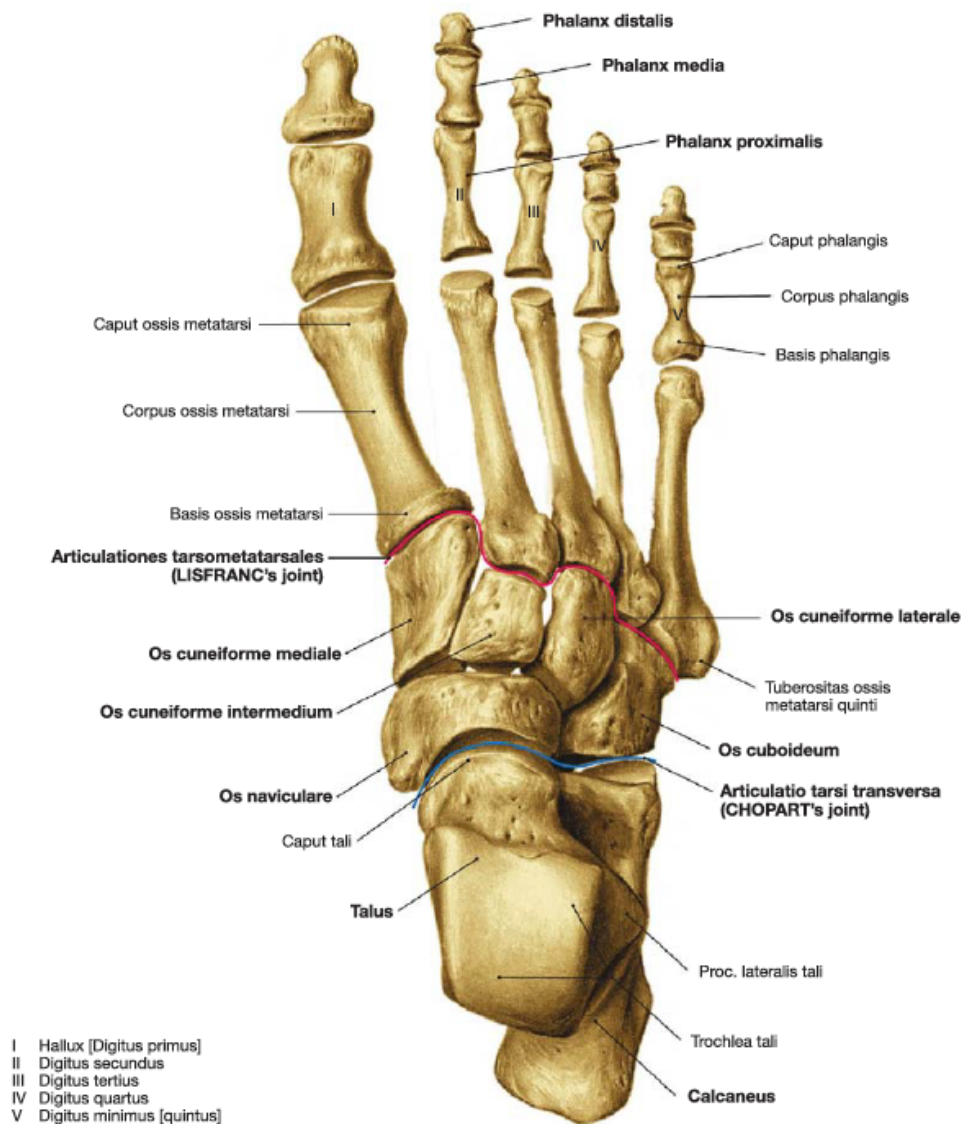
H0: There is no significant relationship between foot anthropometric variables, vertical jump test, Y balance test, and hexagon agility test parameters in adolescent tennis players.

H1: There is a significant relationship between foot anthropometric variables, vertical jump test, Y balance test, and hexagon agility test parameters in adolescent tennis players.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Functional Anatomy of the Foot and Ankle Joint

The ankle joint (AJ) is a synovial hinge joint that provides the movement necessary to walk and transfer body weight to the foot. There are twenty-six bones and thirty-three joints in the foot and ankle. When we examine the functional structure of the foot, it works with a multi-joint mechanism during movement. it acts as a bridge between the ground and the lower extremity [17, 18, 19].



Anatomy of Foot

Figure 2.1. The Bones of Foot [20].

In the ankle, three bones (tibia-fibula-talus) articulate; Talocrural (TC) joint, subtalar (ST) joint, and distal tibiofibular syndesmosis joint,

The important structures of the AJ include:

- Bones and joints
- Ligaments and tendons
- Muscles
- Nerves
- Blood vessels

The TC joint consists of the talus, medial malleolus, distal tibia, and lateral malleolus. It is a hinge-type joint that connects the two distal ends of the tibia-fibula and talus, allowing plantar and dorsiflexion to occur. One ligament of the TC is the medial collateral ligament (MCL), and this ligament is called the deltoid ligament. It is triangular in shape. It supports the medial of the AJ and provides resistance to eversion and valgus stresses of the joint. Although it is a strong bond, it consists of two types of fibers, superficial and deep. The superficial fibers consist of the tibionavicular (TN) ligament, the plantar calcaneonavicular (CN) ligament, and the posterior tibiotalar ligament. The deep fibers are formed from the anterior tibiotalar ligament. Another ligament of the TC is the lateral collateral ligament (LCL) which consists of three different parts; posterior talofibular ligament (PTFL), anterior talofibular ligament (ATFL), and calcaneofibular ligament (CFL). LCL provides resistance to varus stresses. The task of the ST joint, located between the calcaneus and the talus, is inversion and eversion. It has a multidimensional structure. This joint has two different joints. It is associated with the talocalcaneal joint posteriorly and the talocalcaneonavicular joint anteriorly. Ligaments at the talocalcaneal joint are the MCL, LCL, cervical ligament, and interosseous talocalcaneal ligaments. The syndesmosis is located between the fibula and the tibia and limits movement. This joint is the third joint distal to the fibula and tibia. Structurally, the interosseous tibiofibular ligament includes the interosseous membrane, the posteroinferior tibiofibular (PITF) ligament, and the anteroinferior tibiofibular (AITF) ligament. Approximately 35% of ankle stability is by AITF; 33% by PITF; 22% is covered by the interosseous PITF and 9% by the superficial PITF [18, 21].

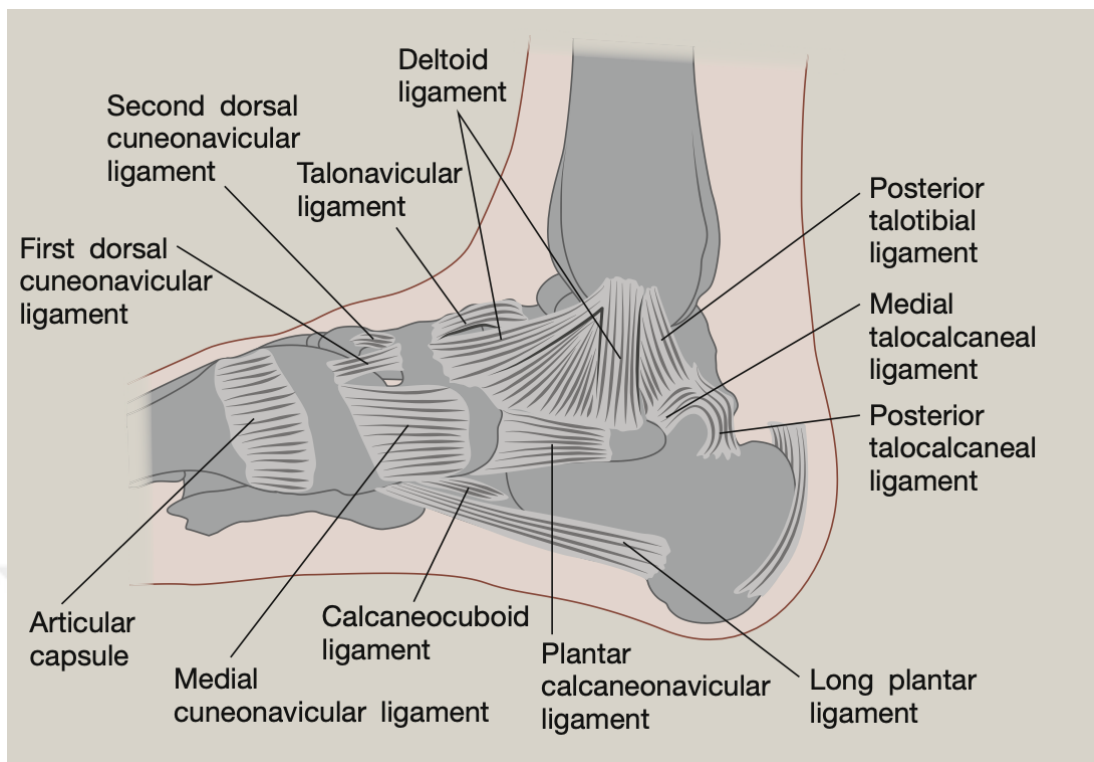


Figure 2.2. The Ligament of the Foot (Medial View) [21]

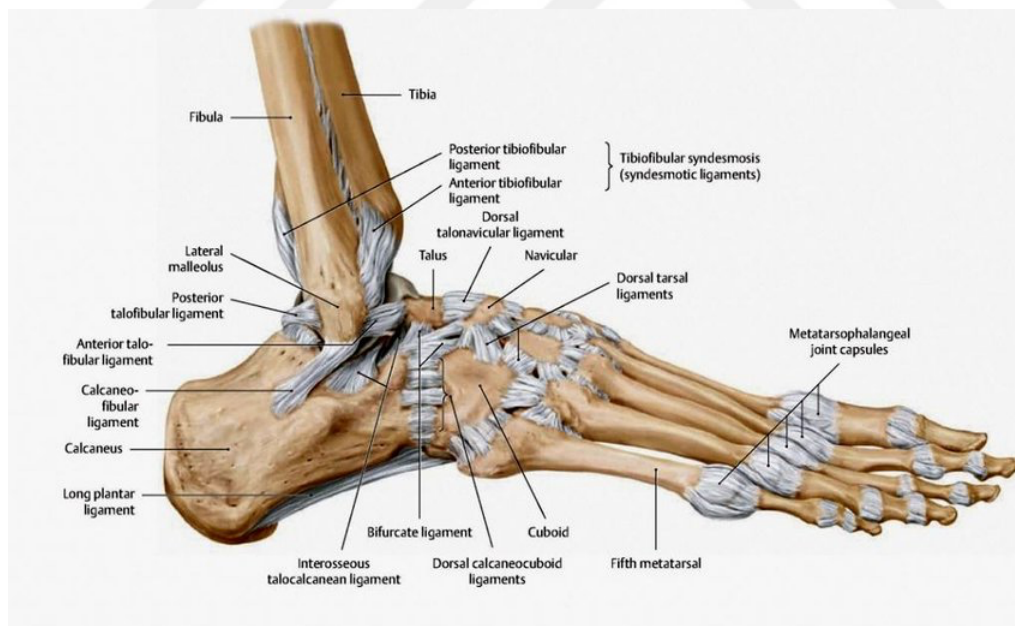


Figure 2.3. The Ligament of the Foot (Lateral View) [22].

2.1.1 Foot Bones

The foot is formed by the union of 26 bones with 37 joints. The anatomical structure of the foot is divided into three parts. These three parts are the hindfoot, midfoot, and forefoot. The bones in the foot are supported by ligaments, each surrounded by a joint capsule and covered with hyaline cartilage. Bone structures are separate groups called metatarsals, tarsal, and phalanx. The talus and calcaneus make up the hind leg. The hindfoot proximally joins with the lower extremity. The talar dome is the articulation of the distal tibia and distal fibula with the body of the talus, forming a recess [21, 23]

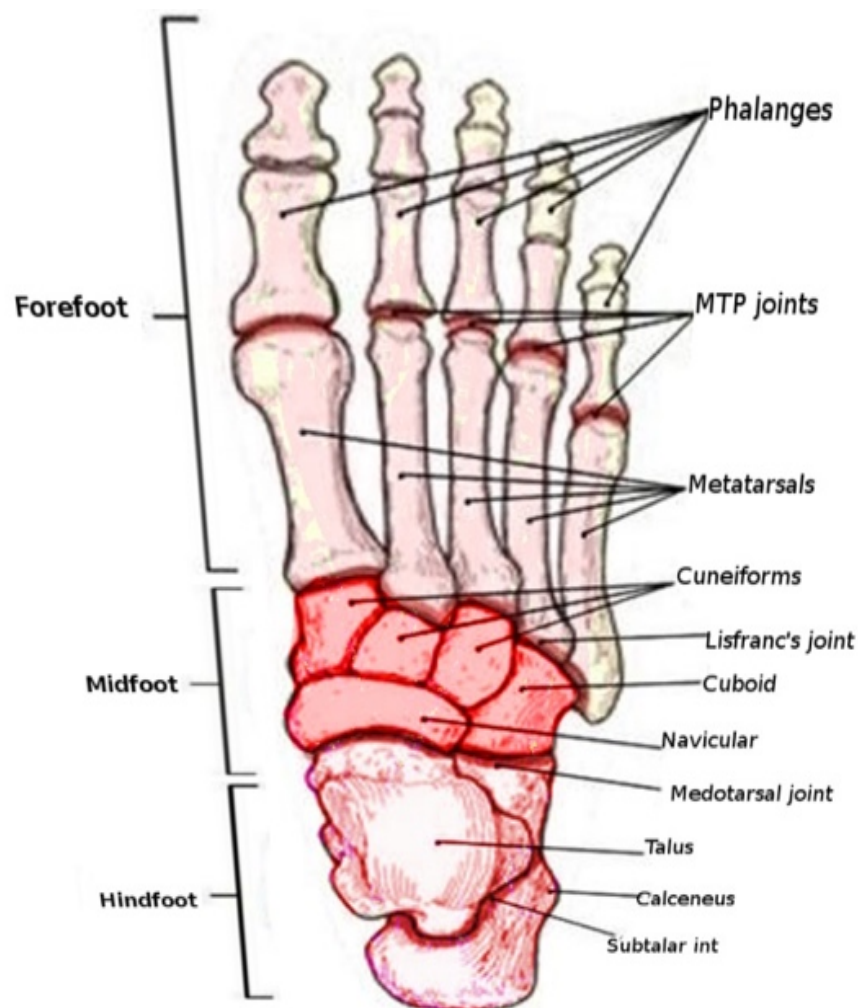


Figure 2.4. Foot joints [24]

- The talus and calcaneus form the hind foot.
- Navicula, cuboid, cuneiforms form the midfoot. The midfoot connects the midtarsal joint with the hindfoot.
- The 5 metatarsal bones and 14 phalanges in the foot make up the forefoot. Except for the 1st phalanx, all phalanges are divided into three (proximal, middle, and distal). There is no middle phalanx in the thumb [21].

The Achilles tendon attaches to the calcaneus. The calcaneus is located below the talus. It forms a uniaxial triplane articulation with the talus. The talus is a concave bone above and below the calcaneus. Articulation is provided by this figure. In this way, inversion and eversion of the ankle can be achieved [25].

Talus: The second largest tarsal bone in the human body is the talus. Its body forms multiple facet joints and 60% is covered with hyaline cartilage. The talar dome is formed by the superior talar body and the tibiotalar articular surface. The talus neck forms the roof of the tarsal canal and is located between the head and body of the talus [23].

Calcaneus: The bone under the talus is the calcaneus and superiorly it articulates with the talus. The calcaneus articulates with the cuboid anteriorly. The calcaneus and ST joints bear approximately 50% of our body weight [23].

The midfoot: The junction of the cuboid, navicular, cuneiform, and five tarsal bones forms the midfoot [23].

Navicula: The navicular bone articulates with the cuboid. It has a convex structure at its distal, and a concave structure at its proximal part. In its distal part, it joins with three facet lines [23].

Cuboid: The cuboid bone, which articulates with the lateral cuneiform and 4th and 5th metatarsals distally and the calcaneus proximally, ossifies after birth. It has a cube-shaped structure. There is a sulcus in the lower medial part. The hindfoot and midfoot are connected by the talonavicular and calcaneocuboid joints [23].

Cuneiforms: The cuneiforms articulate with the navicular proximally. The cuneiform articulates distally with the 1st and 3rd metatarsals. There are three cuneiform bones [23].

Medial cuneiform is the largest and begins to ossify at 2 years of age. The smallest cuneiform bone is the middle cuneiform. It articulates with other cuneiforms medially and laterally. It articulates with other cuneiform writings medially and laterally, articulating with the navicular proximally and the 2nd metatarsal bone distally. The third cuneiform is called the lateral cuneiform. This bone articulates with the middle cuneiform and metatarsals [23].

Metatarsals: There are three regions in the metatarsal bones, but these regions are adjacent to each other. These regions; are the base, trunk (diaphysis), and head [23].

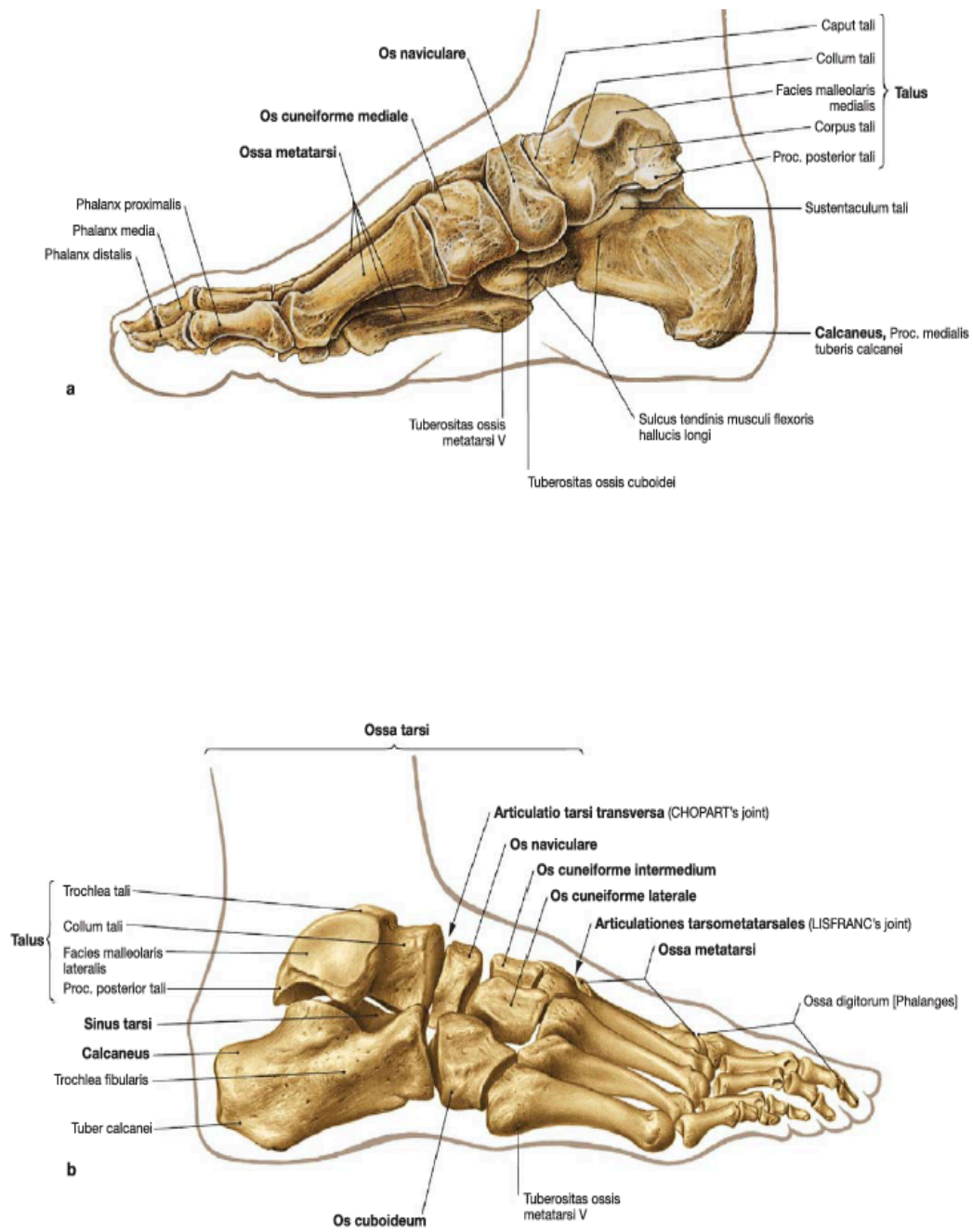


Figure 2.5. A and B Bones of the Foot [20]

2.1.2 Biomechanics of Foot

The foot provides a balance between forces from above and forces from below. It is especially involved in the transmission of force between the lower extremity and the ground and has a shock absorber function. It is structurally flexible [26].

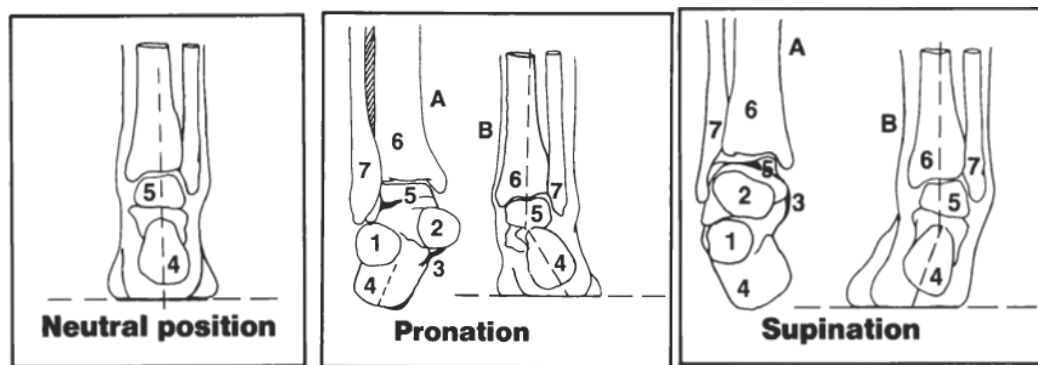


Figure 2.6. Biomechanics of the Foot [28]

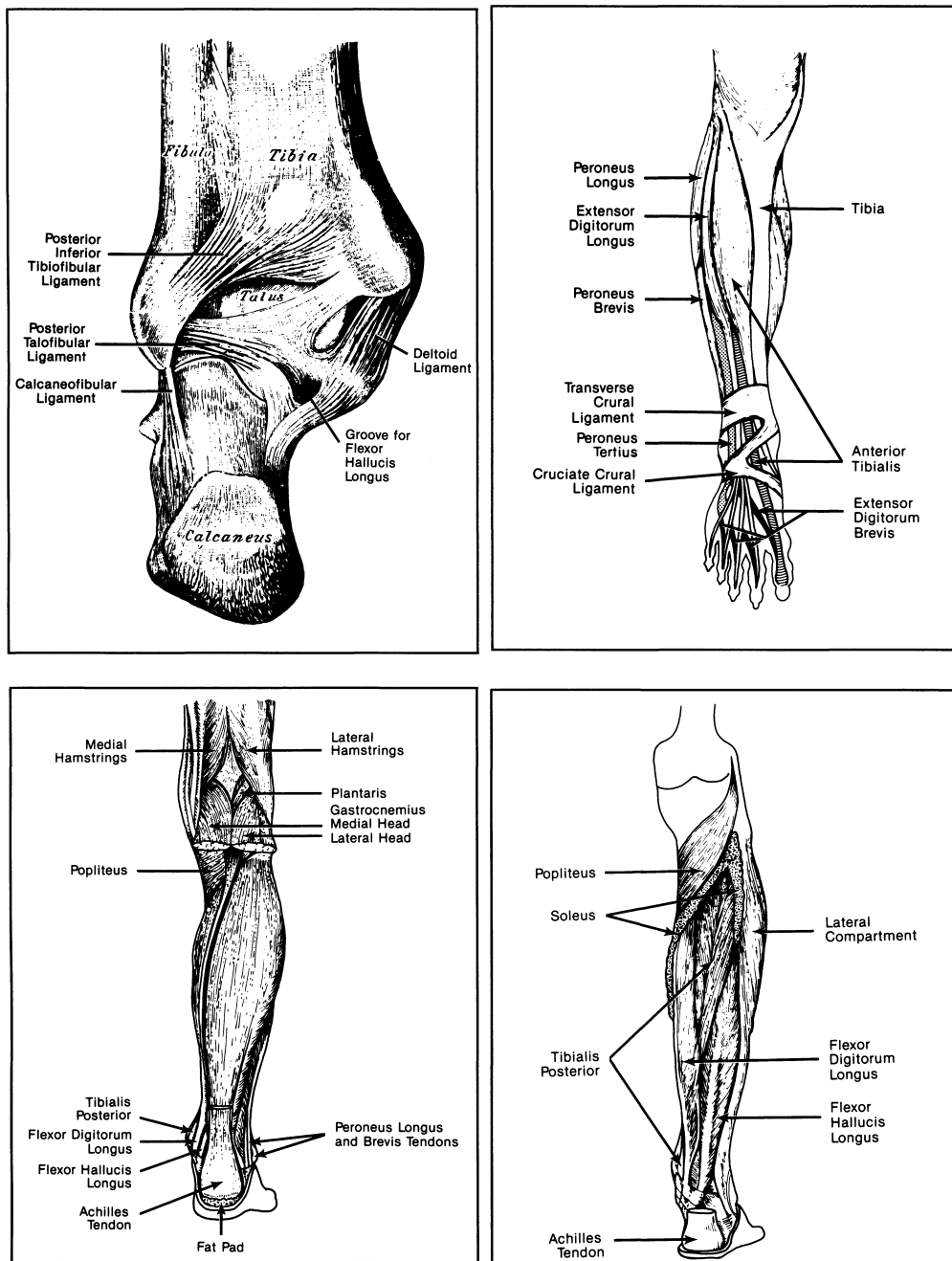
The ankle has six movements. Its main movement is plantarflexion and dorsiflexion. This movement occurs on the sagittal plane. abduction and adduction movements are seen. these movements occur in the transverse plane. Inversion and eversion movements also occur in the frontal plane [18]. Rotational motion is secondary motion. The reason for the occurrence of rotational motion is that the axis of motion is in the oblique position [27].

Combinations of these movements cause supination and pronation of the ST and tibiotalar joints. For supination motion to occur in the ankle, the foot must move together with inversion, plantar flexion, and abduction. For the pronation movement to occur, the foot must move together with eversion, dorsiflexion, and abduction [18].

The AJ has a range of motion (ROM) of 20 degrees in dorsiflexion and 36 degrees in plantar flexion. The rotational movement is 20 degrees depending on the degree of flexion. During walking, 10 degrees of dorsiflexion and 20 degrees of plantarflexion are used [27].

2.1.3 Foot and Ankle Muscles

There are twenty-nine muscles that attach to the foot. Nineteen of these 29 muscles are called intrinsic muscles, and the other ten muscles are directly connected to the ankle. It is shown in figure 2.7.. The muscles connecting the foot are divided into internal and external muscles. Intrinsic muscles provide the emergence of fine motor movements that occur in the foot [28]. The insertion of extrinsic muscles and intrinsic muscles is the foot. However, the origin of the extrinsic muscles is in the ankle. These muscles have a wide variety of tasks in terms of posture and gait [29].



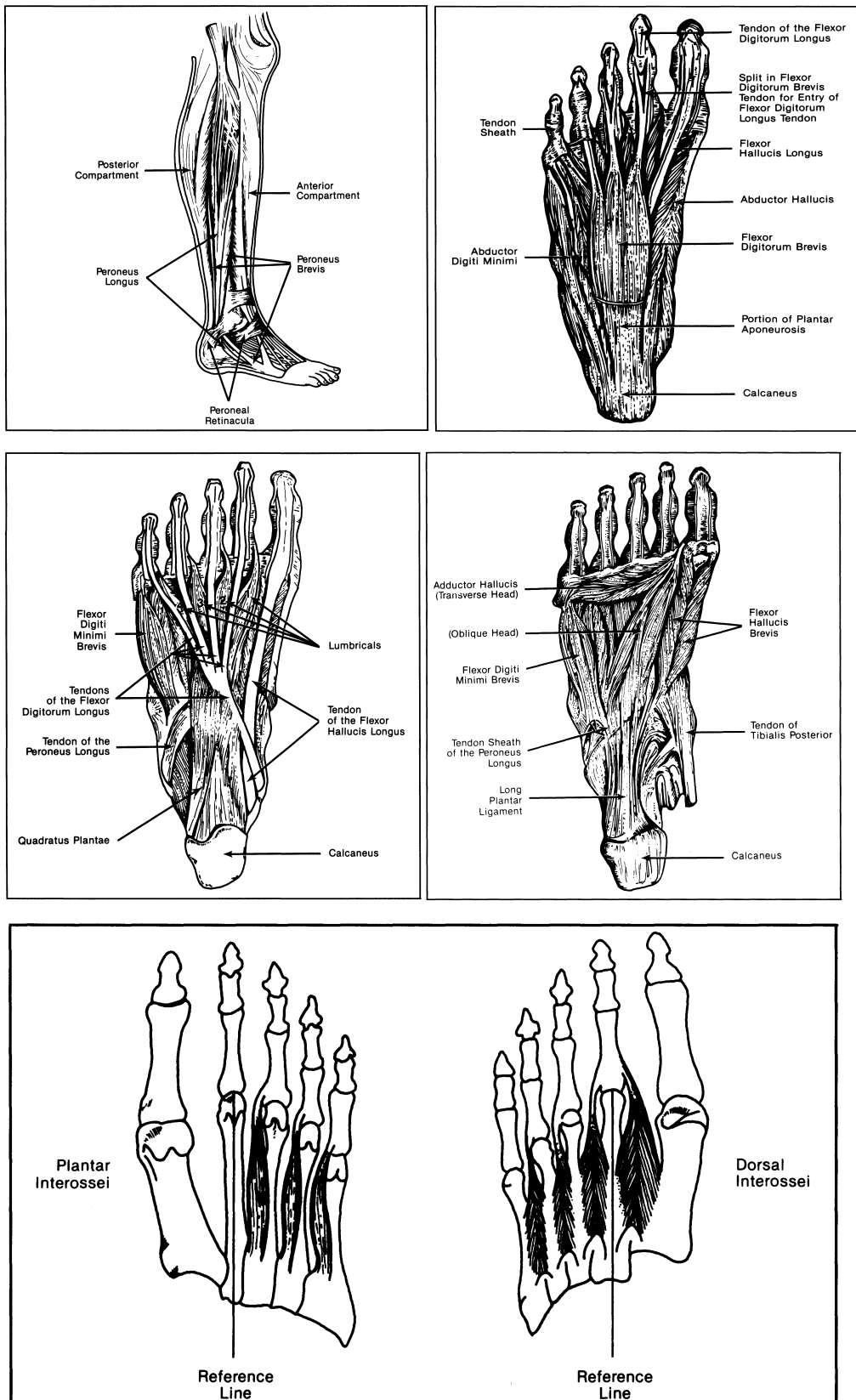


Figure 2.7. Muscles of the Ankle and Foot [30].

Table 2.1. Foot and Ankle Muscles.

• Peroneus longus
• Peroneus brevis
• Peroneus tertius
• Anterior tibialis
• Posterior tibialis
• Extensor digitorum longus
• Extensor hallucis longus
• Flexor digitorum longus (FDL)
• Flexor hallucis longus (FHL)
• Gastrocnemius
• Soleus
• Plantaris
• Extensor digitorum brevis
• Dorsal interosseus
• Extensor hallucis brevis
• Abductor hallucis
• Flexor digitorum brevis
• Abductor digiti minimi
• Quadratus plantae
• Lumbricals
• Flexor hallucis brevis

• Oblique and transverse head of adductor hallucis
• Flexor digiti minimi brevis
• Plantar interossei [23, 31]

2.1.4 Nerves of the Ankle and Foot

The nerves to the foot and ankle are divided into branches as superficial fibula, saphenous, medial plantar, deep fibula, calcaneal and sural (Table 2.2.). The saphenous nerve is formed by the branching of the femoral nerve. The area innervated by this nerve is the medial aspect of the ankle and the distal surface of the first metatarsal of the foot. The fibular nerve in the lower extremity divides into two branches, these branches are called superficial fibular and deep fibular nerves. The skin of the dorsum of the foot, dorsolateral to the 1st phalanx, dorsomedial to the 2nd phalanx, and lateral to the 5th phalanx are innervated by the superficial fibular nerve. The deep fibular nerve innervates the extensor digitorum brevis, dorsolateral skin of the first phalanx, and dorsomedial skin of the second phalanx. The tibial nerve is divided into medial and lateral plantar nerves. The abductor hallucis muscle is innervated by the medial plantar nerve deep. Besides, the medial plantar nerve and its terminal branches innervate the flexor hallucis brevis, first lumbrical, abductor hallucis, and flexor digitorum brevis. The regions where this nerve provides sensory innervation; the plantar surface of the midfoot, are the skin of the first three toes, and the fourth collar toe [32].

Abductor digiti minimi, flexor digiti minimi brevis, adductor hallucis, quadratus plantae, lateral three lumbrical, and plantar/dorsal interossei muscles are also innervated by the lateral plantar nerve. The regions where this nerve provides sensory innervation; are the lateral plantar surface of the foot, lateral to the skin of the 4th toe, and the skin of the 5th toe. The nerve that innervates the hindfoot and midfoot is called the sural nerve. This nerve branches from the tibial and fibular nerves. This nerve branches from the tibial and fibular nerves. The calcaneal nerve provides sensory innervation to the heel and is formed by branches from the tibial and sural nerves [32].

Table 2.2. Nerves, Nerve Branches, and Nerve Origins of the Foot.

• Superficial peroneal (fibular) nerve (roots from the fibular nerve)
• Deep peroneal (fibular) nerve (roots from the fibular nerve)
• Tibial nerve (part of the sciatic nerve)
• Medial plantar nerve (roots from the terminal branch of the tibial nerve)
• Digital nerves (rooted from both medial and lateral plantar nerves)
• Lateral plantar nerve (roots from the smaller terminal branch of the tibial nerve)
• Lower calcaneal nerve, also known as Baxter's nerve (typically arises as the 1 st branch of the lateral plantar nerve)
• Medial calcaneal nerve (roots from the tibial nerve)
• Sural nerve (roots from branches of the fibular and tibial nerves)
• Saphenous nerve (roots from the femoral nerve) [28]

2.1.5. Arches of the Foot

The foot, pelvis, and spine are the supporting bones that are connected. The foot provides the necessary stability to perform daily activities. This stability is created by the arches on the feet. There are three-foot arches (Figure 2.8.). These arches are called medial longitudinal arch (MLA), lateral longitudinal arch (LLA), and anterior transverse arches [33].

2.1.5.1. Medial Longitudinal Arch

The development of MLA is the first step in the evolution of gait. MLA provides sufficient mechanical advantage to the plantar flexors to support the body's weight. It also absorbs some of the increased shocks while walking [34].

Supporting the MLA are the tibialis posterior, FHL, FDL, peroneus longus, tibialis anterior, and intrinsic muscles of the foot [35]. The foot bones that make up this arch are the navicular, calcaneus, three cuneiforms, talus, and first three metatarsals [36].

2.1.5.2. Longitudinal Arch

Another arch in the foot is the Longitudinal arch. This arch is formed by the medial arch and the lateral arch. The calcaneus, two metatarsals, and cuboid bones form the lateral arch. The lateral arch is closer to the ground (3-5 millimeters) [36].

2.1.5.3. Transverse (Metatarsal) Arch

The transverse arch passes in the tarsometatarsal region of the foot. It extends from medial to lateral. proximal to the transverse arch are cuboids, three cuneiforms, and distally five metatarsals [36].

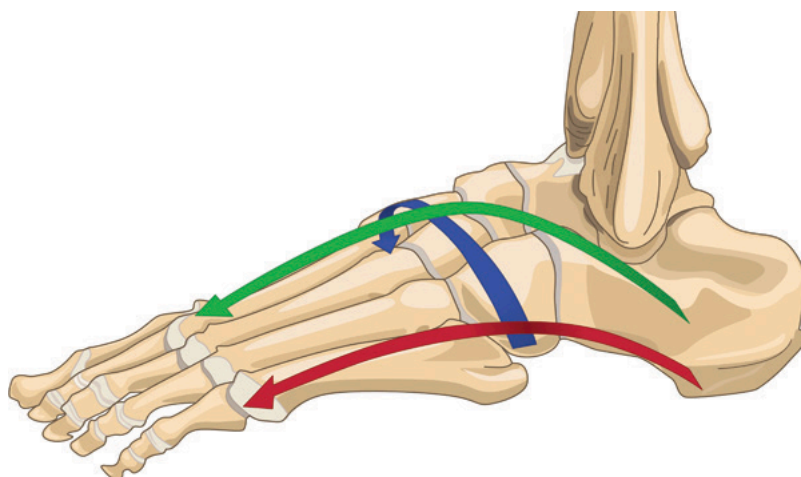


Figure 2.8. Arcs of Foot. The Red-Colored Band is the Longitudinal Lateral Arch. The Green-Colored Band is the Longitudinal Medial Arch. The Blue-Colored Band is the Transverse Arch [37].

2.2. Performance and Tennis

The duration of the tennis match is not fixed. This causes matches to take less or longer. The rally duration of tennis matches varies according to various factors such as play style, shot speed, strategic moves applied. However, a match usually takes about 1.5 hours. The tennis player uses anaerobic and aerobic energy during the match. Multiple unpredictable factors affect the player's performance in tennis. Factors affecting the complex physiological aspects of the game are the choice of shot, the strategy employed, the length of the score, the duration of the match, the weather conditions, and the unpredictability of the opponent's moves. In order to maximize the player's performance, the factors affecting performance are analyzed in detail and many critical physiological variables are incorporated into the player's training. In tennis, the player's first short bursts of energy occur at the start of the match. As the match progresses, the highest oxygen uptake occurs and the heart rate also increases [38].

Sport-specific technical skills in tennis are technical skills such as racket and ball handling, serving skills, and hitting skills. Players compete according to age categories, as performance and skills vary by age difference. The maximum age difference between players in an age category is two years [39, 40].

2.3. Anthropometry

Anthropometry is the science of measurement that determines the physical shape of the body, the dimensions of the limbs and bones relative to each other, their mass properties, and their strength capabilities. It is a measurement method that reveals the relationship between the individual parts of these dimensions. Most of the materials we use in our daily lives are designed to take into account the anthropometric values of people. For example, materials are produced in the furniture industry, road construction, sports equipment, shoes, taking into account the anthropometric results. To reach these measurements, various anthropometric instruments have been designed to evaluate the human body [30, 41, 42, 43].



Figure 2.9. Anthropometric Measuring Instruments

These measurements have been used by researchers since ancient times. Ancient Egyptian, Greek, and Roman civilizations needed anthropometric measurements for the construction of figurative works. The first measurements were made to be used for figurative art. These measurements were later used by anthropologists to describe the basic morphological characteristics of humans. The term was first written in Johann Sigismund Elsholtz's handbook on anthropometry. This handbook is known to be the oldest document investigating the human body for scientific and medical purposes [44].

The first material studied using anthropometric measurement was the human skull. These studies became popular in the 19th century and were used to separate the races. Later, anthropometric features were also used in various fields. For example, it was used for determining factors such as measuring height for men of military age. In the 19th and 20th centuries, anthropometry emerged in measurements of weight, circumference, height, and skinfold thickness used to determine environmental impacts on humans [44].

2.3.1. Foot Anthropometric Variables

There are 32 measurement values for foot anthropometry measurement (Table 2.3.).

Table 2.3. Anthropometric Variables of Foot

1) foot circumference
2) instep circumference
3) heel circumference
4) diagonal ankle circumference
5) bimalleolar circumference
6) ankle circumference
7) foot length (FL)
8) foot length: heel to tip little toe
9) fibular instep length
10) foot breadth
11) instep length
12) bimalleolar breadth
13) heel breadth
14) foot breadth, diagonal
15) first toe length
16) second toe length on of the first toe
17) second toe length on side of the third toe
18) second toe length on side of the second toe
19) second toe length on side of the fourth toe

20) third toe length on side of the fourth toe
21) fourth toe length on side of the third toe
22) fifth toe length on of the fourth toe
23) great toe-tip height
24) great toe height
25) ball height
26) dorsal arch height
27) foot height
28) spherion height
29) medial malleolar height
30) outside ball height
31) spherion fibulare height
32)lateral malleolus height [45]

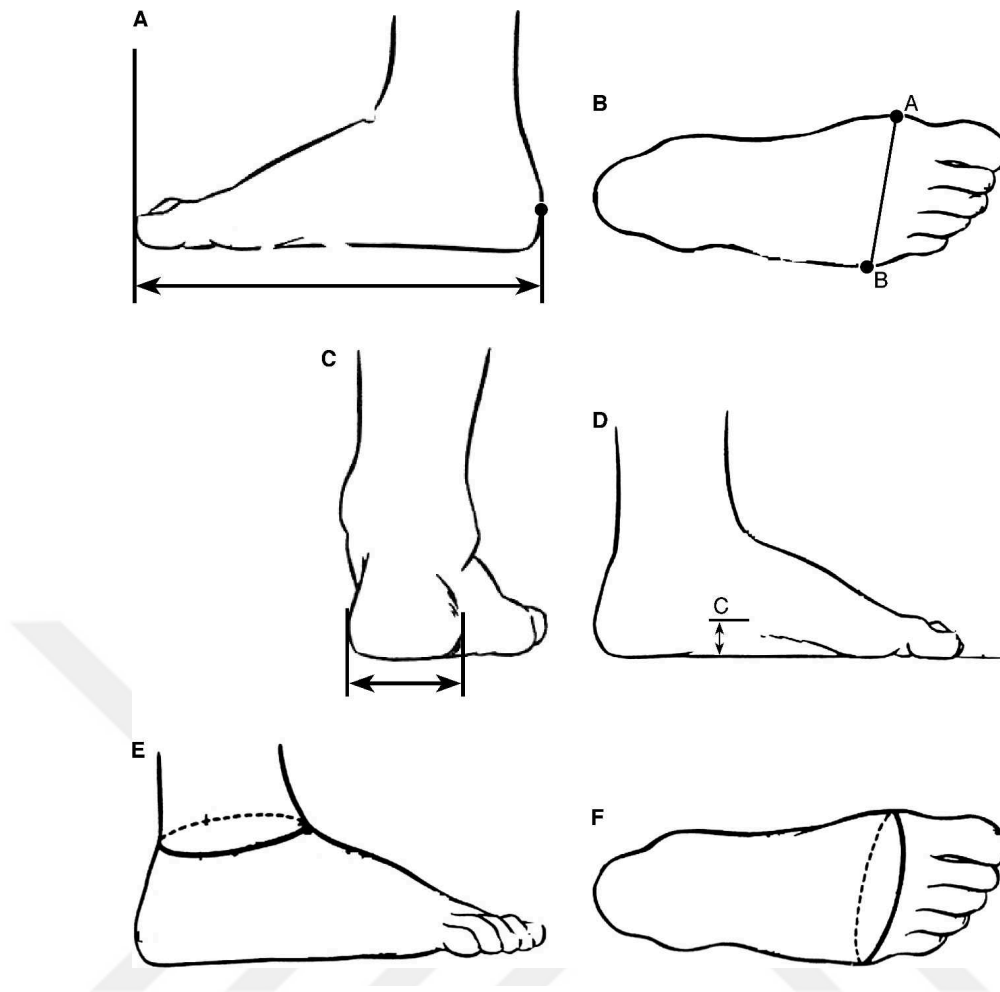


Figure 2.10. Foot Anthropometry [46]

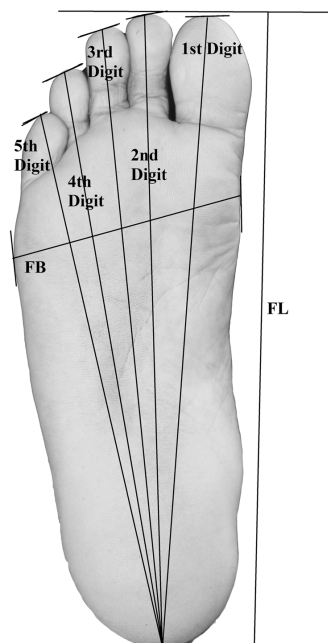


Figure 2.11. Foot Anthropometry Bottom View [47]

2.3.2. The Effect of Foot Anthropometric Variables on Performance

Human foot structure adapts to functions such as walking and running. The sole of the foot is the connection point between the ground and the body. The area of this contact surface and the effect size of the player when pushing the ground while walking or running changes. Runners have longer toes and shorter Achilles tendons. A short Achilles tendon means shortening of the moment arm. This allows the person to increase his thrust with the force he gets from the ground while running. Another example is that people with longer heels create better moments during maximum height jumps [48].

2.4. Tennis

The tennis court is rectangular. The length of the tennis court is 23.77m and its width is 10.97m. The width for the singles competition is 8.23m. There are two 1.07m high poles on the sides of the middle point of the court. there is a steel wire or a net between the poles. The net must fill between the posts and the ball must not pass through the net. The middle height of the net is 0.914m. The lengths of the tennis court are shown in figure 2.12.. The net should be closed with a steel wire band. The band on the net is completely white. The diameter of the steel wire or cord is not more than 0.8 cm in thickness. The width of the middle band is a maximum of 5 cm. The width of the tape is minimum 5 cm and maximum 35 cm from both sides of the steel wire. In tennis, the force emerges by transferring the push from the ground to the racket. In tennis, as in many sports, the force is transferred to the extremity of the player by the body chain. This force, taken from the ground, is transferred to the ankle, lower extremity, trunk, and tennis racket. In tennis, scoring is on average 10 seconds or less. Players use both anaerobic and aerobic energy systems in a tennis match A test method has been determined by the international tennis federation in order to determine the game levels of tennis players. An international tennis number suitable for all levels of players, from professional to amateur, these numbers are ITN 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 10.1, 10.2 and 10.3. [49, 50, 51].

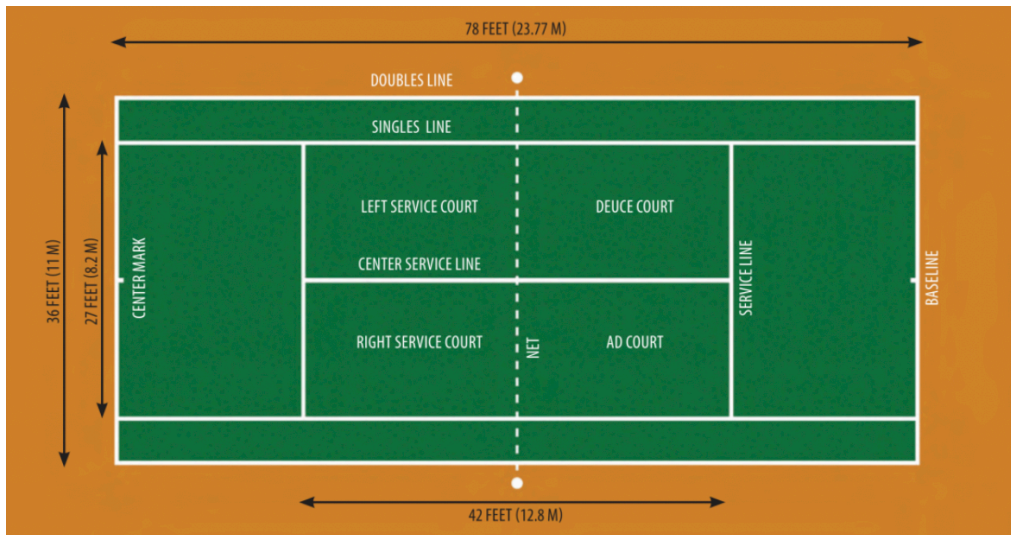


Figure 2.12. Tennis Court [52]

2.5. Performance

Performance is defined as the sum of the efforts put forward to successfully perform a sport that needs to be done [53]. Performance has an important place in the life of the players. It is necessary for the player to get the right feedback in order to improve his performance. Performance analysis is important in evaluating performance. With performance analysis, the needs of the player are determined, weaknesses and strengths in performance are determined [54].

Sports performance emerges as a result of many factors that are interconnected in various ways. These factors enable performance to be determined in different ways that can be distinguished quantitatively, qualitatively and temporally. In order to analyze these factors, the player is evaluated with more than one aspect and variable. Although quantitative and qualitative factors are interdependent, there is a difference between measurement and evaluation. After the evaluations are made, the results are analyzed and the weaknesses and strengths of the player are determined [55].

2.5.1. Agility

Agility is an important performance component required for team athletes. It is defined as the rapid change of direction of the athlete with his whole body [56].

2.5.2. Balance

Balance performance affects the competitiveness of the players. There are two kinds of balance;

- Dynamic balance
- Static balance

These two balances are effective in providing postural control of the player during his activity [57].

2.5.3. Strength

Force is one of the motoric properties. Strength is defined as the ability to withstand and withstand a resistance [58].

3. MATERIAL AND METHOD

3.1. Subjects

The sample of the research consists of 9-16 age group tennis players of the optimum tennis academy in Istanbul, which has the adolescent age group who can train regularly.

Demographic form was distributed to 113 adolescent tennis players who play tennis actively in optimum tennis academy. As a result of the forms, 65 tennis players had inclusion criteria. 48 adolescent tennis players participated in our study. Participants included in the study are ITN 6 level and ITN 7 level players according to ITN. These participants can keep the ball in the playing field in medium hard games, establish coordination between the court and their partner and make successful defense.

3.1.1. Inclusion Criteria

- Being voluntary to participate to the study
- Being between 9 and 13 years old
- Not having a lower extremity injuries in the last six months
- Not having a cardiovascular health problem
- Not doing any heavy physical activity in the 24 hours before the study.
- Not have undergone any surgery to affect the foot and musculoskeletal system.

3.1.2. Exclusion Criteria

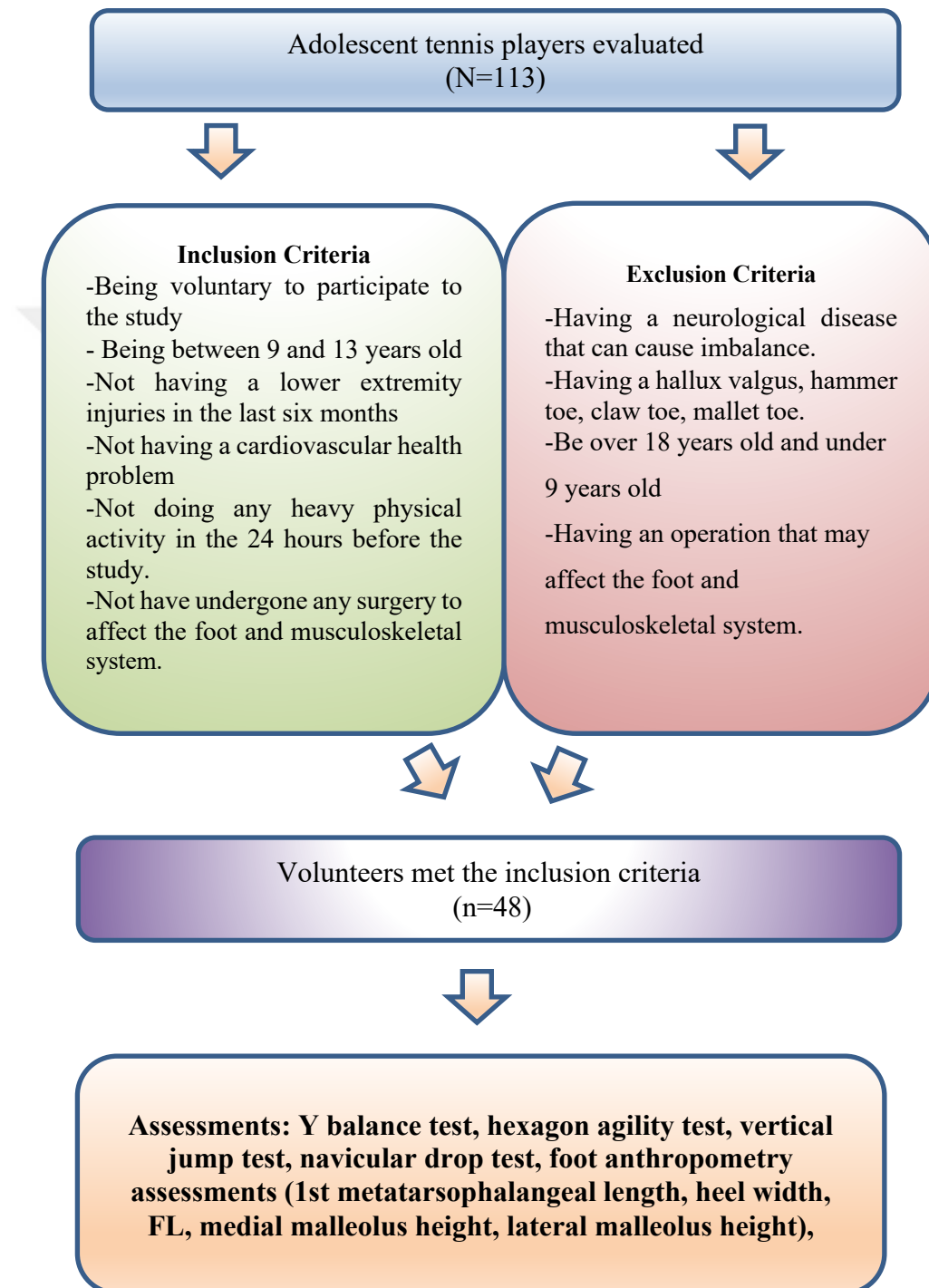
- Having a neurological disease that can cause imbalance.
- Having a hallux valgus, hammer toe, claw toe, mallet toe
- Being over 18 years old and under 9 years old
- Having an operation that may affect the foot and musculoskeletal system.

3.1.3. Flow Chart: Study Process

The families of the young tennis players we could include in our study were first talked to and their family permissions were obtained. Appropriate participants were determined by filling out the demographic form together with the families and tennis players who gave permission. A total of 65 players were eligible to participate in the study. Three players left while the study was in progress because they were participating in the tournament. Six players were injured in the tournament. The families of the five

actors withdrew their children from participating in the research. Three players became covit during the study and could not participate.48 tennis players were able to participate in our study. It is shown table 3.1.

Table 3.1. Flow Chart of Study



3.1.4. Study Protocol

Participants were included in the study voluntarily. Informed parental consent form/informed voluntary consent form was obtained in writing and signed by each participant. The purpose of the study and how it would be implemented were explained to the participants and their parents. The study was conducted with adolescent tennis players. In Optimum Tennis Academy, firstly, the medial malleolus height, foot width, foot length, 1st metatarsophalangeal length, lateral malleolus height, and heel width of the right and left feet were measured. Digital caliper and tape measure were used for measurements. After the measurements were completed, the participants were called for performance tests. Y balance test, vertical jump test, hexagonal agility test and navicular drop test were applied to the participants and the results were recorded.

3.2. Evaluation

3.2.1. Structured Questionnaire

The questionnaire prepared by the researchers was answered together by the participants and their families. In the first part of the questionnaire, to understand the socio-demographic status of the volunteers, they were asked about their age, gender, education level, height, weight, and whether they lived with their family or in the dormitory. The second part of the questionnaire includes questions such as exercise behaviors, drug use, whether they have chronic diseases, whether they have been injured within six months, training times, and how long they have been playing tennis (Appendix 3).

3.2.2. Y Balance

Y balance test enables us to evaluate the dynamic balance in three directions. These three directions are anterior, posteromedial, and posterolateral (Figure 3.1.). The purpose of this test is to evaluate the neuromuscular control and balance of the individual's lower extremity. If an asymmetry greater than 4 cm is revealed as a result of the test applied, the probability of lower extremity injury is 2.5 times higher than those with less asymmetry. A strip is drawn on the floor in three directions (posterolateral, anterior and posteromedial). The athlete stands on one foot at the midpoint of the strips and extends his free foot over these strips (Figure 3.2.). The player repeats this practice once. The test

is canceled and repeated if the player is unable to maintain a one-sided stance, supports the ground with his moving foot, touches his legs, or fails [59]. The reliability of this test is ICC 0.99-1.0 for test-retest reliability in the evaluation of right-left lower extremities. Intermediate measurement ICC 0.85-0.91, 95% CI 0.62-0.96. The reliability of the test in the six- to a twelve-year-old group is ICC > 0.995 [60].

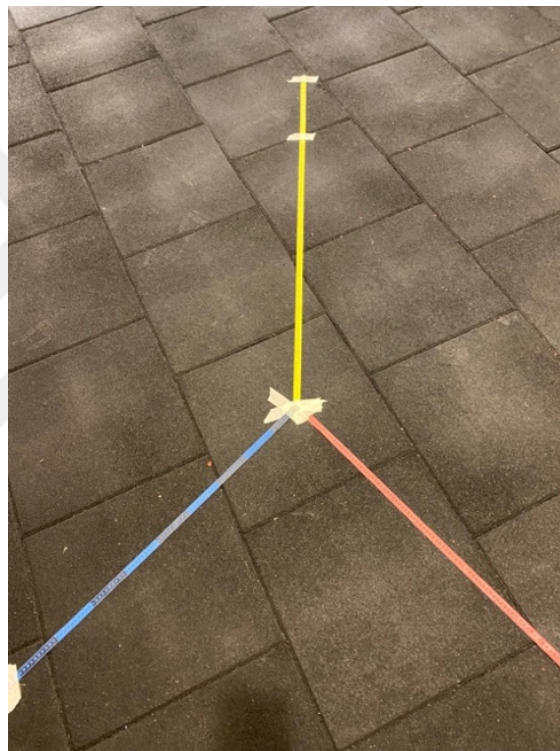


Figure 3.1. Y Balance Test



Figure 3.2. Practical Demonstration of the Y-Balance Test.

3.2.3. Hexagon Agility Test

The hexagon test is a method used to measure a player's agility. The test is performed on a hexagonal floor with a corner angle of 120° and 60.5 cm on each side. The player stands in the middle of this floor (Figure 3.3.). When the player is ready, he starts the test with the start command and the stopwatch starts running. With the start command, the player jumps from the middle of the hexagon out of each corner and returns to the center. The player continues his movement until he turns clockwise 3 times and returns to the center. When it returns to the center, the stopwatch is stopped. If the player cannot jump to each line or has to repeat the experiment, the test is canceled. The hexagon test is a measure of agility routinely used in sports rehabilitation centers. The results of this study show excellent test-retest reliability for both the same-day intraclass correlation coefficient (ICC) model 3.1 = 0.938 and inter-day ICC (3.1) = 0.924 [61].



Figure 3.3. Hexagon Test

3.2.4. Vertical Jump Test

The vertical jump test is a method used to evaluate lower extremity performance (strength) [62]. Before starting the test, the player does a 10-minute warm-up exercise. The player stands on a platform on both legs. The player's right fingers are marked with chalk. Then it jumps vertically with both upper and lower limbs free. He marks the highest point by touching the wall with his fingertips (Figure 3.4.). Three jumps are made and the highest jump is recorded. Waits at least 45 seconds between jumps [63]. The jump test has high intra-class correlation coefficients (0.969-0.995) and low coefficients of variation (1.54-4.82%), ($r = 0.580-0.983$) [64].

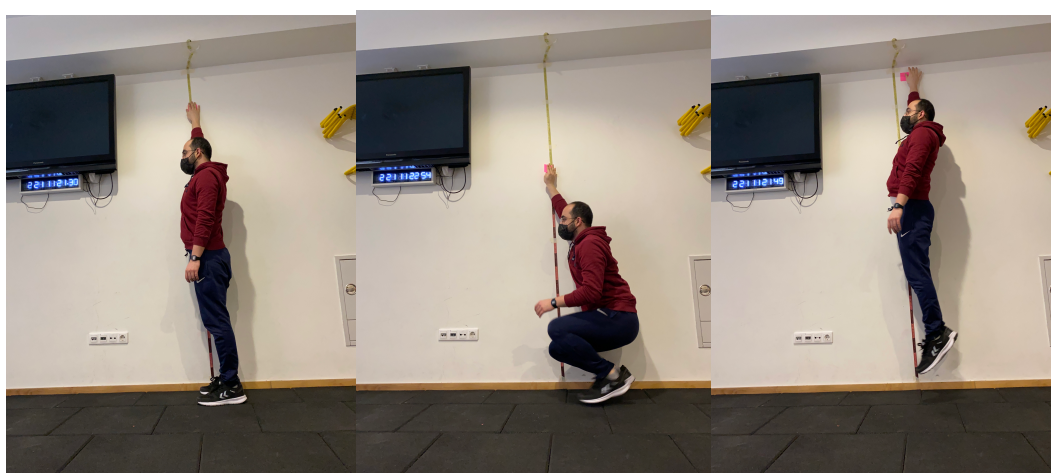


Figure 3.4. Practical Demonstration of the Vertical Jump Test.

3.2.5. Navicular Drop Test

The navicular drop test is a method used to determine the flexibility of the medial longitudinal arch. The player stands with all his weight on his lower extremities. The prominent part of the navicular tuberosity is marked on the foot. The height of the marked point from the ground is measured with the help of a ruler. The player is told to rest and is seated in a chair. After the player sits down, the height of the marked area from the ground is measured again with the help of a ruler. The difference between the standing and sitting measurements gives the result of the navicular drop test. The reliability of this test is ICC = 0.98. The sensitivity and specificity of the navicular drop test were 88.1% and 99.5%, respectively [65].



Figure 3.5. Navicular Drop Test

3.2.6. Foot Anthropometric Values Measurement

Six anthropometric values were recorded for each of the players' right and left feet. The player was placed on the examination table. Heel width (HW) was measured with a digital caliper (Figure 3.6.). A platform with a tape measure was used to measure other values. The player stands on the platform with bare feet, rests his heel on the back of the platform. The midpoint of the medial malleolus and the lateral malleolus was marked with a pencil. The medial malleolus height (MML) and the lateral malleolus height (LMH) from the ground was measured with the help of a ruler. The distal point of the 2nd toe was marked on the platform as the midline of the foot. The distance between the heel and this point was recorded as the foot length (FL). The bone was palpated to

measure the length of the first metatarsophalangeal bone. The distal and proximal of the bone were marked and the distance between them was measured with a ruler. The distance was recorded as the first metatarsophalangeal bone length (1st.ML). The medial of the distal 1st metatarsophalangeal bone was marked on the platform, and the lateral of the distal 5th metatarsophalangeal bone was marked. The distance between them was recorded as foot width (FW). ICC values for intra-rater reliability ranged from 0.33 to 0.62 across two different measurement sessions, and inter-rater reliability ranged from 0.54 to 0.76 [66].



Figure 3.6. Foot Anthropometric Measurements

3.3 Data Analysis

Power analysis G*Power 3.1 program was used to determine the sample size. In our study, $\alpha=0.05$ significance order and $d=0.15$ margin of error were taken into consideration. It was evaluated at the 95% confidence interval. It was determined that the number of participants should be 43 or more. In our study, the Shapiro-Wilk test was used to test whether the continuous variables fit the normal distribution.

Descriptive statistics for variables were expressed as mean $\pm$ standard deviation, and descriptive statistics for categorical variables were expressed as n(%). Evaluations between anthropometric and performance tests Spearman correlation test was applied. Mann-Whitney U test was used to make independent comparisons between groups. SPSS (Statistical Package for Social Sciences, windows, version 21.0.Armonk) program was used for statistical analysis of the data. The significance level was accepted as $p<0.05$.

4. RESULTS

Forty-eight young tennis players who have been regularly trained in Optimum Tennis Academy for at least one year were included in the study.

The physical characteristics of the players (age, weight, height, and body mass index (BMI)) are presented in Table 4.1.

Table 4.1. Physical Features of Participants

Variable(n=48)	Male(n=19)		Female(n=29)	
	mean±SD	t p value	mean±SD	t p value
Age(year)	10,57±1,952	t=-1,397 0,169	11,31±1,649	t=-1,348 0,187
Height(m)	1,47±0,123	t=-1,088 0,282	1,51±0,113	t=-1,069 0,292
Weight(kg)	39,89±11,488	t=-0,829 0,411	42,21±7,909	t=-0,769 0,448
BMI (kg/m ²)	17,97±2,978	t=-0,341 0,735	18,19±1,571	t=-0,302 0,765

Data expressed as mean ± standard deviation. SD: Standard deviation, BMI: Body mass index, n: number of participants, m: metre, kg: kilogram.

While 39.6%(n=19) of the participants were boys, 60,4%(n=29) were girls (Table 4.2.).

Table 4.2. Descriptive Findings of the Participants

		n	%
Gender	Male	19	39,6
	Female	19	60,4
Training Frequency (Weekly)	2-3 Times a Week	17	35,4
	4-5 Times a Week	29	60,4
	Every Day	2	4,2
Duration of Training (Minutes)	30-60 Minutes	7	14,6
	>60 Minutes	41	85,4
Dominant Side	Right	48	100

n: number of participants,, %: percentage

Mann-Whitney U test was performed to compare the performances of girls and boys in terms of applied tests. There is no statistical significance between girls and boys (Table 4.3.).

Table 4.3. Comparison of Dynamic Balance, Agility, and Vertical Jump According to Gender.

		Male (mean±SD)	Female (mean±SD)	z p value
Y Balance Score %	Right	92,70±10,622	95,13±6,559	z=-0,98 0,327
	Left	93,50±11,032	96,73±6,991	z=-1,212 0,225
Vertical Jump Test (cm)	Reached Height	187,11±24,676	193,55±15,487	z=-1,086 0,278
	After Jumping	217,18±26,571	217,73±15,894	z=-0,928

				0,354
	Difference Between Reaching and Jumping	30,05±22,234	24,18±8,128	z=-0,485 0,628
Hexagon Agility Test (seconds)	Clockwise	11,67±1,915	12,21±2,281	z=-0,854 0,393
	Counterclockwise	11,74±2,015	12,64±2,789	z=-0,843 0,399

Data expressed as mean ± standard deviation. SD: Standard deviation,

Mann-Whitney U test was used to compare the navicular drop test results of girls and boys. According to the results of this test, there is no difference between boys and girls (Table 4.4.).

Table 4.4. Comparison of Navicular Drop Test According to Gender.

		Male (mean±SD)	Female (mean±SD)	z p value
Navicular Drop (cm)	Right	0,65±0,259	0,56±0,400	z=-1,092 0,275
	Left	0,66±0,306	0,58±0,302	z=-0,968 0,333

Data expressed as mean ± standard deviation. SD: Standard deviation,

Mann-Whitney U test was performed to compare girls and boys in terms of anthropometric values. According to the result of this test, lower leg length was found to be different between girls and boys ($p<0.05$) (Table 4.5.).

Table 4.5. Comparison of Anthropometric Values for Male and Female

		Male (mean±SD)	Female (mean±SD)	z p value
1st ML (cm)	Right	7,07±1,008	7,14±0,969	z=-0,254 0,800
	Left	7,07±1,008	7,15±0,966	z=-0,275 0,783
HW (cm)	Right	4,34±0,490	4,34±0,425	z=-0,127 0,899
	Left	4,30±0,493	4,33±0,425	z=-0,232 0,817
FL (cm)	Right	22,25±1,494	22,16±1,671	z=-0,169 0,866
	Left	22,03±1,407	22,15±1,575	z=-0,411 0,681
FW (cm)	Right	8,97±1,013	8,93±0,622	z=-0,128 0,899
	Left	9,02±0,955	8,89±0,602	z=-0,328 0,743
MMH (cm)	Right	7,31±0,809	9,79±13,707	z=-0,328 0,743
	Left	7,07±0,907	7,18±0,632	z=-0,697 0,486
LMH (cm)	Right	6,48±0,947	6,44±0,538	z=-0,127 0,899
	Left	6,26±0,817	6,45±0,599	z=-0,994 0,320
LL (cm)	Right	70,48±8,687	74,57±7,068	z=-2,225 0,026
LLL (cm)	Right	37,42±5,011	38,05±3,595	z=-0,886 0,376

Data expressed as mean $\pm$ standard deviation. SD: Standard deviation, 1st ML: 1st metatarsophalangeal length, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height, LL: Leg length, LLL: Lower Leg Length

Mann-Whitney U test was applied to compare the anthropometric values of the right and left foot in adolescent tennis players. According to this test result, no statistically significant difference was found between the right and left foot in anthropometric values (Table 4.6.).

Table 4.6. Comparison of Anthropometric Values for Right and Left Foot

	Right (mean$\pm$SD)	Left (mean$\pm$SD)	z p value
1st ML (cm)	7,11 $\pm$ 0,975	7,12 $\pm$ 0,973	z=-0,033 0,974
HW (cm)	4,34 $\pm$ 0,447	4,31 $\pm$ 0,448	z=-0,407 0,684
FL (cm)	22,19 $\pm$ 1,588	22,10 $\pm$ 1,496	z=-0,257 0,797
FW (cm)	8,95 $\pm$ 0,790	8,94 $\pm$ 0,755	z=-0,103 0,918
MMH (cm)	8,81 $\pm$ 10,662	7,14 $\pm$ 0,745	z=-1,075 0,282
LMH (cm)	6,46 $\pm$ 0,718	6,38 $\pm$ 0,692	z=-0,393 0,694

Data expressed as mean $\pm$ standard deviation. SD: Standard deviation, 1st ML: 1st metatarsophalangeal length, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height

Mann-Whitney U test was performed to compare the navicular and y balance tests concerning the right foot and left foot. According to the results of this test, there was no statistically significant difference between the right and left foot of the Navicular and y balance tests (Table 4.7.).

Table 4.7. Comparison of Navicular Drop Test and Y Balance Test for Right and Left Foot

	Right (mean±SD)	Left (mean±SD)	z p value
Navicular Drop (cm)	0,60±0,350	0,61±0,303	z=-0,159 0,874
Y Balance Score %	94,17±8,383	95,45±8,847	z=-0,740 0,459

Data expressed as mean ± standard deviation. SD: Standard deviation,

Spearman correlation test was performed to compare the relationship between the navicular test and performance tests in boys and girls. According to the results of this test, there is no statistically significant relationship between the navicular test and performance tests in men. As the navicular drop test height decreases (as the lateral arch height decreases) in girls, the height reached and jump height decrease as the value increases (Table 4.8.).

Table 4.8. Comparison of Navicular Drop Test and Performance Parameters for Gender

			Navicular Drop Test			
			Male		Female	
			Right	Left	Right	Left
Hexagon Agility Test	Counterclockwise	r	0,136	-0,273	0,253	-0,052
		p	0,578	0,259	0,185	0,788
	Clockwise	r	0,072	-0,308	0,336	0,039
		p	0,769	0,199	0,075	0,842
Y Balance Score %	Right	r	-0,019		-0,114	
		p	0,939		0,555	
	Left	r		0,111		-0,173
		p		0,651		0,368
Vertical Jump	Standing Reached Height	r	-0,194	-0,290	-0,560	-0,487
		p	0,426	0,229	0,002	0,007
	Reached After Jumping	r	-0,190	-0,247	-0,581	-0,342
		p	0,437	0,308	0,001	0,069

Spearman correlation test was performed to evaluate the relationship between right foot anthropometric values and y balance performance parameter. According to the results of this test, there is no statistically significant relationship between right foot length, medial and lateral malleolar heights, heel width and y balance. The relationship between these parameters is weak correlation. However, there is a statistically significant relationship between right foot width and y balance ($p=0.002$) ($r=-0.435$), and between right 1st metatarsophalangeal length and y balance ($r=-0.510$) ($p<0.001$). There is a moderate correlation (Table 4.9.).

Table 4.9. Correlation Analysis Between Right Foot and Y Balance

Right Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	Y Balance Score (%)
1st ML (cm)	r	1						
	p							
HW (cm)	r	0,260	1					
	p	0,075						
FL (cm)	r	0,157	0,533	1				
	p	0,286	<0,001					
FW (cm)	r	0,416	0,406	0,561	1			
	p	0,003	0,004	<0,001				
MMH (cm)	r	0,255	0,173	0,185	0,157	1		
	p	0,080	0,240	0,207	0,286			
LMH (cm)	r	0,064	0,352	0,468	0,382	0,048	1	
	p	0,665	0,014	0,001	0,007	0,744		
Y Balance Score (%)	r	-0,510	-0,107	-0,089	-0,435	0,018	0,021	1
	p	<0,001	0,471	0,546	0,002	0,901	0,886	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height

Spearman correlation test was used to evaluate the relationship between right foot anthropometric values and vertical jump performance parameter. According to the results of the analysis, there is a statistically significant relationship between foot length($p<0.001$) (strong correlation), heel width($p<0.05$)(moderate correlation), foot width($p<0.05$)(moderate correlation), medial and lateral malleolus high, ($p<0.001$)(moderate correlation) and the height reached while standing and the height reached during vertical jump (Table 4.10).

Table 4.10. Correlation Analysis Between Right Foot and Vertical Jump

Right Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	VJ (Standing) (cm)	VJ (Jumping) (cm)	VJ (Score) (cm)
1st ML (cm)	r	1								
	p									
HW (cm)	r	0,260	1							
	p	0,075								
FL (cm)	r	0,157	0,533	1						
	p	0,286	<0,001							
FW (cm)	r	0,416	0,406	0,561	1					
	p	0,003	0,004	<0,001						
MMH (cm)	r	0,255	0,173	0,185	0,157	1				
	p	0,080	0,240	0,207	0,286					
LMH (cm)	r	0,064	0,352	0,468	0,382	0,048	1			
	p	0,665	0,014	0,001	0,007	0,744				
VJ (Standing) (cm)	r	0,176	0,484	0,788	0,505	0,596	0,553	1		
	p	0,233	<0,001	<0,001	<0,001	<0,001	<0,001			
VJ (Jumping) (cm)	r	0,211	0,318	0,699	0,436	0,605	0,464	0,707	1	
	p	0,150	0,027	<0,001	0,002	<0,001	<0,001	<0,001		
VJ (Score) (cm)	r	0,206	-0,095	0,163	0,127	0,251	0,058	-0,335	0,429	1
	p	0,161	0,520	0,270	0,388	0,086	0,696	0,02	0,002	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height, VJ: Vertical jump

Spearman correlation test was used to evaluate the relationship between right foot anthropometric values and hexagon agility performance parameter. According to the results of this test, there is a negative correlation between the length of the right foot and the clockwise result of the hexagonal agility test ($r=-0.322$; $p=0.026$) (weak correlation)(Table 4.11.).

Table 4.11. Correlation Analysis Between Right Foot and Hexagon Agility, Navicular Drop

Right Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	HA (clockwise) (seconds)	HA (counter clockwise) (seconds)	ND
1st ML (cm)	r	1								
	p									
HW (cm)	r	0,260	1							
	p	0,075								
FL (cm)	r	0,157	0,533	1						
	p	0,286	<0,001							
FW (cm)	r	0,416	0,406	0,561	1					
	p	0,003	0,004	<0,001						
MMH (cm)	r	0,255	0,173	0,185	0,157	1				
	p	0,080	0,240	0,207	0,286					
LMH (cm)	r	0,064	0,352	0,468	0,382	0,048	1			
	p	0,665	0,014	0,001	0,007	0,744				
HA (clockwise) (seconds)	r	0,048	-0,177	-0,322	-0,127	-0,248	-0,111	1		
	p	0,747	0,229	0,026	0,389	0,089	0,453			
HA (counter clockwise) (seconds)	r	0,104	-0,061	-0,208	-0,015	-0,266	-0,032	0,814	1	
	p	0,480	0,678	0,156	0,921	0,067	0,830	<0,001		
ND	r	0,041	-0,088	-0,413	-0,132	-0,239	-0,259	0,232	0,176	1
	p	0,780	0,552	0,004	0,369	0,102	0,075	0,113	0,231	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height, HA: Hexagon agility, ND: Navicular drop

Spearman correlation test was performed to evaluate the relationship between left foot anthropometric values and y balance performance parameter. There is no statistically significant relationship between left foot anthropometric values and y balance. The relationship between these parameters is weak correlation (Table 4.12).

Table 4.12. Correlation Analysis Between Left Foot and Y Balance

Left Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	Y Balance Score (%)
1st ML (cm)	r	1						
	p							
HW (cm)	r	0,222	1					
	p	0,129						
FL (cm)	r	0,154	0,483	1				
	p	0,296	0,001					
FW (cm)	r	0,478	0,365	0,498	1			
	p	0,001	0,011	<0,001				
MMH (cm)	r	-0,042	0,248	0,296	0,225	1		
	p	0,779	0,089	0,041	0,124			
LMH (cm)	r	-0,018	0,288	0,243	0,331	0,449	1	
	p	0,906	0,047	0,096	0,021	0,001		
Y Balance Score (%)	r	-0,269	0,076	0,028	-0,269	0,117	0,148	1
	p	0,063	0,606	0,849	0,064	0,428	0,315	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height

Spearman correlation test was used to evaluate the relationship between left foot anthropometric values and vertical jump performance parameter. According to the results of the analysis, there is a statistically significant relationship between heel width($p<0.05$) (moderate correlation), foot width($p<0.05$) (moderate correlation), medial and lateral malleolus height($p<0.001$) (moderate correlation), and the height reached while standing and the height reached during vertical jump (Table 4.13.).

Table 4.13. Correlation Analysis Between Left Foot and Vertical Jump

Left Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	VJ (Standing) (cm)	VJ (Jumping) (cm)	VJ (Score) (cm)
1st ML (cm)	r	1								
	p									
HW (cm)	r	0,222	1							
	p	0,129								
FL (cm)	r	0,154	0,483	1						
	p	0,296	0,001							
FW (cm)	r	0,478	0,365	0,498	1					
	p	0,001	0,011	<0,001						
MMH (cm)	r	-0,042	0,248	0,296	0,225	1				
	p	0,779	0,089	0,041	0,124					
LMH (cm)	r	-0,018	0,288	0,243	0,331	0,449	1			
	p	0,906	0,047	0,096	0,021	0,001				
VJ (Standing) (cm)	r	0,165	0,450	0,704	0,541	0,586	0,558	1		
	p	0,261	<0,001	<0,001	<0,001	<0,001	<0,001			
VJ (Jumping) (cm)	r	0,199	0,307	0,606	0,454	0,624	0,542	0,707	1	
	p	0,175	0,034	<0,001	0,001	<0,001	<0,001	<0,001		
VJ (Score) (cm)	r	0,201	-0,052	0,051	0,113	0,247	0,115	-0,335	0,429	1
	p	0,170	0,723	0,729	0,445	0,091	0,436	0,020	0,002	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot lenght, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height, VJ: Vertical jump,

Spearman correlation test was used to evaluate the relationship between left foot anthropometric values and hexagon agility performance parameter. There was a negative correlation between left foot length and clockwise hexagonal agility test ($r=-0.357$; $p=0.013$) (weak correlation). There was a statistically significant correlation between left medial height and clockwise hexagonal test and counterclockwise hexagonal test results ($p<0.05$) (medium correlation). In addition, there was a statistically significant correlation between left medial and lateral malleolar heights and navicular drop test ($p<0.05$) (weak correlation)(Table 4.14.).

Table 4.14. Correlation Analysis Between Left Foot and Hexagon Agility , Navicular Drop

Left Foot		1st ML (cm)	HW (cm)	FL (cm)	FW (cm)	MMH (cm)	LMH (cm)	HA (clockwise) (seconds)	HA (counter clockwise) (seconds)	ND
1st ML (cm)	r	1								
	p									
HW (cm)	r	0,222	1							
	p	0,129								
FL (cm)	r	0,154	0,483	1						
	p	0,296	0,001							
FW (cm)	r	0,478	0,365	0,498	1					
	p	0,001	0,011	<0,001						
MMH (cm)	r	-0,042	0,248	0,296	0,225	1				
	p	0,779	0,089	0,041	0,124					
LMH (cm)	r	-0,018	0,288	0,243	0,331	0,449	1			
	p	0,906	0,047	0,096	0,021	0,001				
HA (clockwise) (seconds)	r	0,052	-0,130	-0,357	-0,123	-0,422	-0,091	1		
	p	0,725	0,377	0,013	0,406	0,003	0,540			
HA (counter clockwise) (seconds)	r	0,107	-0,039	-0,224	0,019	-0,366	-0,094	0,814	1	
	p	0,469	0,795	0,126	0,895	0,010	0,524	<0,001		
ND	r	0,092	-0,037	-0,121	-0,173	-0,286	-0,372	-0,122	-0,183	1
	p	0,533	0,80	0,414	0,239	0,048	0,009	0,409	0,213	

1st ML: 1st metatarsophalangeal length, cm: centimeter, HW: Heel width, FL: Foot length, FW: Foot width, MMH: Medial malleolar height, LMH: Lateral malleolar height, HA: Hexagon agility, ND: Navicular drop

5. DISCUSSION

In this study, the relationship between the anthropometric values of the feet of professional adolescent tennis players and their performance parameters was investigated. While there are more studies in the literature on tennis players' hitting techniques, upper extremity structure and strength, studies on feet and lower extremities are limited. In addition, there was no study investigating the relationship between lower extremity anthropometric values and performance in tennis players. A very limited number of studies have been carried out, especially in adolescent tennis players. When the foot anthropometric values were examined in line with our evaluations and statistical results, significant relationships were found between foot width, foot length, foot 1st metatarsophalangeal length, heel width, medial and lateral malleolus height and vertical jump test/ y balance test/ hexagonal agility test. As a result, we found that foot anthropometric values affect the performance of adolescent tennis players. While doing this research, we first measured the foot sizes of adolescent tennis players with a tape measure and caliper. Then we evaluated the players with the performance criteria used in tennis. We think that our hypothesis is correct as we obtained statistically significant results in line with the results we obtained.

Fatima H. et al., as a result of their study, revealed the anthropometric variables that most affect human balance. These variables were listed as leg length, navicular bone and MLA[67]. In another study, Seda S. et al. evaluated the effects of body parameters and foot anthropometric variables on balance. They included 112 men aged 18-25 years in the study. They investigated how dynamic and static balance was affected by heel width, foot height, foot length, medial malleolus height, foot width, lateral malleolus height, metatarsophalangeal height and navicular height. Measurements were made with a digital caliper. As a result of their research, they found a relationship between foot length, metatarsophalangeal height, body size and balance performance[68]. Pirio K. et al. recruited 50 men and 50 women aged between 31 and 80 in their study. They examined the relationship between volunteers' postural balance and body movements and anthropometric variables. As a result of their research, they found that there is a relationship between foot length and balance, knee height and balance, hip height and balance, and body height and balance in men. They found that there was a significant

relationship between foot width and balance in women. They stated that the possible effects of anthropometry should be taken into account in balance studies.[69] Gönül B.I. investigated how foot size and foot posture are related to balance. He selected the volunteers as healthy undergraduate students. 113 people were included in the study. In his research, he used foot measures, static and dynamic balance measures and foot posture index. The results of the study revealed a weak but positive relationship between heel width and static balance. He revealed that there is a negative relationship between foot length and dynamic balance. It has been observed that as the foot length of the individual increases, the dynamic balance decreases. According to the results of this study, Gönül BI showed that early diagnosis of foot posture problems can reduce injuries that can occur both in daily and sports activities [70]. When we look at the literature, we could not find any study investigating the relationship between foot anthropometric values and balance in tennis players. When we examined the relationship between foot length-heel width-lateral and medial malleolus height and y-balance in 46 volunteers participating in our study, we could not find a statistically significant difference. However, we found a negative correlation between foot width ($p=0.002$), 1st metatarsophalangeal length ($p<0.001$) and y balance test (table 4.9.). As a result of our evaluations, we can say that the dynamic balance of the player increases as the foot width-metatarsophalangeal length decreases. We think that it is important to choose the shoes used in daily life and shoes used in sports in these children whose bone growth is not completed. We emphasize that the shoes should be suitable for the size of the child's foot. In addition, we can loosen the plantar fascia with myofascial relaxation methods in order to increase the balance of athletes with wide soles. we can relax the plantar fascia with myofascial relaxation on Players who have the large foot width, for increase the balance

Robert U. N. et al., as a result of their research, found that the amount of force produced by the lower extremity muscle fibers was directly proportional to the participant's jump height. The vertical jump test is a widely used field test that enables the evaluation of lower extremity strength performance in athletes. This test also provides information about the anaerobic condition development of the athlete in all sports [71, 72]. In addition, the vertical jump test is a measure of the athlete's current and potential athletic performance. Davies et al. investigated how body parameters affect the vertical jump test. As a result of the research, they revealed that foot length affects the vertical jump test. They concluded that individuals with longer legs generate additional

propulsion and the person produces more ankle torque [73]. Ali F. et al. investigated how anthropometric variables and vertical jump test affect elite male volleyball players according to their playing positions. Forty men who played in the Iranian first league for at least 4 years were included in the study. In the study, they recorded 17 anthropometric values using caliper and flexible tape measure. Foot length, torso length, fixture sitting height, belly fat, etc. are among the measured parameters. As a result of this study, they found a relationship between thigh body circumference and weight for libero players, and between vertical jump and weight, foot lengths, leg lengths, and calf circumferences for setter and announcer players [74]. N. D. Geledas et al. found a significant association between foot length and performance in swimmers aged 12-14 years [75]. Herman V. W. et al. suggested that musculoskeletal variability affects locomotor function. In their research, they investigated how various motor functions are affected by differences in foot structure. In their study of ten people, they showed that people with longer toes jumped better. They found a correlation between the vertical jump test and foot length, hind leg width, hind leg height, and leg length [48]. Sanchez Ramirez C. et al. studied the relationships between anthropometric and performance variables in a study involving 177 volunteers. They have also contributed to increasing existing knowledge about the relationship between motor performance and foot morphology [76].

When we search the literature, we see that the relationship between foot anthropometric values and vertical jump is evaluated in swimmers, volleyball players and football players. We also see that this research has not been conducted on tennis players. In our study, we also looked at the effect of anthropometric variables on vertical jump in adolescent tennis players. In tennis, it is important that the player jumps and serves successfully, especially in serving throws. We found a statistically positive correlation between foot length-heel width-toe width-medial and lateral malleolar height and vertical jump ($p < 0.001$) test (table 4.10. and table 4.13.). As a result of our evaluations, we proved that as the foot length increases, the jump distance also increases. The wide and long feet of the players allow them to jump more. we can recommend players to use shoes with a wider surface and arch support insoles. In this way, the player will be able to provide a more successful service.

Jose Luis H. et al. investigated the agility of thirty-five young tennis players under the age of 16. They found that the most commonly used test to determine the fitness of tennis players is the hexagonal agility test, and in their study, this test has a high reliability [77]. Haki I. et al. conducted a research on young football players aged 12-14

in the Republic of North Macedonia. They aimed to identify differences in motoric abilities and anthropometric characteristics. They volunteered to recruit 101 football club members, ages 12 to 14, who train and compete regularly. Players' height, right arm length, left arm length, pelvic diameter, knee joint diameter, ankle diameter, thigh circumference, calf circumference, weight, body mass index, etc. Anthropometric measurements were made. As a performance test, long jump, 20 meters sprint, hexagonal agility test, flamingo test etc. Done. As a result, they observed that anthropometric characteristics affect the results of performance tests [78]. In the literature, we could not find any study that measured foot anthropometric values and investigated the relationship between tennis players' agility. In previous studies, it was revealed that the player's agility increases his success. In tennis played with single or double players, success is achieved when all performance parameters are good. For this reason, we examined the relationship between foot anthropometric values and agility in our study. As a result of our research, we found a significant relationship between foot length ($p < 0.05$) and left medial malleolar height ($p < 0.05$). There was a negative correlation between right foot length and hexagon agility test (clockwise) ($r = -0.322$; $p = 0.026$). This shows that as the foot length increases, the player becomes more agile. There is a statistically significant relationship between the medial malleolus height of the left foot and the hexagon test (clockwise) and the hexagon test (counterclockwise) ($p < 0.05$). We can say that as the medial malleolus height increases, the agility of the player decreases. We can say that the player can increase his agility by wearing shoes with long soles and using lateral arch supported insoles in the athlete with a high medial malleolus height.

Rasmus G. N. et al. evaluated 280 healthy volunteers in their study. Their study aimed to evaluate the relationship between foot length, age, gender, and body mass index (BMI) of the navicular drop test. They found that navicular drop was affected by gender and foot length [79]. In another study, Ajit D. et al. examined a total of 120 people. 60 participants had pes planus and 60 participants had normal foot structure. They concluded that the support surface can create biomechanical changes and affect postural control and balance. In this study, they showed that foot width was directly proportional to pes planus and was significantly associated with low navicular [80]. Caner K. examined the relationship between ankle posture and performance tests in 64 healthy young adults aged 18 to 25 years. As a result of his study, he found a statistically significant positive correlation between the vertical jump test and the navicular test [81]. With these studies,

we see that navicular drop affects postural control and balance. When we searched the literature, we could not find any study investigating the effect of foot anthropometry on performance in adult tennis players and child tennis players. We examined whether navicular decline affects performance in adolescent tennis players. As a result of our analysis, we found a significant relationship between the navicular test and vertical jump ($p<0.05$)(negative correlation). We demonstrated a significant relationship between medial malleolus height ($p<0.05$), lateral malleolar height ($p<0.05$), lower leg length ($p<0.05$) and foot navicular height. When we evaluated the results, we revealed that the arch height of the player affects its performance. We can say that the arch height of the player is related to the vertical jump and agility performance. After evaluating the player's medial arch height, the foot can be optimized with medial arch support or lateral arch support.

According to the results we obtained in this study, we suggest examining the foot structure while evaluating the performance of tennis players. In our study, we examined the relationship between performance parameters and foot anthropometric values. Although a performance parameter is not dependent on the anthropometric value of one foot, all values should be examined after performance evaluation. We can say that performance can be optimized with the use of properly supported insoles, myofascial relaxation techniques, strengthening of the foot extensor muscles or strengthening the foot flexor muscles. After evaluating the performance values and the foot structure, which of these techniques will be used in the player, it should be made individually. The limitation of our research was that there was no control group and more cases could not be reached due to the covid epidemic.

6. CONCLUSION AND SUGGESTIONS

- In our study, when we measure foot anthropometry values (foot width; medial malleolus height, lateral malleolus height; foot length, heel width and 1st metatarsal length), we see that there is a relationship between the performance of the player. These variables should also be taken into account when evaluating the player's performance.
- According to our results, the parameter in which the player is underperforming can be determined and necessary biomechanical changes can be applied. We found a negative correlation between right foot width ($p=0.002$), 1st metatarsophalangeal length ($p<0.001$) and y balance test. In the athlete with poor dynamic balance, the sole surface width of the shoes used in the tournament can be narrowed and the contact between the ground and the foot can be reduced. We found a positive correlation between foot length-foot width-heel width-medial and lateral malleolar height and vertical jump test. We found a negative correlation ($r=-0.322$; $p=0.026$) between right foot length and hexagonal agility test (clockwise), and negative correlation between left foot medial malleolus height and hexagon test (clockwise) and hexagon test (counterclockwise) ($p<0.05$). Arch support can be applied to the foot in order to increase the jumping distance and agility of the player.
- Although a performance parameter does not depend on the all anthropometric value of the foot, all values should be examined after performance evaluation. We can say that performance can be optimized by using properly supported insoles, myofascial relaxation techniques, strengthening the foot extensor muscles or strengthening the foot flexor muscles.
- In our research, we could not increase the population due to the covid-19 outbreak and the limited permission of the young tennis players' families. Conducting future studies with more participants can increase the power of the study.

7. REFERENCES

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8. APPENDIXES

APPENDIX 1: ETHICAL COMMITTEE APPROVAL



T.C. YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No
1.0
Sayfa 1 / 2

KARAR FORMU

3.12.2021

ETİK KURUL BİLGİLERİ	Etik Kurulun Adı	Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
	Açık Adres	Yeditepe Üniversitesi Diş Hekimliği Fakültesi, Bağdat Cad. No. 238 Göztepe 34728 Kadıköy, İstanbul
	İnternet Sayfası	http://goetik.yeditepe.edu.tr/
	Telefon	0216 363 60 44
	E-posta	goetik@yeditepe.edu.tr

DEĞERLENDİRİLEN BELGELER	Islak imzalı başvuru dosyası, CD'si ve elektronik başvuru	☒
	Araştırma başlığı ve araştırmacıların isimleri	☒
	Başvuru dilekçesi	☒
	Araştırmanın;	☒
	• Niteliği	☒
	• Önemi ve özgün değeri	☒
	• Amaç ve hedefleri	☒
	• Yöntemi	☒
	• Yönetimi	☒
	• Yaygın etkisi	☒
	• Araştırma bütçesi (Mevcutsa)	☒
	• Süresi ve uygunluğu (Zaman cetveli)	☒
	• Kaynakları	☒
	Araştırma izin belgesi / belgeleri	☒
	Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)	☒
	Taahhütname-1 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt	☒
	Taahhütname-2 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt	☒
	Taahhütname-3 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt	☒
	Taahhütname-4 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt	☒
	Araştırmacıların her birisine ait özgeçmiş formu	☒
Ek belgeler (Varsa kullanılan ölçek izinleri vb.)	☒	

KARAR BİLGİLERİ	Başvuru Numarası	202110100
	Toplantı Tarihi	19.11.2021
	Toplantı Yeri	Çevirim içi (Google Meet)
	Karar No	18

Araştırmanın Başlığı: Adölesan Dönem Tenis Oyuncularında Ayak Antropometrik Değişkenleri ve Performans Arasındaki İlişkinin Değerlendirilmesi

Araştırmacılar: Halil İbrahim Durmuş, Prof. Dr. Feyza Subaşı



T.C. YEDİTEPE ÜNİVERSİTESİ
GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR
ETİK KURULU

Versiyon No
1.0
Sayfa 2 / 2

BAŞVURU NUMARASI: 202110100

KARAR

3.12.2021

☒ KABUL	☐ RET ☐ KAPSAM DIŞI (GİRİŞİMSEL) ☐ BİLİMSEL VE/VEYA ETİK KURALLARA AYKIRI ☐ BİR SORUMLU ARAŞTIRMACININ (TEZ İŞE TEZ DANIŞMANI), BİR TOPLANTIYA İKİ (2) ADETTEN FAZLA ÇALIŞMA BAŞVURUSUNDA BULUNMASI ☐ KURUM İÇİ BAŞVURULARINDA YEDİTEPE UZANTILI E-POSTA HESABI İLE GİRİŞ YAPILMAMIŞ OLMASI ☐ ŞARTLI KABULDE BELİRTİLEN REVİZYONLARIN ZAMANINDA VE/VEYA İSTENİLDİĞİ ŞEKİLDE YAPILMAMIŞ OLMASI
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Prof. Dr. Didem ÖZDEMİR ÖZENEN Başkan <table><tr><td><u>Katılım</u></td><td><u>İlişki</u></td></tr><tr><td>☐Var ☐Yok</td><td>☐Var ☐Yok</td></tr></table>	<u>Katılım</u>	<u>İlişki</u>	☐ Var ☐ Yok	☐ Var ☐ Yok	Doç. Dr. Gökhan ERTAŞ Başkan Yardımcısı <table><tr><td><u>Katılım</u></td><td><u>İlişki</u></td></tr><tr><td>☐Var ☐Yok</td><td>☐Var ☐Yok</td></tr></table>	<u>Katılım</u>	<u>İlişki</u>	☐ Var ☐ Yok	☐ Var ☐ Yok	Doç. Dr. Elif SUNGURTEKİN EKÇİ Raportör <table><tr><td><u>Katılım</u></td><td><u>İlişki</u></td></tr><tr><td>☐Var ☐Yok</td><td>☐Var ☐Yok</td></tr></table>	<u>Katılım</u>	<u>İlişki</u>	☐ Var ☐ Yok	☐ Var ☐ Yok
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Araştırmanın Başlığı	Adölesan Dönem Tenis Oyuncularında Ayak Antropometrik Değişkenleri ve Performans Arasındaki İlişkinin Değerlendirilmesi
Araştırmacılar	Halil İbrahim Durmuş, Prof. Dr. Feyza Subaşı

APPENDIX 2: INFORMED WRITTEN CONSENT

BİLGİLENDİRİLMİŞ EBEVEYN/AİLE ONAM FORMU

Yeditepe Üniversitesi, Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü olarak ayak antropometri özelliklerinin adölesans tenisçilerin performansı üzerindeki etkilerini araştırmayı planlamaktayız

Çalışmaya katılım gönüllülük esasına dayalıdır. Araştırmaya yaklaşık altmış çocuk katılacaktır. Çocuğunuzun çalışmaya katılmasını isteyip istemediğinize karar vermeden önce araştırmanın neden ve nasıl yapılacağını, çocuğunuzu bilgilerinin nasıl kullanacağını ve çalışmanın neleri içerdiğini anlamanız önemlidir. Lütfen aşağıdaki bilgileri dikkatlice okumak için zaman ayırınız. Eğer anlamadığınız ve sizin için açık olmayan şeyler varsa ya da daha fazla bilgi almak isterseniz lütfen bize sorunuz. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuyup anladıktan sonra araştırmaya katılmak isterseniz formu imzalayınız.

Çocuğunuzun araştırmaya davet edilmesinin nedeni; tenisçilerde ayak biyomekaniğinin değerlendirip performans üzerine etkisinin araştırılmasıdır. Ayak biyomekaniğinin tenisçilerin performans parametrelerinden dikey sıçrama üzerine etkisi araştırılırken dinamik denge ve çeviklik performansı üzerindeki etkisi araştırılmamıştır. Bu çalışma ile genç tenisçilerin ayak biyomekaniği ile denge, dikey sıçrama ve çevikliği arasındaki ilişki araştırılacaktır.

Araştırmaya katılmayı kabul ederseniz, çocuğunuzun değerlendirmeleri Fzt. Halil İbrahim DURMUŞ tarafından yapılacak ve bulgular kaydedilecektir. Araştırma kapsamında, çocuğunuza girişimsel olmayan fiziksel değerlendirmeler ve performans testleri uygulanacaktır. Çalışma bir gün ayak antropometrik değişkenlerin değerlendirmesi, bir gün performans testlemesi olmak üzere iki gün sürecektir. Ayak antropometrik değişkenleri ayak uzunluğu, medial malleol yüksekliği, lateral malleol yüksekliği, ayak genişliği, ayak arkı yüksekliği, ayak parmak uzunluklarıdır. Ayak antropometrik değişkenlerin ölçümü tahta blok üzerine yerleştirmiş milimetrik mezura ve kumpas ile yapılacaktır. Medial longitudinal ark yüksekliğini ölçmek için navicular drop test kullanılacaktır. Çalışmaya katılmakla herhangi bir parasal yük altına girmeyeceksiniz ve aynı şekilde bir ödeme yapılmayacak. Araştırmamız katılımcı açısından her hangi bir risk teşkil etmemektedir. Araştırmada yapılacak değerlendirmelerin sonuçları yalnızca araştırma kapsamındaki çalışmada kullanılacaktır. Bu amaçların dışında bu kayıtlar kullanılmayacak ve başkalarına verilmeyecektir. Araştırma bir kongrede ya da dergide yayın olarak kabul edilse bile çocuğunuzun kimliğini ortaya çıkarabilecek kayıtlar gizli tutulacaktır. Araştırmaya katılım tamamen isteğe bağlıdır, istediğiniz zaman herhangi bir ceza veya yaptırıma maruz kalmaksızın araştırmadan çekilebilirsiniz.

Değerlendirme Yöntemleri

- **Y Denge Testi :** Y dengesi testi, alt ekstremité dengesini ve nöromüsküler kontrolü değerlendirmek için kullanılan bir testtir. Y dengesi testi, dinamik dengeyi değerlendirmek için güvenilirdir. Sporcunu dinamik dengesi Y şeklindeki bir platform üzerinde değerlendirilecektir.
- **Dikey sıçrama testi:** Sporcu her iki bacağı üzerinde bir platform üzerinde durur, daha sonra üst ve alt uzuvları serbest olacak şekilde dikey olarak zıplaması istenir. Üç atlama yapılır ve en yüksek atlama kaydedilir. Atlayışlar arasında en az 45 saniye beklenmesi arzu edilir. Sporcunun dominant el ile duvardaki en yüksek noktayı işaretlemesi istedir. Atlamadan önce, sporcu en yüksek zıplamayı yapmak için serbestçe esneyebilir. Test ile katılımcının alt ekstremité gücü ölçülecektir
- **Hexagon çeviklik testi:** Test, her bir kenarı 60,5 cm olan 120 köşe açısına sahip altıgen bir zemin üzerinde yapılır. Sporcu bu zeminde hazır olduğunda start komutu ile teste başlar ve kronometre başlar. Start komutu ile sporcu her köşenin dışında altıgenin ortasından atlar ve tekrar merkeze döner. Sporcu 3 kez saat yönünde dönene kadar hareketine devam eder ve merkeze döner. Merkeze döndüğünde kronometre durdurulur. Sporcunun denge ve çeviklik gerektiren maksimum hızda hareket etme yeteneğini ölçen testtir.

Çalışma ile ayak antropometri değişkenlerinin genç tenisçilerde dikey sıçrama, dinamik denge ve çeviklik üzerine etkisi araştırılacaktır.

Danışman (Sorumlu araştırmacı) Prof. Dr. Feryal Subaşı Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Bölümü feryal.subasi@yeditepe.edu.tr Tdf:02165780000/3216	Araştırmacı Fzt. Halil İbrahim Durmuş Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Spor Fizyoterapisi Yüksek Lisans Programında halilibrahim.durmus@std.yeditepe.edu.tr Tdf: 05059761594
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Bilgilendirilmiş gönüllü olur formundaki tüm açıklamaları okudum. Bana yukarıda konusu ve amacı belirtilen araştırma ile ilgili yazılı ve sözlü açıklama fizyoterapist Halil İbrahim DURMUŞ tarafından yapıldı. Araştırmaya çocuğumun gönüllü olarak katılmasına izin veriyorum, istediğim zaman gerekçeli veya gerekçesiz olarak araştırmadan ayrılabilceğimi biliyorum.

[Gönüllünün/ebeveynin] adı soyadı, telefon numarası, tarih, adresi, imzası	
[Araştırmacı] adı-soyad, telefon numarası, tarih, adresi, imza	
[Tamk] adı soyad, telefon numarası, tarih, adresi, imza	

APPENDIX 3: STRUCTURED QUESTIONNAIRE

Katılımcı Değerlendirme Formu

Tarih: .../.../...

1) Adı/Soyadı:

2) Telefonu:

3) Cinsiyet: ☐ Kız ☐ Erkek

4) Yaş:

5) Boy:

6) Kilo:

7) BMI:

8) Dominant Taraf;

El : Sağ ☐ Sol ☐

Ayak : Sağ ☐ Sol ☐

9) Eğitim Durumu:

☐ Okuryazar değil ☐ İlköğretim ☐ Lise ☐ Üniversite

10) Şuan Yaşadığı Yer: ☐ Ev ☐ Yurt ☐ Diğer Belirtiniz.....

11) Doktor tarafından teşhisi konmuş herhangi bir hastalığınız var mı?

☐ Evet ☐ Hayır

12) Cevabınız evet ise teşhis edilen hastalığınız aşağıdakilerden hangisi/hangileridir?

(Birden fazla şıkkı işaretleyebilirsiniz)

☐ Kalp Damar Hastalıkları ☐ Kanser ☐ Şeker Hastalığı

☐ Romatizma

☐ Ortopedik Hastalık

☐ Nörolojik Problemler

☐ Travma

☐ Sindirim Sistemi Hastalıkları (Karaciğer, Mide Vb.)

☐ Yüksek Tansiyon ☐ Solunum Sistemi Hastalıkları (Akciğer Vb.)

☐ Ruhsal Sorunlar (Depresyon, Aşırı yeme, Kusma, Gece Yeme Vb.)

☐ Kas-İskelet Sistemi Problemleri

☐ Endokrin (Hormonal) Hastalıklar

☐ Vitamin Ve Mineral Yetersizlikleri (Demir, B12 Vitamini Yetersizliği Vb.)

☐ Diğer(Belirtiniz).....

13) Düzenli kullanılan ilaç var mı?

Evet ☐ Hayır ☐ İlaç ismi:

14) Daha önce cerrahi operasyon(ameliyat) geçirildi mi?

Evet ☐ Hayır ☐ Bölge ve işlem:

15) Hiç kaza geçirdiniz mi?

Evet ☐ Hayır ☐

16) Kaza geçirdiyseniz ne zaman geçirdiniz?

1yıl içinde ☐ 1yıldan önce ☐

17) Kullandığı cihaz var mı?

Evet ☐ Hayır ☐ Cihaz ismi:

18) Kas iskelet sistemine bağlı herhangi bir ağrı şikayetiniz var mı?

varsa hangi bölgede?

Ağrım yok ☐

Bel ☐ Kalça ☐ Diz ☐ Ayak ☐

19) Tenis antrenmanımı ne sıklıkta yapıyorsunuz?

Yapmıyorum ☐

Ayda Bir Kezden Az ☐

Ayda 2 Kez veya Fazla ☐

Haftada 1 Kez ☐

Haftada 2-3kez ☐

Haftada 4-5 Kez ☐

Her Gün ☐

20) Tenisi ne kadar zamandır oynuyorsunuz?

3 Aydan Az ☐

3-6 Ay ☐

6 Ay-1yıl ☐

1-3 Yıl ☐

3 Yıldan Fazla ☐

21) Yaptığınız spor her seferinde kaç dakika sürüyor ?

20 dk az ☐

20-30 dk ☐

30-60 dk ☐

60 dk. dan fazla ☐

22) Son 6 ay içerisinde yaralanma/sakatlanma geçirdiniz mi ?

Evet ☐ Hayır ☐

Evet ise =

23) Ayak veya ayak bileğinden rahatsızlığınız var mı ?

Evet ☐ Hayır ☐

Evet ise =

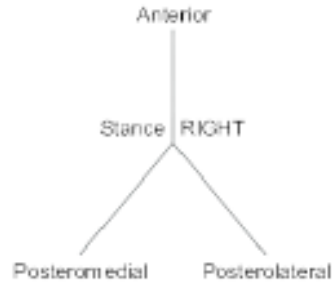
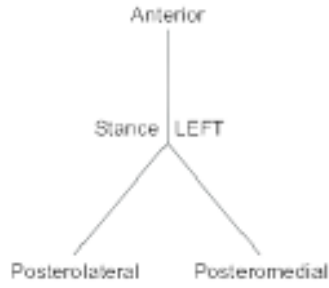
APPENDIX 4: Y BALANCE TEST EVALUATION

KATILIMCI ADI SOYADI:

TARİH:

Y DENGİ TESTİ

Alt ekstremite bacak uzunluğu(cm):



	Sağ(cm)			Ortalama	Sol(cm)			Ortalama	Fark
Anterior									
Posterolateral									
Posteromedial									

$((\text{Anterior} + \text{Posteromedial} + \text{Posterolateral}) / 3 \times \text{Limb Length}) \times 100 =$

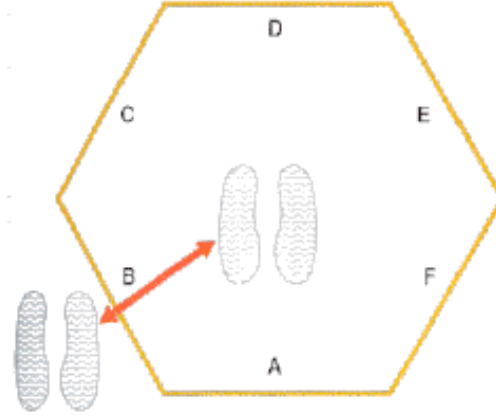
SONUÇ	
SAĞ	
SOL	

APPENDIX 5: HEXAGON AGILITY TEST EVALUATION

KATILIMCI ADI SOYADI:

TARİH:

Hexagon Çeviklik Testi



	Saat Yönünde	Saat Yönünün Tersinde
1.süre		
2.süre		
En İyi Sonuç		

APPENDIX 6: VERTICAL JUMP TEST EVALUATION

KATILIMCI ADI SOYADI:

TARİH:

Vertikal Jump Test				
UZANILAN YÜKSEKLİK(CM)				
ZIPLAMA SONRASI UZANILAN YÜKSEKLİK(CM)				Ortalama
ARADAKİ FARK(CM)				

APPENDIX 7: NAVICULAR DROP TEST EVALUATION

KATILIMCI ADI SOYADI:

TARİH:

Navikular Drop Test				
	Sağ	Sağ fark	Sol	Sol fark
Navikula Tüberkülünün Yerden Yüksekliği(Ayakta)				
Navikula Tüberkülünün Yerden Yüksekliği(Otururken)				

APPENDIX 8: FOOT ANTHROPOMETRY MEASUREMENT EVALUATION

KATILIMCI ADI SOYADI:

TARİH:

Antropometrik Ölçümler:		
Ayak Parametreleri	Ölçülen Değer(cm)	
	Sağ	Sol
Bacak Uzunluğu		
Alt Bacak Uzunluğu (patelladan)		
Ayak 1. Metatarsofalangeal Uzunluk		
Ayak Topuk Genişliği		
Ayak Uzunluğu		
Ayak Genişliği		
Medial Malleol Yüksekliği		
Lateral Malleol Yüksekliği		

APPENDIX 9. CURRICULUM VITAE

KİŞİSEL BİLGİLER	
Akademik Ünvanı	Fzt.
Ad-Soyad	Halil İbrahim Durmuş
Doğum yeri	
Doğum tarihi	
E-Posta Adresi	
Askerlik Bilgisi	
Cep Telefonu	
EĞİTİM BİLGİLERİ	
İlkokul	80. Yıl Bornova İlköğretim Okulu (İZMİR)
Lise	Mehmet Akif Ersoy Anadolu Lisesi (İZMİR)
Lisans	Yeditepe Üniversitesi - Sağlık Bilimleri Fakültesi-Fizik Tedavi ve Rehabilitasyon Bölümü (%100 burslu) (İSTANBUL)
Yüksek Lisans	Yeditepe Üniversitesi - Sağlık Bilimleri Enstitüsü - Spor Fizyoterapistliği (İSTANBUL)
Yabancı dil	
İngilizce (iyi)	
BİLGİSAYAR PROMRAMLARI	
Microsoft Office	
SPSS	
İŞ DENEYİMLERİ	
01.08.2019- 01.04.2020	Paintherapy(Dr. Serkan hezar kliniği)-manuel terapist

01.06.2020- 01.11.2020	Çam ve Sakura Şehir hastanesi	
24.12.2020- 2022	Özel Pendik Tıp Merkezi (baş fizyoterapist- idari işler müdürü)	
BİLİMSEL ÇALIŞMALAR		
Evaluation Of The Effect Of Vestibular Exercise On Balance, Lower Extremity Range Of Motion And Thoracic Mobility İn Healthy People.		
KURS VE SERTİFİKALAR		
6-8.11.2015	Katılım belgesi	8.Ulusal spor Fizyoterapistleri Kongresi- Kas- Tendon-Bağ Yaralanmalarında Rehabilitasyon
06.03.2016	Katılım belgesi	Spor Fizyoterapistliğine Bütüncül Yaklaşımlar Konferansı- Spor Fizyoterapistleri Derneği Gençlik Komisyonu (Yeditepe Üniversitesi)
28.11.2016	Katılım belgesi	Diyabetsizsiniz Adlı Panel (Yeditepe Üniversitesi)
10.02.2017	Sertifika	2. Omurga Sempozyumu (Bahçeşehir Üniversitesi)
05.03.2017	Sertifika	EFFECTİVE COMMUNICATION-Rodos Training
05.03.2017	Sertifika	DICTION-Rodos Training
05.03.2017	Sertifika	BODY LANGUAGE-Rodos Training
07.03.2017	Katılım belgesi	Sporcu Yaralanmaları- Anadolu Efes Spor Kulübü Sağlık Ekibi
30-31.03.2018	Katılım belgesi	Spor Travmatolojisi ve Rehabilitasyonu Kongresi (Üsküdar Üniversitesi)
04.11.2018	Katılım belgesi	Fizyoterapide Girişimcilik ve Kariyer Kongresi (Yeditepe Üniversitesi)
22-23-09. 2018	Sertifika	Osteosports 1ST STEP (INTRODUCTIN)- Osteosports

23-24-25.11.2018	Sertifika	Osteosports 2ND STEP (MANUAL)- Osteosports
11.05.2019	Katılım belgesi	Üsküdar Üniversitesi FTR Öğrenci Sempozyumu (Üsküdar Üniversitesi)
2021	Sertifika	Dry needling (Ümit Erkut)
KİTAP ÇEVİRİLERİ		
Anatomy Trains (Türkçe Çeviri), Low Back Disorders (Türkçe Çeviri), Joint Structure And Function (Türkçe Çeviri)		
REFERANSLAR		
Uzman Fizyoterapist Nuri Üçler- Ege Üniversitesi Tıp Fakültesi Fiziksel Tıp ve Rehabilitasyon Anabilim Dalı Uzmanı, Afazi Ve Dil Terapisti - İzmir Bornova Ege Üniversitesi -		
Yönetici-Kurucu Fizyoterapist- Reşit Taş- RETAFİZ -		
Uzm. Fzt. Tarık ÇETİN- Çiftehavuzlar Fizik Tedavi Merkezi-		