T.C.
YEDİTEPE UNIVERSITY
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RELATIONSHIP BETWEEN CORE STABILITY AND UPPER EXTREMITY FUNCTIONAL PERFORMANCE TESTS IN THE TENNIS PLAYER

MASTER THESIS

SESİL BERKE DOĞRUÖZ, PT

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ADVISER

Assist.Prof. ŞULE BADİLLİ DEMİRBAŞ

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ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun 25/10/2019 tarih ve 2019/17-02 sayılı kararı ile onaylanmıştır.

Prof. Dr. Bayram YILMAZ
Sağlık Bilimleri Enstitüsü Müdürü

DECLARATION

I hereby declare that this thesis is my own 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.

Sesil Berke DOĞRUÖZ

Signature

DEDICATION

I would like to dedicate my thesis to my beloved parents Nurhan and Metin DOĞRUÖZ and I also thank everyone who contributed on me.

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LIST OF SYMBOLS/ABBREVIATIONS

BMI	Body Mass Index
CKCUES	Closed Kinetic Upper Extremity Stability Test
SMBT	Seated Medicine Ball Throw Test
YBT-UQ	Y Balance Upper Extremity Test
M	Medial
SL	Superolateral
IL	Inferolateral
SD	Standard Deviation
ER	External Rotation
IR	Internal Rotation

ABSTRACT

Doğruöz, SB. (2019). Releationship between core stability and upper-extremity functional performance tests in the tennis players. Yeditepe University, Institute of Health Sciences, Department of Sport Physiotherapy Master Thesis. İstanbul 2019.

The sample of the study consists of 40 athletes between 18-50 years old who have been playing tennis actively for at least 1 year at Enka Sports Club in İstanbul and have been training more than 2 hours per week. All participants were evaluated by three upper extremity performance tests (Y balance upper extremity test, seated medicine ball throw test, closed kinetic chain upper extremity stabilization test) and core stabilization measurement and voluntarily participated in the study.

The sociodemographic characteristics of the participants were obtained by a questionnaire specially designed for the study. The questionnaire includes not only sociodemographic characteristics, but also questions about the occupation, education level, marital status, chronic diseases, family history, medication use or smoking habits. All data were analyzed by statistical method.

The results showed a significant difference between core stabilization and CKCUES and SMBT tests ($p < 0.05$). However, there was no significant relationship between core stabilization and YBT-UQ test for each of the right / left arm, IL / M extension directions.

In conclusion, we found in this study that tennis players needed strong core stabilization to improve upper extremity performances. However, further studies are needed regarding the relationship between upper extremity performance components and core stabilization.

Key Words: core, core stability, tennis, performance, upper extremity

ÖZET

Doğruöz, SB. Tenis Oyuncularında Üst Ekstremite Performans Testleri ve Kor Stabilizasyonu Arasındaki İlişki. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Spor Fizyoterapisi Yüksek Lisans Tezi. İstanbul 2019.

Çalışmanın örneklemini İstanbul İli Enka spor kulübünde en az 1 yıldır aktif olarak tenis oynamakta olan ve haftalık 2 saat üzeri antrenman yapan 18-50 yaş arası 40 sporcu oluşturmaktadır. Tüm katılımcılar üç üst ektremite performans testi (Y denge üst ekstremite testi, oturarak öne top atma testi, kapalı kinetik zincir üst ekstremite stabilizasyon testi) ve kor stabilizasyonu ölçümü ile değerlendirilmiş ve gönüllü temeller üzerinden çalışmaya katılmıştır.

Katılımcıların sosyodemografik özellikleri, çalışma için özel hazırlanan bir anketle alınmıştır. Anket sadece sosyodemografik özellikleri değil, aynı zamanda katılımcıların mesleğini, eğitim düzeyini, medeni durumunu, kronik hastalıklarını, aile öyküsünü , ilaç kullanıp kullanmadıklarını, sigara alışkanlığını sorgulayan nitelikte sorular içermektedir. Tüm veriler istatistiksel metotla analiz edildi.

Sonuçlar, kor stabilizasyonu ile CKUEST testi ve SMBT testleri sırasında anlamlı bir fark olduğunu göstermiştir ($p<0.05$). Ancak kor stabilizasyonu ile YBT-UQ testinin sağ/sol kol, PL/PM uzanım yönlerinin her biri için arasında anlamlı bir ilişki bulunmamıştır.

Sonuç olarak, bu çalışmada, biz, tenis oyuncularının üst ekstremite performanslarını artırmak için güçlü bir kor stabilizasyonuna ihtiyaç duyduklarını bulduk. Ancak üst eksremite performans bileşenleri ve kor stabilizasyonu arasındaki ilişki ile ilgili daha çok çalışmaya ihtiyaç vardır.

Anahtar Kelimeler: kor, kor stabilizasyonu, tenis , performans, üst ekstremite..

1.INTRODUCTION AND PURPOSE

Tennis is one of the most popular sports in the world and is played by more than 75 million people (1). It requires speed, flexibility, agility, dynamic balance, explosive power, anaerobic & aerobic fitness and rapid response (2). Unlike many other sports in tennis competitions, there is no time limit; it may take less than one hour or up to five hours (3). In long-term competitions, it becomes difficult for the athlete to make high performance.

Sportive performance is the sum of the efforts made for success during athletic competence (4). Tennis performance depends on the integration of physiological, biomechanical, psychological and perceptual elements. The player's speed, muscle strength, flexibility, strength, adaptation to changing environmental conditions affect performance, as well as technique (5).

The game consists of service, backhand and forehand shots. Service is the kick of the game. A wide range of motion of the glenohumeral and scapulothoracic joints is required during shot. And high rotational force occurs. When the ball is thrown forward, the contralateral gluteus maximus and external oblique muscles are first activated followed by bilateral rectus abdominis muscle. Activation proceeds to the ipsilateral upper and lower trapezius and latissimus dorsi around the scapula. Deltoid and rotator cuff muscles show maximum activation in the last stage of the shot (6).

In forehand stroke, both power and control can be achieved by the correct development of linear and angular momentum. Linear momentum is the amount of linear motion a body has. In the forehand stroke, linear momentum develops through forces on the ground as body weight is transferred from back leg to the front leg. Angular momentum is the amount of angular movement a body has. Angular momentum is developed from ground reaction forces and is revealed by body rotation during the forehand stroke (7). In the forehand, the main factors that make up the stroke rate on the racket are kinetic chain movements, ie trunk rotation, horizontal shoulder adduction and internal rotation (8).

Backhand stroke requires high trunk rotation. Bahamonde (1999) reported that there is a relationship between trunk rotation and racket speed and said that "one of the most important elements of forehand & backhand strokes is the development of optimal trunk rotation." Elliott, Marsh, and Overheu (1989) reported that the shoulders rotated forward from a return position at an angle of 95 degrees to the ball kick. Iino and Kojima (2001) reported that the shoulders and pelvis rotate 98 and 60 degrees against the ball and impact, respectively, from the ball kick in the front kick, starting from the completion of the backward stroke. 60% of shoulder angular displacement is achieved without pelvic angular displacement. This shows that lower extremities may play an important role in trunk rotation (9).

Even though the last move during the stroke is with the upper extremity, the formation and transmission of force in the lower extremity is needed (10). The most important factor that provides balance and movement control between the upper and lower extremities is the core force (11). The “core” region includes the bone skeleton, ligaments and muscles of the proximal regions of the pelvis, hip and lower extremity. Taking into consideration of athletes performing over the head activity, this definition has been extended to include the bone skeleton, ligaments and muscle system of the shoulder girdle. According to this perspective, the muscles of the core includes superficial and deep abdominal wall, pelvic floor, erector spina and segmental back muscles as well as muscles supporting the pelvic girdle / hip and scapula (12). These muscles are responsible for the stabilization of the spine and pelvis and help from proximal to distal energy production and transfer. Therefore, in addition to stabilization function, the muscles of the core also have a mobility function (11).

Core stabilization requires both muscle strength / endurance and neuromuscular control(13). Neuromuscular control is the subconscious activity of dynamic structures around the joint against sensory response. Proprioception, kinesthesia and joint position sensation are the sensory conduction, whereas neuromuscular control is the subconscious motor efferent response generated by afferent sensory data. This response is achieved through functional motor patterns, dynamic joint stability and reactive neuromuscular control. Timing, skill and coordination are very important in the formation of an activity. This is due to the acceptance of good and complete sensory input in the central nervous system with feedback and structuring of the motor output with a well-programmed forward notification. In the feedback closed loop system, processing of data and the formation of a feedback can take a long time. There is not enough time to detect errors, plan and make corrections in rapid movements. For this reason, players should have high core strength in order not to lose their stabilization during the game(14).

Purpose of the study:

The aim of the study is to measure the stabilization of the muscles of the tennis players, to examine the relationship between upper extremity performance tests and to contribute to the literature.

Our hypotheses regarding this study are as follows:

H0: Core stabilization is effective in the upper extremity performance of tennis players**.**

H1: Core stabilization is not effective in the upper extremity performance of tennis players.

2. THEORATICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Anatomy of core

The core is a neuromusculoskeletal structure and consists of structures that allow the movement of the lumbo-pelvic-hip complex in the movement system. These structures, consisting of agonist and antagonist muscles, act at optimum tension along the lumbo pelvic hip complex to provide effective core activity(15).

The core region muscular system consists of 29 different muscles supporting the lumbo-pelvic muscle complex. These muscles are classified as regional and general muscle groups (Figure 2.1). The regional muscular system primarily includes the transversus abdominis and multifidi which provide stability to the trunk muscles. The primary task of these muscles is to provide stability(16). Internal oblique, medial fibers of external oblique, quadratus lumborum, diaphragm, pelvic floor muscles, iliocostalis and longissimus muscles all play a secondary role in the regional system. General core muscles act as the transferring force from the rib cage and pelvis to the extremities. These muscles are responsible for providing trunk movements. These muscles that provide movement are rectus abdominis, lateral fibers of external oblique, psoas major and erector spinae(17). If we examine these muscles in detail;

Local Core Muscles		Global Core Muscles
	Primary	**Secondary**
Transversus Abdominis	Internal oblique	Rectus Abdominis
Multifidi	External oblique medial fibers	External oblique-lateral fibers
	Quadratus lumborum	Psoas major
	Pelvic floor muscles	Erector spinae
	Iliocostalis and longissimus-lumbar portion	Iliocostalis-thoracic portion
	Diaphragm	

Figure 2.1: Classification of core muscles (18)

2.1.1. Abdominals

The core muscles in the abdominal region are rectus abdominis, transverse abdominis, internal oblique and external oblique(19). The anterior abdominal wall is a hexagonal area surrounded by a costal edge and xiphoid process at the superior, a midaxillar line at the lateral, symphysis pubis, pubic tubercle, inguinal ligament, anterior superior iliac spine, and iliac crest at the inferior(20).

The anterior abdominal wall layers are skin, subcutaneous tissue, superficial fascia, deep fascia, muscle, extraperitoneal fascia and peritoneum(21).

External oblique, internal oblique, transversus abdominis, parietal peritoneum are located lateral to the abdominal Wall(20).

There is a rectus abdominis muscle extending vertically on both sides of the midline of the abdomen (Figure 2.2). The three aponeurotic layers surround the rectus sheath as it travels along the rectus abdominis. The rectus sheath joins with the pyramidalis muscle at the bottom.

The rectus abdominis muscle is known as the six pack muscle due to the three-fiber band extending over it and the linea alba. It slows trunk extension and lateral flexion in eccentric contraction and provides dynamic stabilization during functional movements(22).

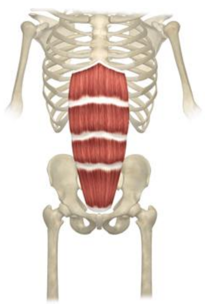


Figure 2.2: Rectus abdominis muscle(23).

The obliquus externus abdominis is the outermost of the three flat muscles under the superficial fascia. The fibers extend downwards and inwards. Aponeurosis almost covers the anterior abdominal wall and continues in the midline and fuses to the linea alba.

The obliquus internus abdominis forms the second layer of the external oblique muscle, which is smaller than the external oblique muscle. Aponeurosis fuses to the front linea alba (Figure 2.3)(24).

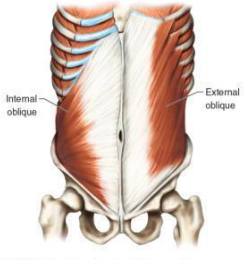


Figure 2.3: Musculus Internal and external obliquus (23).

The transversus abdominis is located deep inside the internal oblique muscle. Aponeurosis adheres to linea alba. It is thought that the horizontal fibers of the transversus abdominis muscle form a belt around the anterolateral portion of the abdominal region, thereby contributing to the stability of the lumbar vertebra (Figure 2.4)(25).

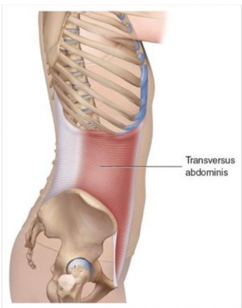


Figure 2.4: Transversus Abdominis muscle (23)

The abdominal wall plays an assistive role in the intercostal muscles, thorax and diaphragm during respiration. While the abdominal wall is involved in expiration during exercise, the transversus abdominis external and internal oblique muscles increase intra-abdominal pressure to meet increased respiratory demand(26).

The diaphragm, iliopsoas and quadratus lumborum muscles form a kinetic chain that allows coordinated movement and force transfer during upper and lower limb activity (Figure 2.5)(27).

Figure 2.5: Diaphragm Muscle (23)

2.1.2. Paraspinals

The quadratus lumborum muscle extends along both sides of the spine laterally in the region between the 12th rib and the ala ossis ilium (Figure 2.6). The lumbar vertebra adheres to the rib cage and pelvis and acts as a strong stabilizer. The fibers of the quadratus lumborum muscle have a large lateral moment. This force prevents lateral displacement due to excessive compression of the spine(28).

MGill has proved that the length of the quadratus lumborum is not changed during spine movements and isometric contraction at all times. Quadratus lumborum is mainly stabilizing in the frontal plane, working with the gluteus medius and tensor fascia latae(29).

Figure 2.6: M.Quadratus lumborum (23)

The erector spinae; it is the largest of the intrinsic back muscles. Consists of 3 vertical muscle columns; the iliocostalis, longissimus and spinalis (Figure 2.7). These muscles adhere to the spine. They pass through costavertebral grooves except the iliocostalis. They connect to the fascia toracolumbaris in the sacrolumbar region.

The iliocostalis; it originates from toracolumbar aponerosis in the thoracic and lumbar region. In the cervical region, adheres to transverse processes amongst C3-C7(30).

The longissimus: Distally connects to mastoid process, cervical transverse process and thoracic transverse processes. Cervicis originates from the transverse process of the first five thoracic vertebrae, and capitis from the C5-C7, T1-T5 vertebral region(31).

The points where the spinalis adheres to the spine are difficult to detect because it is intertwined with the longissimus.

The transversospinalis: it represents the semispinalis, multifidi and rotatores. The semispinalis on the surface, the multifidi in its depth., in the deepest the rotatores are located(32).

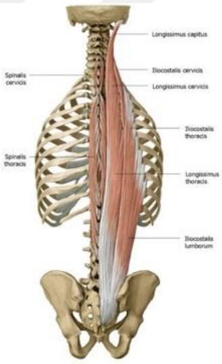


Figure 2.7: M.Erector spinae (23).

The multifidi muscle located in the vertebral grooves along the spine line from the sacrum to the axis bone (Figure 2.8). Numerous researchers have examined the role of multifidi in maintaining lumbar spine stability(33).

Wilke et al. reported that multifidus contributes to increased spinal stiffness during contraction(34).

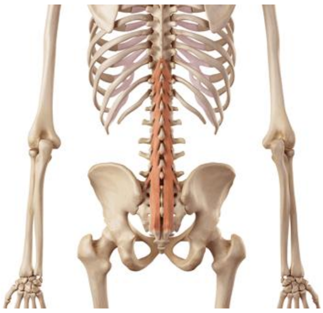


Figure 2.8: Multifidi muscle (23).

2.1.3. Pelvic Floor Muscles

Pelvic floor muscles are part of the trunk stabilization mechanism. They transmit the body weight from the axial skeleton to the appendicular skeleton, thereby counteracting the forces created by the body weight. They also contribute to continence, elimination, sexual arousal, and intra-abdominal pressure.

They consist of superficial, medium and deep layers. It is the only muscle group in the body that extends transversely and carries loads (Figure 2.9)(35).

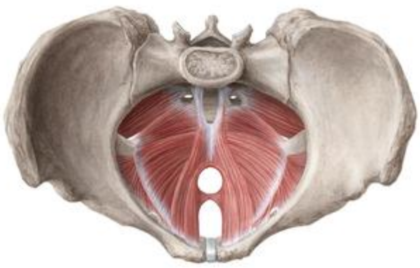


Figure 2.9: Pelvic floor muscles (23).

2.1.4. Gluteal Muscles

The psoas major muscle originates from transverse processes of the lumbar vertebrae and connects with the iliacus to the small torachanter of the femur. The psoas major, along with iliacus, makes the thigh flexion and lateral rotation from the hip joint and flexes the trunk on the hip joint during sitting(36).

Gluteal muscles are the maximus, medius, and minimus (Figure 2.10). The gluteus maximus originates from iliac crest and sacrum. In the large torachanter of the femur, linea is attached to the aspera.

They originate from the gluteus medius and minimus ilium and are attached to the large thorachanter of the femur[37].

Figure 2.10: Gluteal muscles (23).

Tennis is an asymmetric sport as it involves repetitive unilateral activities. Therefore, especially iliopsoas and gluteal muscles are both asymmetric and hypertrophic in tennis players.

Iliopsoas and gluteal muscles are antagonists. As the dominant side iliopsoas is hypertrophic, it provides high performance during fast running. The gluteal muscles stabilize the pelvis during side step maneuvers. The main task of the gluteal muscles is to stabilize the knee joint and keep the trunk in an upright position with the contralateral foot up and the knee extensors in the relaxed position during the match (38).

According to the researchers, lower extremity instability is often caused by the gluteus maximus weakness and delayed firing of the gluteus medius. The gluteal muscular system plays an important role in the transfer of forces from the lower extremity to the pelvis, spine and upper extremity(39).

The weakness of the gluteus maximus can affect the alignment of the lower extremity, making the person open to the injuries. In their study, Bobbert and van Zandwijk showed that the gluteal muscle activation is important to maintain spine stability while attempting to increase core strength(40).

2.2. Core Stabilization

Basically, the passive human spine is an unbalanced structure. For this reason, stabilization is achieved by the activity of the trunk muscles. These muscles, ie the muscles of the core, have anatomical, functional properties designed specifically to provide stability(41).

The hip, shoulder girdle and trunk muscles form the lumbo pelvic region of the body. Stability of the lumbopelvic region is important to provide a basis for movement of the upper and lower extremities, support to carry loads, and protect the spinal cord and nerve roots(42).

Panjabi defined core stabilization as keeping the intervertebral areas in neutral within physiological limits ". Core stabilization is divided into 3 different subsystems: passive subsystem, active muscle subsystem and neural subsystem(43).

The passive subsystem consists of spinal ligaments and facet joints. The passive subsystem allows the lumbar spine to support a load that is much less than body mass. An active muscle subsystem is needed to support heavier loads(44).

Bergmark divided the active muscle subsystem into "global" and "local" muscle groups based on their primary role in stabilizing the core region. As the tension in these muscles increases, the pressure forces between the lumbar vertebrae increase and the spine hardens in the lumbar region to increase stabilization(45).

The neural control system has a complex task of regulating muscle strength against feedback from muscle fibers, golgi tendon organs and spinal cord. The neural subsystem allows joint movement during operation to ensure stabilization(46). (Figure 2.11)

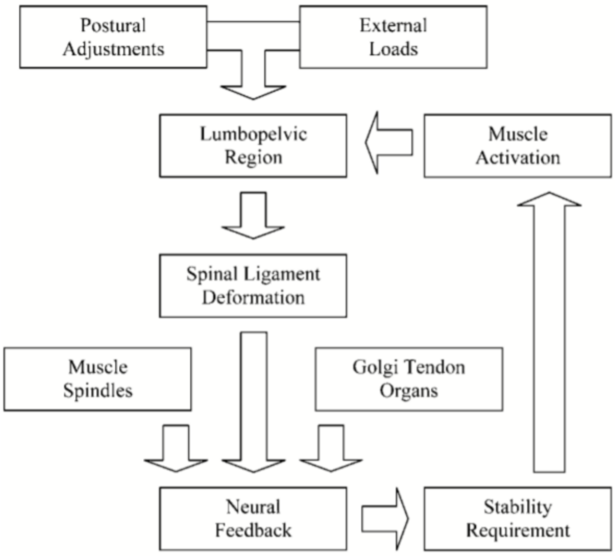


Figure 2.11: Model of core stability (47).

The key muscle working with the neural subsystem to ensure stabilization is the transversus abdominis. Cresswell and Thorstensson have shown that this muscle increases intra-abdominal pressure and reduces the pressure load on the lumbar spine(48).

Although the transversus abdominis is a key stabilizer of the spine, both local and global core muscles work together to provide spinal stabilization during movement. For example, the multifidi and rotator muscles contain high density muscle spindles and provide proprioceptive feedback to the nervous subsystem for stabilization, which facilitates co-activation of global muscles(49).

2.2.1. Core Stabilization Measurement

The strength of the core muscles that stabilize the spine can be measured by static and dynamic tests(50). Static strength indicates the ability of the person to maintain a certain position. During static endurance tests, high stabilization, prolonged, lower severe muscle activation is required compared to dynamic endurance tests(51).

Dynamic endurance shows one's ability to repeat the movement over a period of time. During dynamic endurance tests, more motion, speed, strength, shorter duration and high intensity muscle activation are required compared to static endurance tests(52).

2.2.1.1. Static endurance tests:

McGill tests are most commonly used in the clinic practice. These tests consist of four positions: anterior trunk flexion test, right / left lateral plank test, posterior trunk extension test(53).

2.2.1.1.2. Anterior trunk flexion test:

This test is used to assess the durability of the anterior core muscle system (rectus abdominis).

For the test, participants are placed in a seated position in, with the back resting against a jig angled at 60 degrees from the floor. The knees and hips are flexed 90 degrees, the arms are folded across the chest with the hands placed on the opposite shoulder, and the feet are secured. To begin, the jig is pulled back 10 cm, and the person holds the isometric posture as long as possible. Failure is determined when any part of the person’s back touches the jig(54).

2.2.1.1.3. Posterior trunk extension test:

This test is used to evaluate the erector spinae and multifidi muscles(55). The clinician stands to the side of the client’s torso to ensure correct alignment. The upper body cantilevered out over the end of the test bench in prone position with the pelvis, knees, and hips secured. The upper limbs are held across the chest with the hands resting on the opposite shoulders. Failure occurs when the upper body drops below the horizontal position of the test bench (54).

2.2.1.1.4. Right/left lateral plank test:

This test is used to evaluate the obliquus internus/externus, transversus abdominis, and quadratus lumborum(55). The side bridge position is taken. Legs are extended, and the top foot is placed in front of the lower foot for support. The uninvolved arm is held across the chest with the hand placed on the opposite shoulder. Failure occurs when the person loses the straight-back posture and/or the pelvic position is impaired(54). If the individual can not achieve the correct position, gross weakness of the lateral core muscles is significant(55). The duration of each test position is recorded and a break of at least 5 minutes should be given between each test(54).

2.2.1.2. Dynamic endurance tests:

Some of the tests used for the dynamic endurance of the core muscles are; sit-ups, modified push-ups, right and left lateral flexion repeat tests. Athletes are asked to perform each test at maximum repeat for 60 seconds(50).

2.2.1.2.1. Sit-ups test:

In the supine position, the pelvis and knees are flexed, the subject is asked to lift the scapula off the ground with the arms engaged on the trunk and return to the initial position.

2.2.1.2.2. Modified push-ups test:

In the prone position, hands are open in shoulder wide and on the ground, elbows are in full extension, shoulders and knees are flexed and interlocked. The participant is asked to bring the body closer to the ground with the arms parallel to the ground. The head and body position should not change during the movement. Then participant returns to the starting position.

2.2.1.2.3. Lateral flexion-repeat test:

The test is evaluated as right and left. In lateral lying, the evaluated side is positioned with the arm perpendicular to the ground, elbow 90˚ flexed and the forearm in place, with the upper extremity crossed over the trunk, the lower limb in extension and the upper foot in front of the lower foot. The subject is asked to raise his body on his forearms and toes and then return to his starting position(56).

2.2.1.3. Core Stabilization Measuring Instruments

Stabilization of the lumbar region is difficult to maintain in the posterior and anterior pelvic tilt posture. It has been proven in studies that, the biofeedback unit assists individuals with proprioception and kinesthetic awareness in such cases(57).

In a study by Norris, a Stabilizer Pressure Biofeedback unit (Chattanooga Group Limited, Bicester, UK) was used to monitor posterior pelvic tilt during lumbar stabilization exercises (Figure 2.12). The biofeedback unit has allowed researchers to reach objective conclusions about trunk stabilization(58).

Figure 2.12: Pressure Biofeedback Unit (Stabilizer)(59).

2.3. History and Development of Tennis

Tennis has been regarded as an elite sport since its inception. First, the 13th century. It was played by the aristocrats in the French court under the name "Le Jeu du Paume (palm game) (Figure 2.13). Jeu du Paume is also popular because it is one of the rare sports that men and women can play together. The play Le Jeu du Paume, which disappeared with the aristocracy after the French revolution, was able to survive in the English Palace with the efforts of some French "paume" experts(60).

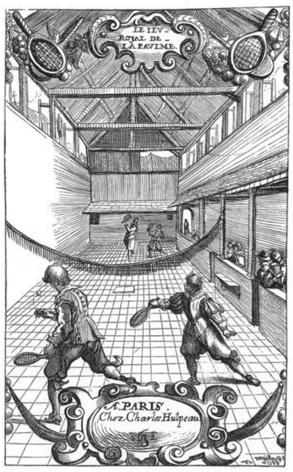


Figure 2.13: Le Jeu du Paume (61).

In 1555 Antonio Scaino da Salo wrote his first tennis book, Trattato del Givoco della Palla di Messer "About the Principles of Ball Game), in Venice. Antonio also made the first string racket in 1542.

Tennis has undergone some changes in the 18th century. In the first period, tennis games consisting of 24 games then changed to 12 games first and 6 games in 3 series later on(62).

Numbers are divided into 15, 30, 40, 60 by dividing one hour into four. After 40, it is called "game", not 60. Differences in the number system were completed in the 19th century. In 1858, the first tennis court was established in Birmingham, England. This court was 2.13 meters and divided in half. The tennis court reached its standard measures in 1883.

The first international match was played in July 1883 between the British twins Renshaws and the American Clark brothers. The first competition among women was held in 1884. Lawn Tennis has become popular in a short period of time because it is a game where both men and women can play at the same time. It was played not only on grass but on all kinds of surfaces and indoors. However, regardless of the surface, the name of the game remained as Lawn Tennis until the 1970s. In the 1970s, even though countries started to say tennis briefly, the International Tennis Federation did not change this name until 1977. The English Tennis Federation still uses the word Lawn Tennis Association(63).

Tennis started to be played in Turkey in 1915. The stars shining on the clay court at Fenerbahce Şirinyan, Suat Subay and Sedat Erkoğlu known as the best of Turkey. Adriel Sadak, Vecihe Taşçı, Mediha Baydar and Hidayet Karacan have achieved great success as women tennis players. Our athletes played their first national games against the Greeks in 1930. They won the Balkan championship against Bulgaria, Greece and Romania. Turkey Tennis Federation was founded in 1923(64).

The most important tennis organizations are:

1. Wimbledon: Since 1877.

2. USA Open: It has been held since 1881.

3. Davis Cup: It has been held since 1900.

4. Australia Open: It has been held since 1905.

5. French Open (Roland Garros): It has been held since 1925 (65).

Tennis Court Measurements and Types

The tennis court is rectangular:

8.23m x 23.77 m (singles court)

10.97m x 23.77 m (doubles court)

There is a net that separates the field from the middle. There are two service boxes in each of the half-pitches on the right and left, at a distance of 6.40 from the net.

The boundary of the court is defined by lines. The mark in the middle of the lines is the baseline center mark and its thickness is 5cm.

Surface types:

• Grass

• Clay

• Carpet

• Hard Courts (66)

Rules of the Tennis Game

Tennis is played between two different groups: singles and doubles.

Points: Once the ball has crossed the field, the opponent loses points if the opponent fails to hit the ball or if the ball bounces in more than one place, throws the ball out or into the net.

Set: To win a set, the player must win six games with at least two points above the opponent (such as 6-0, 6-1, 6-2, 6-3, 6-4). If there is a equalisation in games (5.5), the set is extended until one opponent makes a difference in two games (7-5, 8-6, 9-7, etc.). In some tournaments, the "Tie-break" rule is applied when the set is 6-6.

Game: Points continue as "15", "30", "40". After 40 points, the game becomes. If it's 30-30, it's called a "draw" or "deuce." For the first point received after a draw, the situation is an "advantage". If the advantageous player wins another point, he / she gets the game. If the advantageous party loses points, there will be a draw again (67).

2.4. Tennis Biomechanics

Biomechanics is the science that examines the movements and the effective forces of the body parts during the motor skill and the technique of the player. The main parameter in tennis game is shot. Shooting motion is a kinetic chain mechanism in which neuromuscular coordination is required. This mechanism is the event of elastic energy transmission from heavy and slow moving proximal to light and fast moving distal (68).

2.4.1.Elastic Energy

Elastic energy is the capacity of a body to perform work during reformation. The elastic energy generation mechanism consists of the contractile element (CE), which provides active force formation during muscle shortening, a series of elastic components (SEC) for the storage and release of energy, and the elastic component (PEC), which stores the elastic energy in parallel with the contractile element (70).CE provides cross-bridging between thick and thin myosin and actin filaments. Sarcomers can be stretched by 10% of their length, forming a large number of cross-bridges, but not all of the formed cross-bridges contribute to the force production (71). The increase in performance during the concentric phase is due to this tension in the muscle fibers during the eccentric phase (69).

The SEC extends through the tendinous tissues and is located in the muscle fibers. PEC is composed of muscle tissue around connective tissue (72).The formation of eccentric tension before the concentric phase in the muscle tension mechanism is known as stretch-shorten cycle (SSC) (73).Cavagna et al. examined the work output of the gastrocnemius muscle of a frog just before contraction and in a stretched state, found a difference of about 3 times more. The resulting force output difference is due to the potential energy stored in the SEC before concentric contraction (74).If the player wants to hit the ball strongly and achieve a better shot, the stored elastic energy is needed. This energy, which is stored during the eccentric contraction in each phase of the service, forehand, backhand strokes, is released during the concentric contraction.

2.4.2.Service:

This is the start shot of the game. There are 3 types of servings; flat service, topspin (twist, rotate) service and sidespin service(75).

During shots, the position of the trunk to the pelvis and the shoulder girdle to the ball differ. Therefore, the type of activated muscle is also different (76).

A wide range of motion of the glenohumeral and scapulothoracic joint is required during service shot. There is a high degree of rotational force on the shoulder joint, often causing injury. Therefore, the biomechanics of the stroke has been examined by many researchers (77). The stroke is divided into phases in biomechanical and kinetic aspects: wind-up, cocking, acceleration, and follow-through.

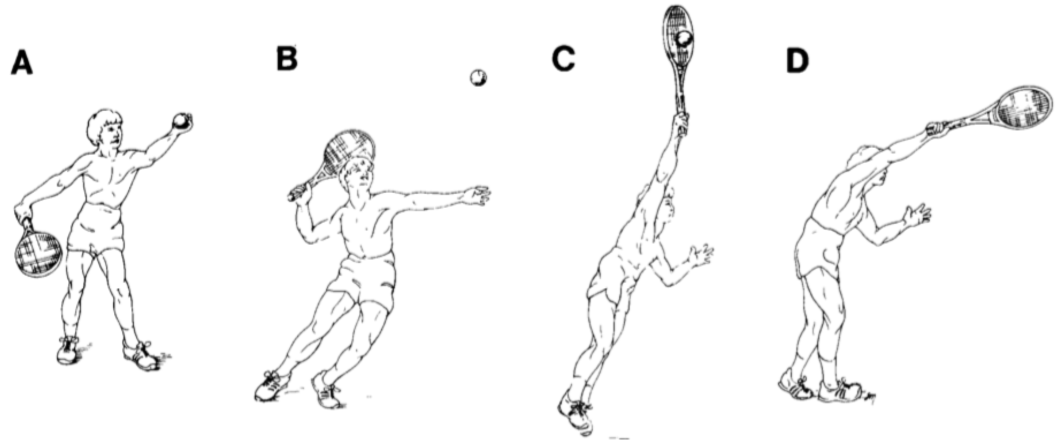


Figure 2.14: The four stages of the serve: A-wind-up, B-cocking, C-acceleration, D-follow-through.(78)

1-wind-up: This is the starting position, ending with the release of the ball in the non-dominant hand. In this phase, potential energy is stored in the upper extremity (79).

2-Cocking phase: Includes the movement within the time between the release of the ball and the external rotation of the dominant shoulder. There are two phases as early and late phases. ER starts at an early stage, increases during knee flexion and contact with the ground and more energy is stored in the passive elastic structures of the shoulder. In the late phase, the anterior shoulder capsule can withstand a maximum of 40% of body weight. Therefore, secondary impingement, SLAP lesion and anterior labral injury may develop during this phase (80).The first activated muscle in this phase is the serratus anterior. The upper trapezium is then activated to provide scapular stabilization and elevation of the acromion. The aim is to provide the ER of the scapula and posterior tilt of the humerus. Scapular stabilization and acromial elevation are completed with lower trapezoidal activation. The rotator cuff is activated to ensure the concentric contraction of the lower trapezius.

During the late cocking phase, the scapula changes from 45 degrees rotation to 60 degrees rotation. The lower trapeze is active to maintain acromial elevation, control the IR of the arm, and protect the rotator cuff from impingement.The anterior part of the deltoid is active to provide eccentric control during ER and horizontal abduction of the arm during the early cocking phase.

Supraspinatus, works with the deltoid as a force pair to depress the humerus head, stabilize the scapula to control the ER (81).

3- Acceleration: It covers the movement of the shoulder from the maximum ER to the ball. During the early phase, the IR starts, the majority of the movement occurs in the late phase. During late phase humeral deceleration and infraspinatus is engaged to provide distraction of the shoulder joint. The potential energy stored in this phase is converted to kinetic energy (80).Activation of all activated muscles during the other phases proceeds above the initial level in this phase (81).

4- Follow-through: In this phase, the acceleration force on the joints is distributed and normal posture is returned.Since horizontal adduction and IR are not required, the anterior deltoid is disabled by the acceleration force generated by trunk rotation. All other muscles are disabled in the late follow through phase by the eccentric muscle control mechanism of the arm.Before the normal posture, the lower trapeze is active to ensure stabilization of scapula, supraspinatus and teres minor are active to ensure stabilization of humerus head, the posterior deltoid is active to ensure stabilization of the upper arm (81).

2.4.3.Forehand:

For an effective forehand shot, the ball must be well-perceived and oriented accordingly. There are two types of it: open and closed forehand (82).The standing phase varies for open or closed forehand. In the open stroke, the position of the hips and feet position relative to the net is parallel. In the closed stroke, the hips and feet are angled 180 degrees relative to the net. In a closed forehand strike, linear momentum occurs with trunk movement as the player moves towards the ball, and angular momentum occurs during pelvic rotation. In the open forehand stroke, there is no linear momentum transfer, segmental turns are used to generate power (83).

Forehand stroke consists of 3 stages: preparation, acceleration and follow-through

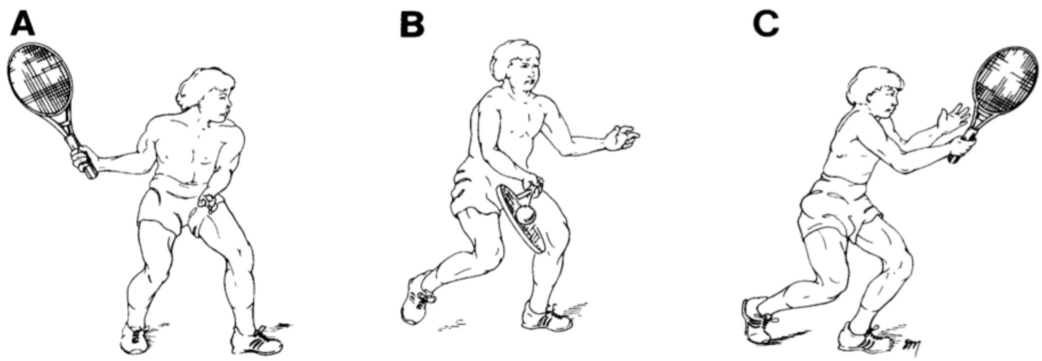


Figure 2.15: The three stages of the forehand groundstroke: A-preparation, B-acceleration, C- follow-through(78)

Preparation: It starts with shoulder rotation and ends when weight is transferred to the front foot. Abduction of the shoulder and ER occurs during this phase during trunk and lower extremity rotation (84).The upper body is 90-100 degrees counter-rotated at this stage relative to the baseline. The hip is 30° beyond rotated (85).Muscle activation in this phase is minimal. Minimum activation of the muscles provides driving force for trunk and lower limb rotation, shoulder extension and ER (84).

Acceleration: It starts with the transfer of weight to the front foot and the forward movement of the racket and ends when the ball hits the racket. Rapid IR and adduction of the shoulder, elbow extension and scapular protraction occur.At this stage, the subscapularis, pectoralis major, biceps brachii and serratus anterior muscles show high activation. Infraspinatus, the middle part of the deltoid and latissimus dorsi musles show low activation (84).

Follow-through: It starts with the ball shot and ends with the end of the shot. Infraspinatus has moderate activity. Muscle movements occurring in the 2nd stage continue at a lower intensity at this stage (84).

2.4.4.Backhand:

There are two types: single and double hand backhand. A two-handed backhand stroke requires greater body rotation than a single-handed backhand stroke (86).In the one-handed backhand technique, the player performs a rapid ulnar deviation of the wrist during the ball kick. Repeated mechanical overload causes pathological changes in the extensor mechanism (87).

The backhand stroke consists of 3 stages: preparation, acceleration and follow-through.

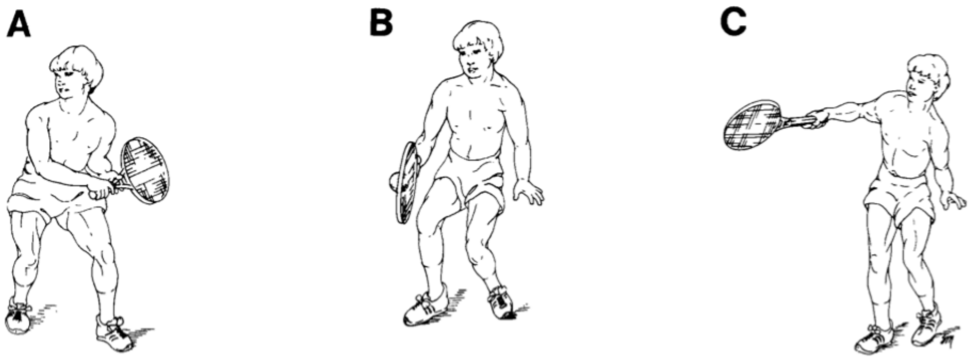


Figure 2.16: The three stages of the backhand groundstroke: A-preparation, B-acceleration, C- follow-through(78)

Preparation: It starts with shoulder rotation and ends when the weight is transferred to the front foot. Adduction of the shoulder and IR occurs during this stage during rotation of the trunk and lower extremities.

Acceleration: It starts with the transfer of weight to the front foot and the forward movement of the racket. Shoulder ER, abduction, scapular retraction and elbow extension occur. At this stage, supraspinatus, infraspinatus and the middle part of the deltoid show high activation. Serratus anterior, pectoralis major, subscapularis and latissimus dorsi have low activation.

Follow-through: It starts with the ball shot and ends with the end of the shot. Biceps brachii is active in both the acceleration and follow-through phase, controls elbow extension (84).Extensor carpi radialis longus/brevis, extensor digitorum communis, pronator teres, flexörr carpi radialis muscles are active in 3 phases of double/single hand backhand shots.

Exstensor carpi radialis longus, extensor digitorum communis and exstensor carpi radialis brevis muscles are most active during the acceleration phase. Exstensor carpi radialis longus is more commonly used in a two-handed backhand than a single-handed backhand. Extensor digitorum communis and exstensor carpi radialis brevis are more active in one hand backhand stroke.

Pronator teres shows max activity in acceleration phase in two-handed backhand stroke and in follow-through phase in single-handed backhand stroke. In the acceleration phase, the forearm is more pronated in the one-hand backhand than the two-hand backhand, and the pronator teres is more active.

Flexor carpi radialis muscle has one-hand backhand shot max activity in the follow-through phase, has two-hand backhand shot max activity in the acceleration phase (87).

2.4.5. Kinetic Chain

The kinetic chain is a coordinated sequence of activation, mobilization, and stabilization of body segments to generate strength, regulate movement, and protect joints from increased strain during athletic activity.The kinetic chain serves three purposes:

- Provides efficient transfer of kinetic energy and force to the distal segment by using the “sum of velocity” principle, where velocity and force developed in each segment in the body are facilitated and increased by the movements of the proximal segments.

- Adjusts and absorbs the forces having an impact on the joints by making postural adjustments for optimal formation of athletic activity and provides stabilization and positioning of body parts..-By preventing the eccentric loading that will disrupt the body posture and stabilization, spreads the loads along the entire limb, (88).

Service shot is the most important shot in terms of kinetic chain in tennis. Because the service shot is the only shot the player controls before the ball is hit. Service is examined in two patterns in the kinetic chain as push-through and pull-through.

The 'push-through' activation sequence uses knee flexion and rear leg drive to maximize the ground reaction forces that push the body up from the locking position to the ball impact and create long axis rotation in the arm. In the normal working kinetic chain, legs and trunk sections are the stable proximal base for motor and distal mobility for force development. This connection enhances 51 to 55% of the kinetic energy and power given to your hand[7], creating angular momentum from the rear leg to the front leg to drive the arm forward, and forms a diameter that allows centripetal movement to occur - due to its high cross-sectional area, large mass and high moment of inertia. The functional result of this stable base is believed to represent core stability.

Without core stability and the ability to produce force and torque, reaching the optimum performance becomes difficult. A 20% reduction in trunk kinetic energy requires a 33% increase in shoulder movement speed or a 70% increase in shoulder muscle mass to achieve the same kinetic energy.The Leg muscles are mostly used to generate power in the push-through pattern. The internal rotational moments of the shoulder are reduced, and the shoulder abduction is increased to minimize the risk of impingement, providing a fast kick to the ball.In the pull-through pattern, trunk muscles are used to create long axis rotation in the arm. Knee flexion and lower limb activation are minimized. With this activation, shoulder IR, scapular protraction and glenohumeral angulation increase, shoulder abduction decreases.Pull-through activation patterns produce less stabilization of the shoulder and higher force loading (89).

2.5. Performance in Tennis

Tennis players need some physical parameters to shoot forward and fast, and compete effectively against their opponents: strength, continuity in strength, endurance, flexibility, coordination and anaerobic and aerobic capacity (Figure 2.17) (90).

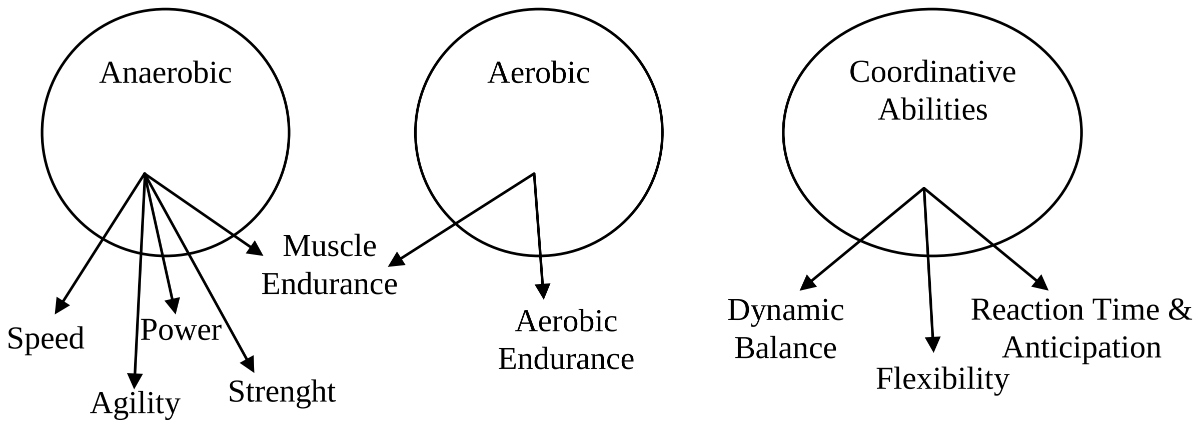


Figure 2.17: Performance factors of tennis (90)

Successful performance cannot be defined only by dominant physical characteristics. In a study, anaerobic threshold speeds of tennis players were found to be 14.5 km / h in males and 13 km / h with 1.5% incline on treadmill. The anthropometric properties of the players also affect their performance (91).

2.5.1. Anaerobic Components

2.5.1.1. Speed

Speed is the ability to perform the movements quickly. Speed is often confused with the concept of quickness, but does not mean the same. Speed is genetically transmitted and can be improved by conscious, long-term training. The focus of the training program is the physiological and mechanical qualities of speed.

Speed depends on how quickly the external stimulus is detected and answered and how quickly the motor impulses are transmitted from the stimulation center to the target muscles.

Speed classification in terms of training sciences:

a) Speed of Individual Movement:

Movement speed in different body parts. An example of the speed of individual movement is the arm speed of a tennis player. This skill is associated with neuromuscular process and movement.

b) Frequency of Movement:

The frequency of movement performed over unit time. The maximal movement speed of the joints in the body varies. In the finger joints; 300-400 / min and 690 / min in the wrist joint.

c) Sprint Speed: This is the time until an athlete reaches the average speed of running 30 meters. The average athlete reaches to maximal speed in 4 -5 sec. or at 28.5 - 36.5 meters.

d) Action Speed: It is the work speed during the movement.

e) Continuity in Speed: An athlete achieves and maintains a submaximal or maximal speed (92).

Tennis players cannot reach the maximum running speed (obtained on a straight line between 20 and 30 m) as they change direction continuously. Therefore, positive and negative acceleration, acceleration and deceleration are very important for tennis players(93). To increase speed in tennis, step length and speed should be improved(94).

Factors Affecting Speed;

-Genetic

-Tennis players with genetically fast contracted FT fibers are more advantageous.

-Reaction Time

-Agility

-Body composition (95)

2.5.1.2. Agility

Tennis is an unclear and unpredictable game, in which the player must have good neuromuscular coordination in order to respond quickly(96). Agility is the ability to change the direction of sudden and rapid changes necessary to create this answer. Agility includes not only the ability to change the direction of movement, but also the ability to anticipate the opponent's movement and react in certain game situations(97).

Therefore, neuromuscular conditioning is also considered to be the re-application of motor programming by neural adaptation of muscle spindles, the golgi-tendon organ(96).

The researchers discussed the components that affect agility performance. In particular, they stated that agility had two main components; the ability to change direction and the ability to quickly decide. Within these two main components, subcomponents exist as indicated in Figure 2.18(98).

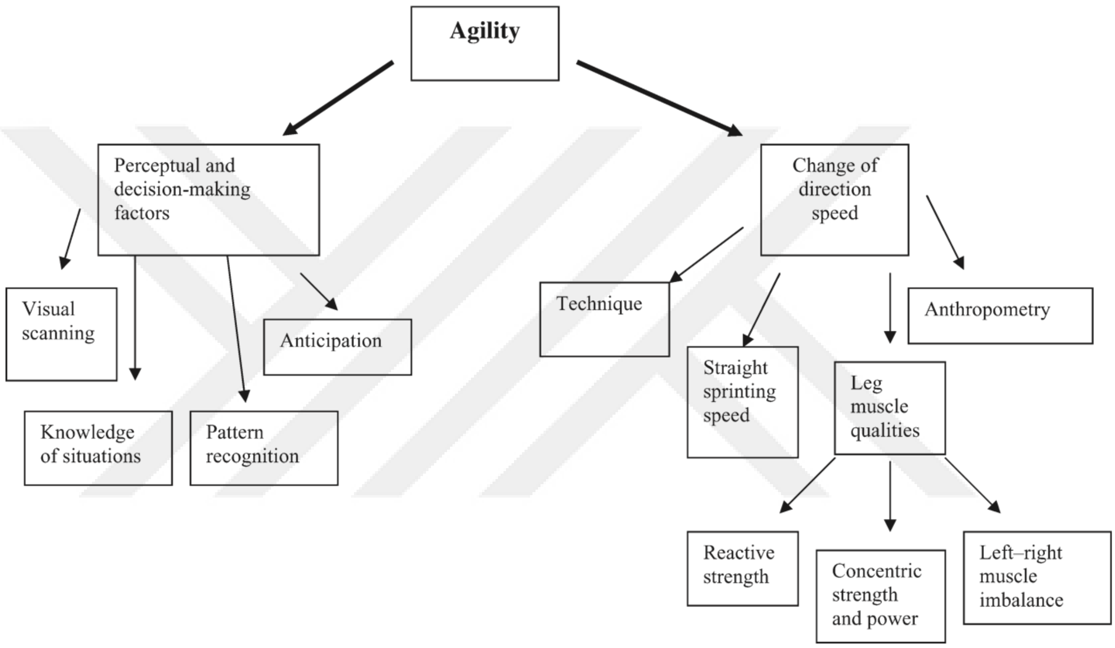


Figure 2.18: Universal agility components (98)

Agility is essential to the player's performance for three main reasons:

1. The development of agility will provide a strong basis for the control of the neuro-muscular system and motor skills.
2. Direction changes are a common cause of injury, thus reducing the risk of injury by developing appropriate individual movement mechanics.
3. Increasing the ability to quickly change direction will improve overall performance in both offense and defense(99).

According to the study conducted by Maman Paul and his friends on 30 tennis players, 8-week agility training showed a significant increase in the performance of the experimental group(96).

2.5.1.3. Power

Metabolic potential energy can be converted to work or heat by generating power, strength and speed. With the development of strength, the amount of work can be increased. Because the force makes it easier to move an object or move it away. Power is developed only when the same amount of work is performed in a shorter time or if the work done in the same time period is increased. So speed is an important element to improve power(100).

Girard et al. (2005) compared lower extremity muscle strength between elite, middle and novice tennis players, but no significant difference was found between the player groups. Studies report the local muscle group strength, yet not the total body muscle strength. However, it is important for tennis players to have high total body muscle strength for fast / strong service and forehand, backhand strokes(101).

Strength and speed must be developed in athletes without distinguishing one from the other since it requires strength. If the force is increased and the speed is lacking, the muscles will slow down. This reduces the power released during the hit to the ball(102).

Power in tennis creates explosive movement. It allows more and faster response and creates stronger movements with less effort. Having an explosive first step affects the speed of entering the fast position, effective hitting and catching the balls thrown away by the opponent's side(103).

2.5.1.4. Strength

Strength is defined as the neuromuscular ability to overcome internal and external resistances. The greatest strength that an athlete can produce depends on the biomechanical nature of the movement and the severity of contraction of the associated muscle groups(104).

Classification of Strength

General Strength

The general strength is the strength of all muscle groups without leaning to any specific sport area. It should be developed intensely when first started to exercise. A low overall strength is an important factor that limits the athlete's development.

Special Strength

The special strength is the strength required for a specific sport area. It can be thought of as the strength of the basic moving muscles that cause a movement to occur.

The special force should be developed gradually for the athletes towards the end of the preparation phase and combined with other motoric features.

Pure Strength

Pure strength is the highest strength that an athlete can exert regardless of body weight.

Training loads are determined according to the maximum weight the athlete can lift in one attempt. With the regular training program, pure strength can be increased in parallel to body weight.

Relative Strength

The relative strength is obtained by dividing pure strength by body weight. Relative strength is the greatest strength an athlete can create against body weight. Relative strength is used to compare muscle strength and body weight. It is important to provide the necessary maximal f strength in the weight that is present in the relative strength. It refers to the force of magnitude corresponding to kilograms(105).

Maximal Strength

It is the greatest strength created by the neuromuscular system during voluntary contraction.

Quick Strength

It is the strength produced by the neuromuscular system against high resistance by contracting at high speed.

Strength Continuity

Repeated contractions are the long-term resistance of the muscular system to fatigue.

Static Strength

It is only the strength produced by the change in tension while the length of the muscle is constant.

Dynamic Strength

It is the strength produced as a result of changes in muscle length and tension(106).

Sportive efficiency develops depending on the increase in strength. For this reason, many practitioners include strength exercises in athletes to increase sportive success(107).

Because the tennis game is a repetitive and the matches last long, the player's muscles must be able to contract continuously. High repetitive, light-medium resistance is preferred when organizing tennis-specific strength training programs(103).

2.5.2. Aerobic

2.5.2.1. Muscular Endurance

Muscle strength is defined as the resistance of the muscle to the work performed. Muscular endurance is the muscle's ability to repeat a movement or the ability to maintain a tension for the expected duration(108).

If the endurance is low, the muscle becomes fatigued, and the way to minimize fatigue during the match is to increase endurance. There are three types of endurance; Short term, long term and power. In order to obtain explosive strength in tennis and to prevent fatigue from repetitive movements, players must improve strength endurance.

Strength training creates a high amount of low speed while the endurance training creates a low amount of high speed muscle contraction(109).

2.5.2.2. Aerobic Endurance

Aerobic capacity / power is the maximal oxygen transport and the muscle tissue's capacity to use oxygen. Aerobic power is also an index of cardiovascular system capacity.

Aerobic capacity can also be defined as the capacity to deliver the oxygen required to the muscles to generate the energy needed during exercise(110).

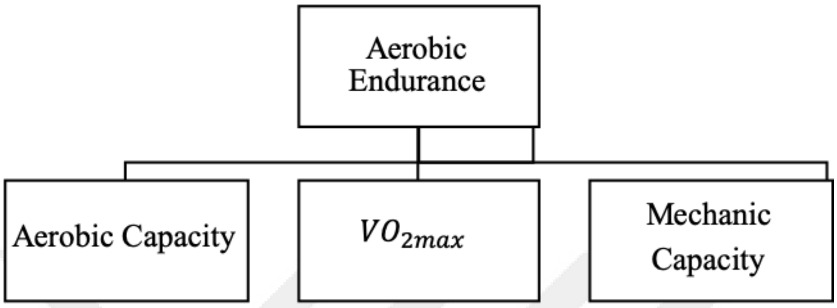


Figure 2.19: Aerobic Endurance Parameters (110)

The diagram shown in Figure 2.19 has determinants of durability performance. Trainings aimed at improving endurance performance should be directed towards the development of these three components.

The endurance capacity of the athlete is demonstrated by anaerobic capacity or ability to generate energy while in an oxygenated environment. The athlete's ability to carry O_2 is limited to aerobic strength. Therefore, the O_2 delivery system should be increased to improve the endurance capacity of the athlete(111).

Cardiovascular endurance can be defined as the ability of the athlete to resist fatigue in long-term activities. This level of resistance depends on the working quality of the cardiovascular and respiratory systems. Aerobic working capacity develops in childhood depending on lifestyle and cardiovascular system functioning(112).

To use VO_2max effectively, a maximum heart rate of 80-90% or 90-95% of VO_2max is required. During the tennis match, 46-56% of VO2max occurs with oxygen uptake and an average heart rate of 140 - 160 beats per minute. Therefore, the stimulus required to increase aerobic capacity during the match is not provided, this parameter should be developed separately(113).

2.5.3. Coordinative Skills

Skills that require coordination are revealed as a result of "learning processes". Coordination ability is an element of physical performance ability and belongs to the psycho-motor performance group. In the classification of skills according to environmental conditions, open skills occur when the environmental conditions are variable and unpredictable throughout the movement, while closed skills occur in constant and predictable environmental conditions. In the classification of skills according to the construction of the movement, continuous skills occur during continuous movements and broken skills are formed by performing independent movements one after the other. Series of skills are the combination of continuous and discontinuous skills. Tennis sport requires broken skills due to its style of play. The learning stage should consist of closed skills training, and intermediate and advanced levels should include studies that require open skills(114).

The reaction time is part of the movement speed. It is the time from the stimulus to the conscious movement. It is based on neurophysiological properties. It consists of stimuli such as visual, auditory and sensory. Simple reactions can be shortened by training between 10-15% and complex reactions by 30-40%(115).

According to the study conducted by Mustafa Söğüt et al., motor coordination and service speed were found to be correlated. Increasing motor coordination will increase the service speed for tennis players(116). Gürhan Suna et al. found that coordination training positively affected balance, speed and agility characteristics of male tennis players(117). Therefore, coordination exercises are needed during training to improve performance.

2.5.3.1. Balance

The balance is that the body maintains the position of the center of gravity vertically on the support base and performs neuromuscular actions coordinated by rapid, continuous feedback from visual, vestibular and somatosensory structures. There are two types of balance, static and dynamic. Static balance is the ability to maintain stability and maintain posture with minimal movement. Dynamic balance is the state of maintaining balance with minimum movement on an unstable surface while maintaining or recovering the fixed position(118).

Balance is important for dynamic sports, such as tennis, which involve sudden direction changes in the movement pattern. The continuity of the position before the explosive force is established is achieved by balance(119). When the games last for 2-3 hours, it becomes difficult to maintain balance for a long time(120). Researches show that 80% of the mistakes in tennis are caused by the deterioration of the balance during the hit to the ball. Mistakes such as strokes being made too far or too close to the body, bad position of the elbow, elevation of the shoulders are usually caused by loss of balance(119).

Strong postural control is required for good balance. Postural control is the integration of the central nervous system, sensory inputs from the somatosensory, visual and vestibular systems, and subsequent generation of appropriate motor outputs(121). Sensory and motor response strategies for postural control are shown in Figure 2.20 (122).

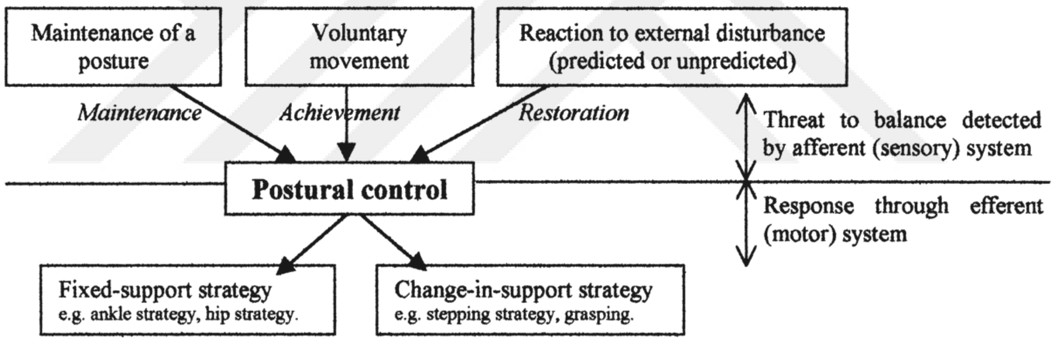


Figure 2.20: Classes of function requiring postural control and postural control strategies(122).

The contribution of improved motor or sensory function to balance performance is not fully known. Proprioception, in other words of saying the sense of joint position, is part of the sensory system that provides information about detecting joint movement and is a component of the balance system. It has been questioned whether proprioception can actually be improved with exercise, and it has been concluded that athletes may be more capable of focusing and participating in important sensory cues by producing refined motor responses(122).

Balance training can lead to specific neural adaptations at the spinal and supraspinal levels. Inhibition of muscle stretch reflexes may increase agonist-antagonist muscle contraction, which increases joint stiffness, stabilizes joints against perturbations, and consequently increases balance. Balance training is thought to cause a shift from cortical to subcortical and cerebellar structures in motion control(123).

Balance training was found to increase the activation of the rectus femoris during the jump. This suggests that equilibrium development during activities involving eccentric and concentric phase may improve performance(124). Motor balance (mobility, quickness and endurance) during balance measurements has been shown to affect balance in athletes(125).

2.5.3.2. Flexibility

Flexibility is an important component of physical fitness for competitive and recreational athletes, such as tennis players. It is a performance determinant that allows you to move freely over a wide range of motion during activity. Increased range of motion allows athletes to increase the distance applied to muscle strength(126).

It is controversial whether the reduced flexibility of players adversely affects performance, but increases the risk of injury. The flexibility of the muscles that form the shoulder girdle is important for tennis players who perform shoulder movements in succession. Players often found a decrease in the range of motion (ROM) of the internal rotation and an increase in the external rotation of the dominant shoulder(127).

The only hit in tennis controlled 100% by the player is service hit. During the service, forces must be transferred from the ground through the kinetic chain to the ball. Lack of optimum flexibility results in strain on the joints during force transfer and increases the risk of injury(128).

Static or dynamic stretching exercises are used to increase flexibility. Static stretching exercises are static stretching, passive stretching, active stretching, proprioceptive neuromuscular facilitation and isometric stretching. Dynamic stretching exercises are ballistic stretching, dynamic stretching and isolated active stretching.

Static stretching exercises have been reported to reduce muscle performance when administered before maximum muscle activities. It is not yet understood why static stretching causes power loss, but power loss has been associated with viscoelastic changes in tendons, neuromuscular factors, reduced activation of the motor unit and reflex sensitivity. According to Bompa (2001), static stretching exercises adversely affect power due to the decrease in myotatic reflex sensitivity when applied for more than 15 minutes(129).

Dynamic stretching exercises have a positive effect on muscle strength development. Although the mechanisms of action in power development are not fully defined, two possible explanations are emphasized. One of the explanations; heat increase in muscles positively affects glycogenesis, glycolysis, high energy phosphate degradation, which positively affects the relationship between strength and speed. Another possibility is that neuromuscular activities resulting from dynamic stretching exercises contribute to other factors that increase muscle strength(130).

Although there is evidence that pre-activity stretching exercises do not improve performance, stretching is a common activity used in pre-sport warm-up routines. Recent studies have shown that stretching leads to significant reductions in muscle strength and jumping performance. This lasts for about 60 minutes and is thought to be due to changes in reflex sensitivity, muscle tension, and neuromuscular activation. If this effect is evident in the tennis match, complete muscle performance may return to the end of the second set(131).

3. MATERIAL AND METHOD

3.1. Experimental Groups and Study Design

The sample of the study consists of 40 athletes between 18-50 years old who have been playing tennis actively for at least 1 year at Enka Sports Club in Istanbul and have been training more than 2 hours per week.

40 participants are 19 women (47.5%) and 21 men (52.5%). The average age of students was 32.1 ± 9.73 years. Average weight was 69.8 ± 13.97 kg. The average height was 173 ± 0.08 cm. The average BMI was 23.15 ± 3.44 kg / m2.

As a result of the evaluations made before the pre-test, participant's information such as age, height and BMI are given in Table 3.1.

Table 3.1: Distribution of average Age, Height, Weight, and BMI Values in tennis players.

	Mean ± SD	**Min-max**
Age (yr)	32.10+9.73	20.00-49.00
Weight (kg)	69.87 + 13.97	45.00 - 98.00
Height (cm)	1.73 + 0.08	1.59 - 1.90
BMI (kg/m2)	23.15+ 3.44	16.33 - 30.10

Standard warm-up program was applied to 40 selected athletes before the test. The warm-up program consisted of versatile shoulder movements; 10 repetition flexion-abduction-push-ups on the wall.

Then, 3 randomly selected performance tests were performed. After the tests, the stabilization of the core was measured with the stabilizing device.

3.1.1. Inclusion Criteria

- 18-50 years.
- Playing tennis for 2 hours or more per week for at least 1 year.

3.1.2. Exclusion Criteria

- Shoulder dislocation,
- Presence of cardiac or neurological deficit,
- The presence of major traumatic orthopedic surgery in the upper and lower extremities (long bone fracture, repaired muscle rupture, intraarticular fracture, fracture to disrupt range of motion),
- Inhibition of participation in sports due to skeletal-muscle pain in the last 6 months,
- To participate in the rehabilitation program within the last 6 months due to a skeletal-muscle problem.

The study protocol was approved by Yeditepe University Ethics Committee on 28.02.19 and its publication number was 1588 . Participants voluntarily participated in the study. The form containing the explanations regarding the purpose and plan of the study was explained to the participants and their signatures were obtained (Appendix 8.3).

3.2.Evaluation

3.2.1.Survey Questioning Demographic Characteristics of Participants

The questionnaire prepared by the researchers and applied face to face includes: age, height, weight, gender, occupation, education level, marital status, chronic diseases history, family history, medication use history, and questions about smoking habits.

3.2.2.Upper Extremity Performance Tests Measurements

In this study, upper extremity performance of tennis players was examined. The balance, strength, endurance and stabilization characteristics of the athletes were evaluated by Y balance upper extremity test, seated medicine ball throw test, closed kinetic chain upper extremity stabilization test.

Before the measurement of the tests, a warm-up program consisting of 10 repetition flexion-abduction-wall push-up movements was applied to the subjects.

Necessary recovery times were provided between tests and test trials.

3.2.2.1.Y Balance Upper Extremity Test

This is a closed kinetic chain functional screening test for upper extremity. The test evaluates the parameters of balance, functional mobility, range of motion and strength of the upper extremity.

Prior to the test, the upper extremity length of the participants, the arm standing at 90 ° abduction, the elbows extended and the thumb pointing up, was measured separately from the C7 for the right / left arm based on the most distal point of the middle finger.

3 strips with 135-135-45 degrees of angles were attached to the ground. Participants took a three-point position with the shoulder perpendicular to the tested wrist and the feet wide open. The farthest points where the moving arm can extend in medial(M), inferolateral(IL), superolateral(SL) directions were marked and recorded in centimeters. After two application trials, three test runs were performed for each side with 30 seconds of rest between each trial. The test was repeated when the participant fails to maintain the three-point contact. The average of 3 test runs was recorded (Figure 3.1) (132).

Figure 3.1: YBT-UQ directions.

3.2.2.2. Seated Medicine Ball Throw Test

It is an open kinetic chain functional screening test to evaluate the power of the bilateral upper extremity.

During the test, both muscular strength and power in the shoulder flexors (anterior deltoid) and elbow extensors (triceps brachii, anconeus) were needed to be succesful.

The participants lean on the wall as their head, shoulders and back touching it. The 2 kg ball was held in a 90 degree shoulder abduction and wrist flexion position. The participants tried to throw the weight ball straight ahead as far as possible, keeping the head and shoulders in contact with the wall. After three application trials, four test trials were performed with a 1 min rest between each trial. The distance between the wall and the ball to the ground was calculated and recorded. The four test trials were averaged (Figure 3.2)(133).

Figure 3.2: SMBT.

3.2.2.3. Closed Kinetic Chain Upper Extremity Stabilization Test

It is a closed kinetic chain physical performance test for upper extremity. Evaluates the strength, endurance and stabilization parameters of the upper extremity(134).

The instability that may occur during the measurement is related to the athlete's balance, muscle strength and coordination skills.

The test consists of load and swing phases. The position of the scapula during the load and swing phases of the test is internal rotation, upward rotation and posterior tilt. In the middle of the load and swing phase, the scapular internal rotation reaches its maximum level. Upward rotation increases in the swing phase relative to the load phase. The posterior tilt decreases in the swing phase compared to the load phase (135). Muscles activated in the upper extremity during the test: anterior deltoid, pectoralis major, biceps brachi, triceps brachi, upper trapezius, serratus anterior, posterior deltoid (136).

For testing, 2 tapes of 91.4 cm were attached to the floor. The subjects were positioned with the hands on the band, with the wrist shoulder level perpendicular to each other, with the feet open at the shoulder width. With the dominant hand, the non-dominant hand was touched and returned to the starting position. The same thing is repeated with the other hand. Participants were instructed to make as many alternate touches as possible within 15 seconds while maintaining the correct push-up position. After a submaximal lapping trial, 3 maximum performance trials were performed with a 45 second rest between them, and the 3 trials were averaged. The results were saved numerically (Figure 3.3)(135).

Figure 3.3: CKCUES.

3.2.2.3. Core Stabilization Measurement

A “Chattanooga Corporation, Hixson, Tennessee” stabilizer device was used to measure core stabilization.

Before the test, the participants were laid down. The wall goniometer was positioned so that it is aligned with the participant's large torachanter. Posterior and anterior pelvic tilt positions were taught. After learning the participant position, the device was placed under the waist and the pressure of the device was adjusted to 40 manometers. The investigator then raises the subject's legs with the knees extended, with the hip flexed 90 degrees. The investigator slowly releases the subject's legs and asked the subject to lower them without his or her control, while maintaining the pressure of 40 manometers. The subject's legs were held at the point where the pressure begins to fall. The angle between the legs and the floor was measured and recorded from the wall goniometer. If the test is performed incorrectly, it was repeated after a 4-minute interval (Figure 3.4)(137).

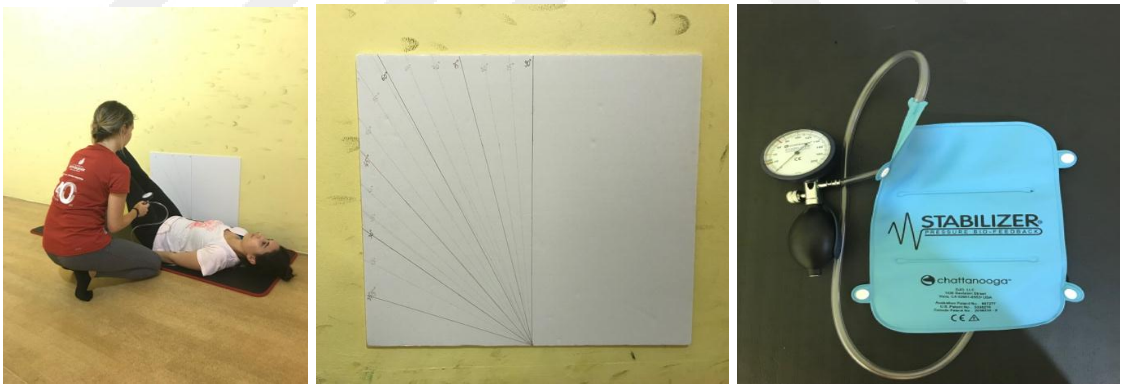


Figure 3.4: Core stability measurement and instrument.

4. RESULTS

DESCRIPTIVE STATISTCS

Physical and Sociodemographic Features

The study included 40 tennis players who were 19 women (47.5%) and 21 men (52.5%). Mean age of students was 32.1 ± 9.73 years (min 20 years, max 49 years).

When we group by age, there are 15 (37.5%) between 18-25 years, 8 (20%) between 26-33 years and 17 (42.5%) between 34-50 years.

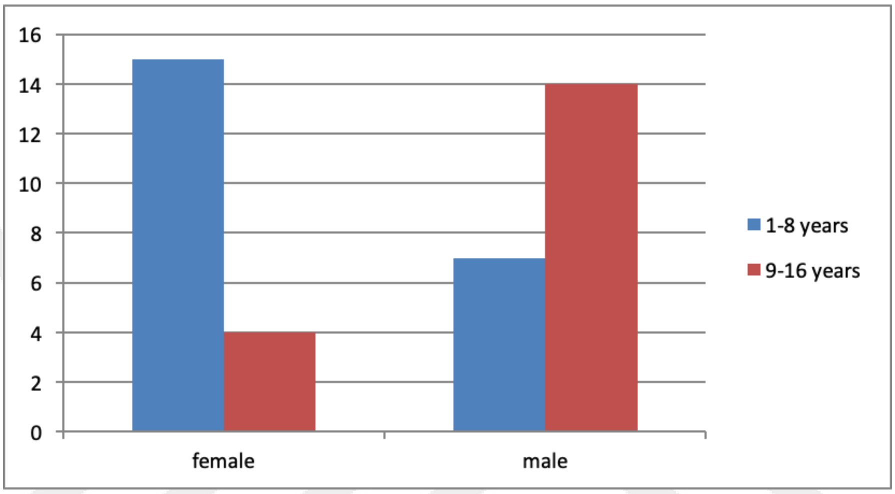
Table 4.1: Physical properties of participants.

		N	**%**
Gender	Women	19	47.5
	Men	21	52.5
Age	18-25	15	37.5
	26-33	8	20.0
	34-50	17	42.5
Smoking Habbits	Non smoker	21	52.5
	Former smoker	5	12.5
	Smoking more than 15 cigarettes in a day	3	7.5
	Smoking less than 15 cigarettes in a day	11	27.5
Medication use in last one month	Yes	23	57.5
	No	17	42.5

Twenty-one (52.5%) of the participants were non-smokers, 5 (12.5%) had former smoker, 3 (7.5%) smokes more than 15 cigarettes per day, and 11 (27.5%) smokes less than 15 cigarettes per day.

When drug use in the last 1 month was questioned; 23 (57.5%) used drugs and 17 (42.5%) did not use.

Table 4.2: Tennis experience of players as years according to gender



When the participants were grouped by tennis experience in years; group1 (1-8 years) and group2 (9-16 years).

The group1 included 22 tennis players who were 15 women and 7 men.

The group2 included 18 tennis players who were 4 women and 14 men.

Table 4.3: Descriptive analysis (mean and SDs) of the results for YBT-UQ (cm), CKUEST (number of touches), SMBT (cm) tests and core stability measurement scores for athletes divided by playing tennis years.

	Grup 1 (1-8 year) Mean ± SD	**Grup 2 (9-16 year)** Mean ± SD	**t**	**p**
Core Measures	49.54+7.40	39.38+4.97	**t:** 4.96	**0.00**
CKCUES	20.88+4.17	26.83+4.86	**t:** -4.16	**0.00**
SMBT	407.18+116.43	587.36+77.94	**t:** -5.61	**0.00**
M-right	117.68+13.94	122.27+12.65	**t:** -1.07	0.28
IL-right	69.86+21.36	65.63+13.00	**t:** 0.73	0.46
SL-right	68.81+13.36	82.58+15.69	**t:** -2.99	**0.00**
M-left	61.62+11.03	63.89+12.53	**t:** -0.60	0.54
IL-left	123.56+14.36	116.45+15.03	**t:** 1.52	0.13
SL-left	73.17+19.46	88.76+24.77	**t:** -2.23	**0.03**

Tests for the participants: CKCUES (closed chain upper extremity stability test), SMBT (seated medicine ball shot), YBT-UQ (Y balance upper extremity test). Core stabilization was measured. The distribution of measurements and tests (group 1: 1-8 years, group 2: 9-16 years) according to tennis years is given in table 4.5.

The SL-left/right components of YBT-UQ test and core stabilization measurement, SBMT, CKCUES tests were significantly better in group 2 than group 1 (p <0.05).

Table 4.4: Descriptive analysis (mean and SDs) of the results for YBT-UQ (cm), CKUES (number of touches), SMBT (cm) tests and core stability measurement scores for athletes divided by sex differences category.

	Grup 1 Female Mean ± SD	**Grup 2 Male** Mean ± SD	**t/z**	**p**
Core Measures	50.63 + 6.46	39.71 + 5.98	**t:** 5.52	**0.00**
CKCUES	20.17 + 4.11	26.60 + 4.45	**t:** -4.74	**0.00**
SMBT	374.94 + 73.07	585.48 + 90.30	**t:** -8.13	**0.00**
IL-left	63.80 + 10.99	60.63 + 11.73	**t:** 0.88	0.38
M-left	127.90 + 11.96	114.62 + 13.53	**t:** 3.29	**0.00**
SL-right	70.94 + 12.88	77.19 + 16.17	**t:** -1.35	0.18
IL-right	120.58 + 12.14	119.32 + 13.88	**z:** -0.48	0.62
M-right	72.97 + 15.85	62.17 + 10.73	**z:** -2.58	**0.01**
SL-left	72.69 + 15.45	82.57 + 24.79	**z:** -0.93	0.35

Tests applied to the participants; CKCUES (closed chain upper extremity stability test), SMBT (seated medicine ball throw), YBT-UQ (Y balance upper extremity test). Core stabilization was measured. The distribution of the measurements and tests performed by gender (group1: female, group2: male) is given in the table 4.6.

The M-left component of YBT-UQ test and core stabilization measurement was significantly better in females than males (p <0.05). The results of CKCUES and SMBT tests were significantly better in males than in females (p <0.05)

Table 4.5: Descriptive analysis (mean and SDs) of the results for YBT-UQ (cm), CKUEST (number of touches), SMBT (cm) tests and core stability measurement scores for athletes divided by age category.

	Grup 1 (18-25) Mean+SD	**Grup 2 (26-33)** Mean+SD	**Grup 3 (34-50)** Mean+SD	**f/h**	**p**
CKCUES	24.06 + 5.51	21.21+4.09	24.20+5.67	**f:** 1.98	0.11
SMBT	469.80+131.44	451.50+149.21	515.30+131.24	**f:** 4.12	**0.00**
Core Measures	45.93+7.89	46.37+10.05	43.29+7.90	**f:** 5.22	**0.00**
M-left	121.90+15.45	121.28+13.88	119.90+14.29	**f:** 0.63	0.64
IL-left	65.71+11.19	58.19+13.74	60.85+10.02	**f:** 3.48	**0.01**
SL-right	79.44+14.74	64.44+15.59	74.22+12.96	**f:** 6.03	**0.00**
M-right	70.17+9.08	64.88+16.93	65.91+17.00	**h:**3.71	0.15
IL-right	118.56+14.64	123.84+12.05	119.27+12.11	**h:**1.77	0.41
SL-left	86.49+20.69	60.40+12.82	78.50+20.70	**h:**9.19	**0.01**

When the participants were grouped by age; group1- (18-25), group2- (26-33), group3- (34-50). According to SMBT test, a significant difference was found between group3> group1> group2 (p <0.05). A significant difference was found between group2> group1> group3 according to core stabilization measurement (p <0.05). There was a significant difference between group1> group3> group2 for the IL-left, SL-right and SL-left values of the YBT-UQ test ($p < 0.05$).

Correlation analysis was performed to examine the relationship between CKCUES, SMBT, YBT-UQ test, core stabilization measurement, age, number of years in playing tennis. There was a positive correlation between number of years in playing tennis between SBMT, CKCUES, SL-right/left values ($p < 0.05$).

There was a negative correlation between core stability measurement and number of years in playing tennis, SBMT, CKCUES, SL-right/left values ($p < 0.05$). Because the lower stability value represents a better score.

A positive correlation was found between SMBT and CKCUES, SL right / left values ($p < 0.05$). Also a positive correlation was found between CKCUES and SL right / left values ($p < 0.05$).

Table 4.6: Pearson Correlation analysis between age, tennis experience in years, core measures, SMBT, CKCUES and YBT-UQ tests.

		1	2	3	4	5	6	7	8	9	10	11
1.Age	PC	1										
	Sig.(2-tailed)											
2.Tennis Experience in Years	PC	.118	1									
	Sig.(2-tailed)	.468										
3.Core Measures	PC	-.174	-.628	1								
	Sig.(2-tailed).	.284	**.000**									
4.SMBT	PC	.192.	.673	-.978	1							
	Sig.(2-tailed)	.235	**.000**	**.000**								
5.CKCUES	PC	.002	.560	-.712	.722	1						
	Sig.(2-tailed)	.990	**.000**	**.000**	**.000**							
6.M-right	PC	.117	.172	-.225.	.229.	.278	1					
	Sig.(2-tailed)	.472	.288	.164	.155	.083						
7.IL-right	PC	.128	.118	.266	.286	.238	.035	1				
	Sig.(2-tailed)	.431	.467	.097	.073	.140	.832					
8.SL-right	PC.	.108	.437	-.482	.451	.424	.434	.281	1			
	Sig.(2-tailed)	.509	**.005**	**.002**	**.004**	**.006**	**.005**	**.079**				
9.M-left	PC	.313	.098	-.057	. 007	.196	.283.	.409	.367.	1		
	Sig.(2-tailed)	.050	.547	.729	.967	.226	.077	**.009**	**.020**			
10.IL-left	PC	.151	.240	-.207	.253	.126	.296	.217	.072	.472	1	
	Sig.(2-tailed)	.354	.135	.200	.115	.440	.063	.179	.658	.002		
11.SL-left	PC	.146	.340.	-.472	.432	.421	.426	.062	.854	.305	.154	1
	Sig.(2-tailed)	.370	**.032**	**.002**	**.005**	**.007**	**.006**	.704	**.000**	.055	.341	

5.DISCUSSION

In this study, the relationship between upper extremity performance tests and core stabilization of 40 tennis players was evaluated. Results were analyzed according to age, gender and tennis experience in years.

COL Deydre S. Teyhen et al. In their study to investigate the effect on strength, balance, flexibility and functional movement, they found that there was no significant difference between age and YBT-UQ test, whereas men's performance was significantly better than women(138). In our study, evaluations according to , M-left value of YBT-UQ test in women was found to be better than men. According to the evaluations per age, IL-left, SL-right and SL-left values of the YBT-UQ test, group1> group3> group2 were found to be significantly different.This difference may be due to the differences in demographic characteristics between male and female participants, and how often the participants played tennis.

In 2010, Robert M. Malina and colleagues conducted four tests to assess the functional capacity of 309 athletics students. One of the tests is the SMBT test. The test results were evaluated by gender and the performance of men was found to be better than that of women(139). In our study SMBT tests were found to be significantly better in men than in women. This study supports our findings.

Chris Sharrock et al. evaluated 35 student athletes core stabilization, including tennis players. According to the data obtained from this study, males scored higher on average in the core stabilization test than females. In our study find core stabilization measurement was significantly better in females than males. In a study conducted by Chris Sharrock et al., there is no data for height and weight measurements of the subjects. It is thought that there may be a relationship between these variables and core stabilization(137). The reason for this difference between male and female participants may be the frequency of playing tennis and the differences in training.

Leetun et al. Reported that males had a higher core strength in consideration of postural differences in pelvis compared to females and bone structure. Minor changes in the pulling angle of the muscles on the pelvis may result in reduced ability to control the trunk. This may lead to gender differences(140).

In a study conducted by Richard B. Westrick et al., on 30 college students, YBT-UQ test, CKCUES test, trunk rotation test, shoulder active range of motion and isometric muscle strength test, shoulder mobility access test, trunk rotation test, trunk extensor endurance test, lateral trunk endurance test and trunk flexor endurance test were used as a closed kinetic chain performance test. As a result of the study Richard B. Westrick et al found a significant relationship between YBT-UQ and CKCUES tests (141). In our study, a significant relationship was found between YBT-UQ and CKCUES tests. The results support our study.

Dorien Borms et al in their performance evaluation performed on 206 (volleyball, tennis, handball) overhead athletes; YBT-UQ, CKCUES and SMBT tests were used. They concluded that there was a little correlation between the tests.In our study a significant relationship was found between CKCUES and SMBT tests. A significant correlation was found between SBMT and CKCUES tests and YBT-UQ test in the direction of anterior reach for the right / left arm. The findings of this study support our study)(142).

Core stabilization was measured with the stabilizer in a double lowering position on the back. There is no test considered to be the gold standard in the measurement of core stabilization, but the double-leg lowering test is considered a valid and reliable test in the literatüre(142).

Improvements in lower back injuries as a result of increasing core stabilization have been reported in the literature. Few studies, however, correlate core stabilization with sporting performance(143).

According to a review by Sheri P. Silfies et al, a limited number of studies support the relationship between core stabilization and upper extremity athletic performances of baseball, football and swimming athletes(12).

Chris Sharrock et al. evaluated the relationship between core stabilization and athletic performance in a group of 35 people, including basketball, soccer, tennis, volleyball and swimming players. To measure the core stabilization, the stabilizer used to tests for athletic performance (SMBT, vertical jump, forty yard dash). There was a correlation between core stabilization test and SMBT, vertical jump, forty yard dash tests, but they indicated that more research is needed to give a definitive answer about the quality of this relationship(144).The findings of this study support our study because we as well found correlation between core stabilization test and SMBT test.

In this study, there was a negative correlation between core stabilization values of players and SMBT, CKCUES, YBT-UQ test right / left arm anterior reach direction values. Because the lower mean value represents a better score.

In the literature, studies showing the effects of core stabilization measurement, SMBT, YBT-UQ and CKCUES tests on body composition have been rarely encountered. The results of the studies reveal different results, and the reason for this difference is thought to be related the experimental groups.

Limitations of the Study

There are some limitations in this study. We needed more participants who are elite tennis athletes. The latest age category of the study was between 34-50 which can be considered as a quite wide range. Due to this, the age range could be divided into two groups as 34-41 years and 42-50 years. Yet, since the number of participants are not enaugh, those two groups were merged into one age category. Although this should be considered as a limitation, we believe that the number of participants represents the actual trends in the population. Other than this, another tests might be used to test core stabilization.

Medicine ball throw test was not evaluated in overhead position. In the sitting position test, we aimed to eliminate the muscles of the trunk and to emphasize arm muscle strength. Upper extremity muscle strength was not measured separately.

Low back pain was not questioned while assessing core stabilization.

Further studies are needed in the literature to support the conclusion that core stabilization needs to be strengthened to improve the performance of tennis players.

6. CONCULUSION

Summarizing the findings, it can be said that players with good core stabilization perform better during CKCUES and SMBT tests and YBT-UQ test right / left arm SL reach direction values. Correlation between core stabilization and right / left arm and IL /M extension directions of YBT-UQ test was not significant.

During the acceleration and follow-through phases of service shot, the player should be able to reach forward towards the superior direction. The correlation between core stabilization and right/left arm and IL/M extension directions of YBT-UQ test shows us that a strong core stabilization is needed for a good servise shot.

Although there are few studies in the related literature, the results of the present studies indicate that tennis players need a strong core to improve their upper extremity balance, stabilization and shooting performance. However, further studies are needed regarding the relationship between upper extremity performance components and core stabilization.

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8. APPENDIX

Appendix 8.1

Personal Informations

Name	Sesil Berke	**Surname**	Doğruöz
Place of Birth	Bartın	**Date of Birth**	04.06.1993
Nationality	Turkish	**TR ID Number**	18302892520
E-mail	sesilberke@gmail.com	**Phone number**	05383407014

Education

Degree	Department	The name of the Institution Graduated From	Graduation year
Doctorate			
Master			
University	Physical Therapy and Rehabilitation	**İstanbul Medipol University**	2016
High school	Science	**Bartın Science High School**	2011

Work Experience (Sort from present to past)

Position	Institute	Duration (Year - Year)
Physical Therapist	Anima Rapha Manual Therapy Center	2017-2019
		-

Appendix 8.2

TARİH:

Demografik Bilgi Formu

ADI-SOYADI:

CİNSİYET:

YAŞ: **Adres :**

BOY:

KİLO:

ÖZGEÇMİŞ: **Telefon:**

SOYGEÇMİŞ:

Kaç yıldır, haftada kaç gün tenis oynuyorsunuz?

Son bir ay içinde ilaç kullandınız mı?

EVET HAYIR

MEDENİ DURUM:

-HİÇ EVLENMEMİŞ -EVLİ -DUL/BOŞANMIŞ

EĞİTİM DURUMU:

-OKUR-YAZAR DEĞİL -OKUR-YAZAR -İLKOKUL -ORTAOKUL

SİGARA:

-HİÇ İÇMEMİŞ -DAHA ÖNCE İÇMİŞ

-GÜNDE 15 SİGARADAN FAZLA-GÜNDE 15 SİGARADAN AZ

MESLEK:

Appendix 8.3

Tenis Oyuncularında Üst Ekstremite Performans Testleri ve Kor Stabilizasyonu Arasındaki İlişki

ARAŞTIRMAYA KATILIM ONAM FORMU

Bu çalışma Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Bölümü tarafından yürütülen **"Tenis oyuncularında üst ekstremite performans testleri ve kor stabilizasyonu arasındaki ilişki"** başlıklı araştırma kapsamında planlanmıştır. Bu çalışmanın amacı, kor stabilizasyonu ile üst ekstremite performans testleri arasındaki ilişkinin belirlenmesidir. Çalışmamıza katılmayı kabul eden gönüllü sporcuların; yaşı, cinsiyeti, sosyo-demografik koşulları, var olan hastalıkları, geçirilen cerrahi durumları, yaralanmalarına dair bilgiye ulaşılarak, çalışma grubuna dahil edilecektir. Ve belirlenen parametreler kapsamında değerlendirilecektir.

Araştırma ile ilgili sizden doldurmanızı istediğimiz formları doğru bir şekilde doldurmanızı ve herhangi bir şikayetiniz ya da rahatsızlığınız olduğunda bize bildirmeniz gerekmektedir. İstediğiniz zaman çalışma dışına çıkma hakkınız olduğunu bilmenizi isteriz. Bu araştırma kapsamında yapılacak olan değerlendirmelerde herhangi bir risk bulunmamakta ve yapılacak hiçbir değerlendirme size zarar vermeyecektir. Bu araştırma dahilinde sizden herhangi bir ücret talep edilmemektedir. Bu araştırmada yer almanız nedeniyle size hiçbir ödeme yapılmayacaktır. Kişisel bilgileriniz herhangi bir amaçla, kurum yöneticileri veya üçüncü kişilerle paylaşılmayacaktır.

Katılımınız için teşekkür ederiz.

Sorumlu araştırmacı: Dr.Öğr.Üyesi Şule BADİLLİ DEMİRBAŞ

Yardımcı Araştırmacı: Fzt. Sesil Berke DOĞRUÖZ – 0538 340 70 14 (24 saat ulaşılabilecek kişi)

"Tenis oyuncularında üst ekstremite performans testleri ve kor stabilizasyonu arasındaki ilişki" isimli çalışmada katılımcıya/gönüllüye verilmesi gereken bilgileri okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. **Çalışma hakkında yazılı ve sözlü açıklama adı belirtilen araştırmacı tarafından yapıldı.** Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Gönüllünün Adı /Soyadı /İmzası /Tarih

Açıklama Yapan Kişinin Adı /Soyadı /İmzası /Tarih

Appendix 8.4

T.C. YEDİTEPE ÜNİVERSİTESİ

Sayı : 37068608-6100-15- 1618 **28/02/2019**
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

İlgili Makama (Sesil Berke Doğruöz)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü Dr. Öğr. Üyesi Şule Badıllı Demirbaş'ın sorumlu olduğu **"Tenis Oyuncularında Üst Ekstremite Performans Testleri ve Kor Stabilizasyonu Arasındaki İlişki"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası (**1588** kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **27.02.2019** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 970**).

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Klinik Araştırmalar Etik Kurulu Başkanı

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