

Comparison of The Effects of Clay and Hard Surface Court Tennis Training on  
Leg Strength

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ORIGINAL ARTICLE

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**Abstract**

Tennis is a high-paced sport that demands considerable physical capabilities, including muscular strength, which plays a vital role in movement efficiency and injury prevention. Court surface type hard or clay may influence physical performance. This study aimed to investigate the effects of playing on hard and clay courts on the isokinetic strength of the quadriceps and hamstring muscle groups in novice male tennis players. Twelve novice male tennis players participated in this crossover-designed study (mean age: 22.67 ± 1.371 years; height: 179.42 ± 6.360 cm; body weight: 72.92 ± 5.807 kg; body mass index: 22.66 ± 1.696 kg/m<sup>2</sup>). Each participant completed a 1-hour standardized tennis training session on both hard and clay courts, with a 3-day interval between sessions. The training consisted of five structured drills emphasizing stroke execution and on-court movement. Prior to testing, all participants underwent three familiarization trials with the test procedure. Fifteen minutes after each session, isokinetic strength testing of the dominant leg was performed using a Cybex NORM® isokinetic dynamometer, measuring concentric and eccentric peak torque values (Nm) of the quadriceps and hamstring muscles at an angular velocity of 60°/s. Statistical comparison between the two surfaces was conducted using a paired samples t-test, with significance set at p < 0.05. No statistically significant differences were found between hard and clay courts in the concentric and eccentric strength values of the quadriceps and hamstring muscles (p > 0.05). The findings suggest that court surface type does not significantly affect isokinetic lower limb strength in novice male tennis players. Short-term training (acute effect) on different surfaces may not lead to measurable differences in muscular strength; however, further research is needed to explore long-term adaptations.

**Keywords:** Isokinetic Strength, Clay Court, Hard Court.

**Toprak ve Sert Zemin Tenis Kort Antrenmanlarının Bacak  
Kuvvetine Etkisinin Karşılaştırılması**

**Öz**

Tenis, hareket verimliliği ve sakatlanmaların önlenmesinde önemli rol oynayan kas kuvveti de dâhil olmak üzere, önemli fiziksel yeterlilikler gerektiren yüksek tempolu bir spordur. Kort yüzey tipi – sert veya toprak – fiziksel performansı etkileyebilir. Bu çalışma, sert ve toprak kortlarda oynamanın, başlangıç düzeyindeki erkek tenisçilerin kuadriseps ve hamstring kas gruplarının izokinetik kuvveti üzerindeki etkilerini incelemeyi amaçlamıştır. Bu çapraz tasarımlı çalışmaya on iki başlangıç düzeyinde erkek tenis oyuncusu katılmıştır (yaş ortalaması: 22,67 ± 1,371 yıl; boy: 179,42 ± 6,360 cm; vücut ağırlığı: 72,92 ± 5,807 kg; vücut kitle indeksi: 22,66 ± 1,696 kg/m<sup>2</sup>). Her katılımcı, seanslar arasında 3 günlük ara ile hem sert hem de toprak kortlarda 1 saatlik standart tenis antrenman seansını tamamladı. Antrenman, vuruş tekniği ve kort içi hareketi vurgulayan beş yapılandırılmış drilden oluşmuştur. Test öncesinde, tüm katılımcılar test prosedürüne üç kez alıştırmaya denemesi yaptı. Her seanstan on beş dakika sonra, baskın bacakta izokinetik kuvvet testi, kuadriseps ve hamstring kaslarının konsantrik ve eksantrik tepe tork değerlerini (Nm) 60°/s açısız hızda ölçen bir Cybex NORM® izokinetik dinamometre kullanılarak gerçekleştirilmiştir. İki kort yüzeyi arasındaki istatistiksel karşılaştırma, eşleştirilmiş örneklem t-testi ile yapılmış ve anlamlılık düzeyi p < 0.05 olarak belirlenmiştir. Sert ve toprak kortlar arasında kuadriseps ve hamstring kaslarının konsantrik ve eksantrik kuvvet değerlerinde istatistiksel olarak anlamlı bir fark bulunamamıştır (p > 0.05). Bulgular, kort yüzey tipinin acemi erkek tenisçilerde izokinetik alt ekstremite kuvvetini önemli ölçüde etkilemediğini göstermektedir. Farklı yüzeylerde yapılan kısa akut antrenman sonuçları kas kuvvetinde ölçülebilir farklılıklara yol açmayabilir; ancak uzun vadeli adaptasyonları araştırılması için daha fazla araştırmaya ihtiyaç vardır.

**Anahtar Kelimeler:** İzokinetik Kuvvet, Toprak Kort, Sert Kort.

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## Introduction

Tennis is a high-intensity intermittent sport that predominantly engages anaerobic energy systems and requires a combination of various biomotor skills, including endurance, muscular strength, agility, coordination, and speed (Parpa et al., 2022; Kaya et al., 2018). Throughout a match, players are constantly exposed to physically demanding movements such as rapid accelerations, abrupt directional shifts, and repeated jumping actions, all of which place significant strain on the body (Hoppe et al., 2014). A key variable influencing the effectiveness and intensity of these movements is the type of court surface, as it directly affects traction, stability, and overall biomechanical demands (Doğan et al., 2021). Surface characteristics not only shape the technical and tactical dynamics of play but also have a considerable impact on players' physiological responses, including energy expenditure, fatigue levels, and recovery capacity. In light of these considerations, Martin et al. (2011) highlighted that the court surface should be regarded as a central factor when developing tailored training programs for elite-level tennis athletes, as it fundamentally alters the physical and strategic requirements of the game.

Tennis is played on different types of court surfaces, including grass, hard, and clay courts, each of which has a distinct influence on the biomechanics of player movement, particularly footwork patterns (Pavailler and Horvais, 2015). The surface characteristics play a critical role in determining how the tennis ball behaves upon contact with the ground, especially in terms of bounce height and velocity (Johnson and McHugh, 2006). This behavior is largely governed by two mechanical factors: the coefficient of friction, which affects the interaction between the ball and the surface, and the coefficient of restitution, which relates to how much kinetic energy is retained after the ball hits the ground. Clay courts, categorized as slower surfaces, generally exhibit higher values for both coefficients, leading to slower but higher ball bounces compared to faster surfaces like grass (Brody, 1987). These physical properties not only influence the pace and style of play but also have broader implications for match dynamics, including the average rally length, total match time, and effective playing duration (Martin et al., 2011). As such, court surface type represents a key variable in both the technical and tactical demands of the game.

In tennis, the lower-body muscles need to be strong and resistant to fatigue because the sport relies heavily on large muscle groups. In this sport, players' ability to demonstrate superior serve performance is directly proportional to their strength characteristics (Wu et al., 2001). Strength is defined as the force generated by muscle contraction against resistance (Kaya et al., 2018). Muscular strength is critically important in tennis not only for increasing racket speed or executing powerful serves, but also for enhancing movement efficiency on the court, maintaining balance, and reducing the risk of injury (Kovacs, 2006). Specifically, the hamstring muscle group plays a key role in knee

flexion and dynamic stabilization, while the quadriceps group is responsible for knee extension. Adequate strength production by these two major muscle groups plays an essential role in achieving high-level performance during both offensive and defensive movements in tennis. Previous research has demonstrated a meaningful relationship between lower-body strength and serve performance in tennis players (Kaya et al., 2018). At the start of the tennis serve, the force generated by the lower-limb muscles is transferred sequentially through the trunk, shoulder, elbow, and wrist before reaching the racket (Elliott et al., 1995; Güzel & Can, 2022). This link between force production and performance highlights the importance of understanding factors that may influence lower-limb strength. Examining whether different court surfaces affect leg muscle strength is therefore relevant to performance development. However, the available literature contains no studies that have specifically investigated how playing surface type influences lower-limb strength. In response to this gap, the present study was designed to compare the short-term effects of training on hard and clay courts on lower-limb strength in novice male tennis players.

## Materials and Methods

### Study Design

To ensure familiarity with the experimental equipment, all participants completed the test three times during the week leading up to the experiment. This study was designed using a cross-over model in which all participants completed both surface conditions. Data collection was conducted digitally. On the initial day of testing, participants were randomly assigned into two groups (each consisting of 6 individuals). One group underwent testing 15 minutes after completing a standard 1-hour tennis training session on a clay court, while the other group was assessed following the same training session on a hard court. Three days later, the procedure was repeated, but the groups switched court surfaces. The study focused on evaluating isokinetic strength in the dominant leg. Previous research has shown that dominant and nondominant lower limbs naturally differ in strength, indicating that unilateral assessments based on the dominant leg can adequately represent lower-limb performance in many athletic populations (Ren et al., 2025). Participants were also instructed to avoid engaging in strenuous physical activity for at least 48 hours prior to each test session.

Table 1

#### Exercise Programme

| Drill Number | Drill Name                  | Description   | Duration |
|--------------|-----------------------------|---|----------|
| 1            | Lateral Rally Practice      | Players rally from side to side using both forehand and backhand strokes, with slow-paced ball feeds from the coach.              | 10 min   |
| 2            | Directional Control & Reset | Players target different court zones with each stroke, returning to a central stance between shots; coach increases feeding pace. | 15 min   |

|   |                               |  |        |
|---|-------------------------------|--|--------|
| 3 | Repetition and Rotation Drill | Every 25 consecutive hits prompt a change in position; players concentrate on maintaining rhythm and quick recovery. | 15 min |
| 4 | Partner Baseline Challenge    | In pairs, players alternate baseline rallies with built-in footwork drills, including figure-eight running patterns. | 15 min |
| 5 | Rotating Groundstrokes        | Players take turns executing forehand and backhand drives from the baseline, swapping roles after every minute.      | 5 min  |

### Study Group

A total of 12 male tennis players at the novice level voluntarily took part in this study. All participants were fully informed about the purpose of the research, the procedures to be followed, and any potential risks or discomforts, after which written informed consent was obtained. In addition to basic demographic characteristics, information regarding the players’ tennis backgrounds was collected to more clearly describe the sample. All individuals had approximately six months of tennis experience and regularly practiced for about 80 minutes per week. This training exposure met the criteria for novice-level athletes and ensured a homogeneous skill level across participants. Descriptive characteristics of the sample, including age, height, weight, and training background, are presented in Table 2 to provide a comprehensive overview of the study group.

Table 2  
Descriptives of Participants

| Parameters               | N  | Minimum | Maxium | Mean   | Std. Dev. |
|--------------------------|----|---------|--------|--------|-----------|
| Age (year)               | 12 | 21      | 25     | 22,67  | 1,371     |
| Height (cm)              | 12 | 169     | 190    | 179,42 | 6,360     |
| Body Weight (kg)         | 12 | 61      | 80     | 72,92  | 5,807     |
| BMI (kg/m <sup>2</sup> ) | 12 | 19,25   | 24,66  | 22,66  | 1,696     |

### Data Collection Tools

#### Isokinetic Strength Test

Isokinetic strength assessments of the knee joint were carried out using a Cybex NORM® isokinetic dynamometer (Humac, CA, USA) in the kinanthropometry laboratory at Selçuk University. Participants were seated securely in the testing chair, with proper alignment ensured. To minimize movement and enhance test reliability, stabilization straps were applied across the mid-thigh and upper body. For additional support, participants were instructed to hold onto the side handles attached to the chair throughout the procedure.

Testing involved the execution of movements across a full range of motion, beginning at 90° of knee flexion and extending to approximately 10°. Measurements were restricted to the dominant leg, which was identified prior to testing. Before the actual strength tests, all participants completed a familiarization phase consisting of three submaximal contractions (both concentric and eccentric) performed at an angular velocity of 60°/s, as suggested by Van Cingel et al. (2001).

To reduce the effects of muscular fatigue and ensure consistent effort across trials, participants rested for two minutes between each test condition, in line with the recommendations of Magris et al. (2024). Following the rest interval, they were asked to perform three maximal-effort repetitions at the same angular velocity, incorporating both concentric and eccentric actions of the knee joint. Standardized verbal encouragement was provided during all repetitions to maximize participant effort. The dynamometer automatically recorded the isokinetic data, and only the peak torque values (in Newton-meters) were extracted and used in the final analysis (Tatlici et al., 2024).

### ***Statistical Analysis***

Descriptive data were expressed as mean and standard deviation values. The Shapiro-Wilk test was applied to determine whether the data were normally distributed. In cases where normality assumptions were not satisfied, skewness and kurtosis values were also taken into consideration. To compare isokinetic strength outcomes between hard and clay court training conditions, a paired samples t-test was employed. Additionally, effect sizes were computed using Cohen's *d*, with the following classification criteria: small ( $0.2 \leq d < 0.5$ ), moderate ( $0.5 \leq d < 0.8$ ), and large ( $d \geq 0.8$ ) (Cohen, 1988). All statistical analyses were carried out using SPSS software, version 24.0 (SPSS Inc., Chicago, IL, USA), and the statistical significance threshold was set at  $p < 0.05$ .

### ***Ethics of Research***

Before beginning the study, all participants were clearly informed about its purpose, procedures, and any potential risks involved. Each individual voluntarily signed a written informed consent form after receiving this information. The research was carried out in full compliance with ethical guidelines and was officially approved by the Ethics Committee of Selçuk University, Faculty of Sports Sciences (Protocol No: : 62/31.05.2024). During the current research process, all procedures were conducted in accordance with the "Higher Education Institutions Scientific Research and Publication Ethics Directive".

## Findings

Table 3  
Comparison of Hard Court and Clay Court Leg Strength

| Parameters | Group | Mean (Nm) | Std. Dev. | t      | 95% Confidence Interval of the Difference |        | P     | Cohen's d |
|------------|-------|-----------|-----------|--------|---|--------|-------|-----------|
|            |       |           |           |        | Lower                                     | Upper  |       |           |
| QCon       | Hard  | 141.17    | 17.99     | 0.416  | -8.926                                    | 13.093 | 0.685 | .120      |
|            | Clay  | 139.08    | 23.97     |        |   |        |       |           |
| HCon       | Hard  | 104.17    | 30.01     | -1.074 | -26.938                                   | 9.272  | 0.306 | .030      |
|            | Clay  | 104.75    | 27.29     |        |   |        |       |           |
| QEcc       | Hard  | 162.00    | 29.91     | -0.194 | -23.713                                   | 19.879 | 0.850 | .056      |
|            | Clay  | 163.92    | 44.79     |        |   |        |       |           |
| HEcc       | Hard  | 118.50    | 28.19     | 0.372  | -11.466                                   | 16.133 | 0.717 | .107      |
|            | Clay  | 116.17    | 26.81     |        |   |        |       |           |

\*:p<0.05 Q: quadriceps, H: hamstring, Con: concentric, Ecc: eccentric

Based on the results summarized in Table 3, there were no statistically significant differences in the concentric and eccentric strength measurements of the quadriceps and hamstring muscles between training on hard and clay court surfaces ( $p > 0.05$ ). Additionally, the Cohen's d values calculated for all parameters remained within the small effect range.

## Discussion

This research set out to explore the potential impact of varying tennis court surfaces—specifically hard and clay courts—on the lower limb strength development of novice male tennis players. The primary focus was placed on examining the concentric and eccentric strength capacities of two major muscle groups involved in tennis-specific movements: the quadriceps and the hamstrings. Upon analysis of the data, no statistically significant differences were found between the two surface types in terms of the measured muscular strength parameters. That is, training on a hard court did not produce noticeably different outcomes compared to training on a clay court with regard to either concentric or eccentric contractions in the targeted muscle groups. These findings suggest that, within the scope of short-term exposure and among players at the novice level, the type of court surface may not play a decisive role in altering lower limb strength characteristics.

The absence of a statistically significant difference in the effect of court surface on lower limb strength may be explained by several factors. Firstly, muscle strength development occurs through processes such as motor unit adaptation, neuromuscular coordination, and muscle fiber hypertrophy. These types of adaptations typically require at least 4–6 weeks of regular and systematic training to occur (Fernandez-Fernandez et al., 2023). However, in this study, each training session lasted only one hour per court surface, which may have been insufficient for such adaptations to develop. In their

study, Ponzano and Gollin (2017) reported that tennis matches lasting less than 90 minutes did not lead to performance declines caused by fatigue, regardless of the playing surface.

Secondly, hard court surfaces, due to their lower energy absorption and higher ground reaction forces, lead to greater eccentric loading, particularly in the quadriceps muscle group. Therefore, hard courts may better support movements that require explosive strength. In contrast, clay courts, with their softer surface, higher energy absorption, and lower ground reaction forces, allow for longer rallies (Reid et al., 2013; Pereira et al., 2016; Kilit et al., 2024). Additionally, the slippery nature of clay courts may enhance proprioceptive muscle activation and lead to greater involvement of the hamstring and stabilizer muscles. Alexander et al. (2022) reported that lower extremity injuries were more prevalent on hard surfaces compared to clay courts among four different surface types. Similarly, Lisi et al. (2025) emphasized that clay courts are the most favorable tennis surface. The effects of such surface-related differences on muscle strength are more likely to be observed through long-term training interventions.

This study demonstrated that short-term tennis training did not lead to changes in lower limb strength. Similar findings have been reported in the literature. In a study analyzing the effects of different types of tennis court training (clay, grass, carpet, and hard courts) on physical fitness, each participant performed one hour of on-court practice. The study reported no significant differences in strength and endurance parameters among tennis players aged 14 to 16 years following training on different surfaces (Kuganesan, 2015). Similarly, Pavailler and Horvais (2015) stated that sliding on both hard and clay courts generates comparable muscular stress and that a player accustomed to sliding on clay courts may possess adequate muscular preparation for sliding on hard courts as well.

Furthermore, the current study assessed lower limb strength exclusively through isokinetic testing conducted at an angular velocity of 60°/s. Although this specific velocity is widely accepted for evaluating peak or maximal muscular strength, it does not effectively represent other crucial components of neuromuscular performance, such as reactive strength or explosive power. These qualities, which are particularly relevant in dynamic sports like tennis, may exhibit surface-dependent variability due to differences in mechanical properties such as grip, shock absorption, and energy return. Therefore, relying solely on a low-speed isokinetic protocol may have limited the sensitivity of the study in detecting subtle performance differences between training on hard versus clay courts. Supporting this interpretation, Parpa and Michaelides (2024) observed that isokinetic assessments performed at 60°/s failed to detect inter-limb asymmetries in the lower extremities of youth tennis athletes, suggesting that slow angular velocities may not be adequate for capturing certain functional or surface-specific adaptations.

This study has several limitations. The small sample size, consisting only of novice male tennis players, restricts the generalizability of the findings. In addition, the intervention consisted of a single one-hour training session on each surface, which was likely insufficient to produce meaningful neuromuscular adaptations. The use of isokinetic measurements at only one angular velocity (60°/s) may also have limited the detection of subtle differences between surfaces. Therefore, future studies should employ larger and more diverse samples and longer training durations to strengthen the validity of the results.

## **Conclusion**

In conclusion, the findings of this study revealed that short-term tennis training conducted on different court surfaces specifically hard and clay courts did not result in statistically significant differences in the isokinetic strength levels of the quadriceps and hamstring muscle groups among novice male athletes. This indicates that, over a limited duration and under controlled training intensity, court surface alone may not exert a substantial influence on lower limb strength development. The absence of measurable changes suggests that more prolonged, frequent, and physiologically demanding training interventions may be necessary to provoke meaningful neuromuscular adaptations. Therefore, it can be inferred that surface-specific strength gains may only become evident under extended and resistance-oriented training conditions. For this reason, future research is encouraged to adopt longer-term protocols incorporating diverse training loads and modalities to more comprehensively examine the role of court surface in strength progression among tennis players.

## **Ethical Approval Information**

Ethics Committee: Selçuk University Faculty of Sport Sciences Ethics Committee

Date of Approval: 31 May 2024

Approval Number: 62

## **Author Contribution Statement**

Both authors contributed equally to all stages of the study.

## **Conflict of Interest Statement**

The authors declare that there is no conflict of interest related to this research.

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