International Journal of Sport Culture and Science
September 2025 : 13(3)
ISSN : 2148-1148
Doi : 10.14486/IntJSCS.2025.754

Examination of Performance Parameters of Elite Level Players in Tennis Competitions Played on Open and Closed Courts

Sedat ÖZCAN[1], Yalçın KAYA [2]

[1] Süleyman Demirel University, Isparta, Turkey
https://orcid.org/0000-0002-0428-3883
[2] Selçuk University, Konya, Turkey
https://orcid.org/0000-0002-6983-1932

Email: sedatozcan@sdu.edu.tr, ykaya@selcuk.edu.tr

Type: Research Article (Received: 09.04.2025 – Accepted: 22.09.2025)

Abstract

This study aimed to examine the effects of different court surfaces (outdoor hard, indoor hard, and clay) on the physiological and performance parameters of elite tennis players using a GPS-based tracking system. It was hypothesized that different court surfaces would impose distinct physiological loads and performance demands, with clay courts expected to require greater endurance and higher physiological stress compared to hard court .Sixteen elite players (mean age 13.7±0.1 years, height 157.4±4.1 cm, body weight 53.9±3.9 kg, training age 9.5±0.8 years, BMI 20.5±0.01) participated voluntarily. Each player completed three matches on different courts with 72-hour rest intervals. Standardized tennis-specific warm-up and stretching protocols were applied before matches. During competition, Catapult GPS vests and Polar monitors recorded average and maximum heart rate, total running distance, sprint counts, maximum speed, distance per minute, and average speed. Data were analyzed using Shapiro-Wilk, t-tests, one-way or repeated-measures ANOVA, and Bonferroni post-hoc tests with SPSS 26. Significant differences were observed across court types. Outdoor hard courts yielded lower average and maximum heart rates compared to indoor and clay courts ($p<0.01$). Total running distance was significantly lower on indoor courts compared to outdoor and clay courts ($p<0.01$). Sprint counts were also lower on indoor courts, while outdoor courts showed lower values than clay ($p<0.01$). Maximum speed values were higher on clay compared to outdoor courts ($p<0.01$), and indoor courts were higher than clay ($p<0.05$). Distance per minute was greatest on clay courts ($p<0.01$), followed by indoor and outdoor courts. No significant differences were found in average match speeds ($p>0.05$). Court surface significantly influences physiological load and performance outcomes in tennis. These findings suggest that training and match preparation programs should consider surface-specific physical demands to optimize athlete performance.

Keywords: Catapult, Polar Team Pro, Tennis Performance

Introduction

From a historical perspective, tennis is a sport that dates back to ancient times and has evolved into one of the most popular and widely played sports today (Aktürk, 2017). Throughout its development, tennis has been regarded as an elite sport for both players and spectators.

The origins of tennis can be traced back to 13th-century France, where it was initially known as Le Jeu du Paume and was exclusively played by the nobility (Ölçücü, 2011). With its rapid development and increasing global reach, tennis became part of various international sports organizations in the 20th century. Among the most prestigious events are the Grand Slam tournaments, which include four major competitions held annually: the Australian Open (hard court) in mid-January, the French Open (Roland Garros, clay court) in late May to early June, Wimbledon (grass court) in early July, and the US Open (hard court) in late August to early September. Additionally, other significant competitions such as Masters tournaments (1,000 and 750 ranking points), the Davis Cup, and the FED Cup contribute to the sport's competitive landscape (Ölçücü, 2011). Tennis was introduced to Turkey in the early 1900s by the British. During that period, British residents in Istanbul organized a tournament called the Challenge Cup, which they won three years in a row. Initially, these tournaments were played exclusively among British expatriates. However, the construction of tennis courts in different parts of Istanbul facilitated the sport's recognition and development in Turkey (Çamlıbel, 2019).

Today, tennis can be played on various surfaces, including grass, concrete, asphalt, clay, and synthetic turf (tartan) courts (Kabasakal, 2006). The bounce height and speed of the ball vary depending on the court surface, influencing the performance of players. Some athletes achieve better results on specific court types that align with their individual playing styles. Clay courts, for example, are known as "slow courts" due to the high friction, which reduces the speed of the ball. As a result, matches played on clay courts tend to have longer rally durations, emphasizing endurance and mental resilience. Another characteristic of clay courts is that they leave visible ball marks, which help in determining line calls for uncertain shots. On the other hand, grass and hard courts allow for a lower and faster ball bounce, earning them the label of "fast courts." These courts favor players with high shot velocity and quick footwork (Eren, 2019). Tennis coaches and sports scientists often seek to determine the "ideal body type" for optimal performance in different sports. Athletes are typically compared based on weight, height, body mass index (BMI), and posture. However, in reality, not all individuals fit a single body type, and characteristics such as weight, body fat percentage, and posture can be further developed through training and exercise over time (Koronas & Tsigelidou, 2018). In tennis, explosive power and speed are critical components of athletic performance. The sport involves high-intensity, short-distance runs with frequent changes in direction. Acceleration is a key factor in determining performance over short distances. For instance, standing long jumps have been found to positively influence sprint performance in young tennis players. Therefore, incorporating standing long jump exercises into training programs in a game-like format may help enhance speed development in young athletes (Yıldız et al., 2018).

Although previous studies have examined the physiological and performance demands of tennis on different surfaces, limited research has focused on young elite players using GPS-supported tracking systems. This study aims to address this gap by providing objective data on how surface type influences performance parameters in 12–14-year-old elite tennis players.

Material and Method

Ethics Committee Permission

Ethical approval was obtained for the study from the Non-Interventional Clinical Research Ethics Committee of Selçuk University, School of Physical Education and Sports, with decision number 142 on 03.12.2021

Participants

A total of 16 elite male tennis players aged 12–14 voluntarily participated in the study. While the relatively small sample size may reduce statistical power and limit the generalizability of the results, this number reflects the inherent difficulty of accessing a narrow and specific group of elite junior athletes. The sample size is consistent with similar research in elite sports contexts. The matches were conducted on the tennis courts of Ankara Tennis Club and Ankara University. Detailed information regarding the study and its procedures was provided to the participants. Afterwards, informed consent forms were presented to both the athletes and their coaches, read thoroughly, and signed voluntarily.

Participants were selected using purposive sampling, as they met specific criteria including voluntary participation, being healthy with no injury risks, being male, having a background in tennis and being ranked at the top levels of the Turkish Tennis Federation (TTF), being between 12 and 14 years of age, not receiving medical treatment or using medication during the study, and having comparable playing skills. All participants fulfilled these requirements and volunteered to take part in the study.

Grouping of Participants

Participants' biceps and triceps strength (Cybex dynamometer) and anthropometric measures (height and weight, G-TECH) were assessed, and athletes were paired accordingly to ensure balanced competition conditions and minimize performance differences due to physical characteristics. A survey model was used to collect data, and a relational survey method to examine differences between variables.

Study Design

This research was conducted within the framework of the survey model to examine the performance parameters of elite tennis players on different court surfaces, and the relational survey model was employed to determine the differences between court types and performance variables. The participants were selected from among elite tennis players aged 12-14, who had at least 8-10 years of sports experience, were ranked at the top levels by the Turkish Tennis Federation, frequently competed against each other in tournaments, knew each other's playing styles well, and typically played closely contested matches. Each participant was trained individually at least 3 to 5 times a week. The training sessions were structured as team practices in the morning and individual training in the afternoon. Team training sessions, lasting approximately 1.5 to 2 hours, included game endurance, special point drills, deep and powerful stroke exercises, precision shots, serve, and return practices. The individual training sessions focused on addressing the athlete's personal deficiencies with their respective coaches, including strength training, strength endurance, stamina, and agility exercises. Generally, these workouts were implemented with tennis balls in practical drills. Before the measurements were taken, comprehensive information was given to the athletes about the importance of the study and the expected procedures. Players were matched for the matches based on their classification points to ensure equal playing levels and high competitiveness. The ITN test was used to perform this matching process.

Prior to each match, the athletes performed a warm-up as if preparing for an official tournament match. A 30-minute warm-up period was completed to minimize the risk of injury. Afterward, GPS devices were removed from the main unit, calibrated, and the designated devices were assigned to each player. Then, the athletes wore vests equipped with Catapult GPS devices, and the synchronization of the devices with the computer system was confirmed to ensure they were operational and ready for measurement. All matches were started simultaneously under identical weather conditions to ensure fairness. After the matches on the hard outdoor court were completed, matches on the indoor hard court and clay court followed, with players asked to pay careful attention to their nutrition, rest, and sleep routines as if they were competing in a tournament. The same strict protocol was applied for matches on each surface. A recovery period of 72 hours was given before matches on different court surfaces to ensure standardization.

Data Collection Tools

Height Measurement

The athletes' heights were measured using a stadiometer (Seca 213) with a precision of ±1 mm. Measurements were taken with the athletes barefoot, standing upright on a flat surface, feet together, and the head in the frontal plane, with the highest point of the head (vertex) aligned with the device.

Body Weight Measurement

Body weight was measured with an electronic scale (Tefal-5241) with a precision of ±0.1 kg, while the participants wore lightweight clothing that did not add extra weight. The Body Mass Index (BMI) was calculated by dividing the body weight in kilograms by the square of the height in meters.

GPS-Based Athlete Tracking System (Catapult)

A GPS-based athlete tracking system (10 Hz Sensor GPS, 200 Hz MEMS Motion Sensor) was used to monitor performance parameters, while heart rates were measured with a Polar H9 heart rate sensor and chest strap (Figures 2.2 and 2.3). The Catapult system recorded average and maximum heart rate, total running distance, sprint count, maximum speed, distance per minute, and average speed. Data were processed via the Catapult application and web service, and transferred to a computer and iPad for analysis.

Statistical Analysis

Descriptive statistics (mean, standard deviation, and median) were calculated for the data sets. The Shapiro-Wilk test was used to test for normal distribution. For small sample sizes where $p<0.05$, skewness and kurtosis values were evaluated, and values within ±1.96 were considered normally distributed.

As the observed data met the assumptions of normality and homogeneity, an independent samples t-test was used for comparisons between two independent variables, and a paired samples t-test was used for similar variables. For comparisons involving more than two independent variables, a one-way ANOVA or one-way repeated measures ANOVA was conducted.

The Bonferroni post-hoc test was applied to determine which groups caused significant differences when more than two groups were compared. All statistical analyses were performed using SPSS version 26 for Windows (IBM SPSS Statistics for Windows, Version 29.0. Armonk, NY).

Findings

In this study, three different data sets were used. The first dataset pertains to matches played on outdoor courts, the second to matches played on indoor courts, and the third to matches played on clay courts. The analysis focused on certain key performance parameters of elite-level tennis players during these matches. Statistical evaluations were conducted to determine the differences between these parameters across the different court types. The parameters that showed statistically significant differences are detailed in the tables and figures below. A significance level of $p < 0.05$ was accepted for all statistical analyses. The descriptive statistics for outdoor, indoor, and clay court performances are presented in Table 1.

Table 1. Descriptive Statistics of Participants

Group	Outdoor Court		Indoor Court		Clay Court	
	Mean ± SD	Median	Mean ± SD	Median	Mean ± SD	Median
Age (years)	13.68±0.11	13	13.68±0.11	13	13.68±0.119	13
Height (cm)	157.4 ± 4.13	158	157.38 ± 4.13	158	157.38 ± 4.13	158
Weight (kg)	53.87±3.913	53.5	53.87±3.91	53.5	53.87±3.91	53.5
BMI (Body Mass Index) (kg/m²)	20.50±0.01	21.5	20.50±0.01	21.5	20.50±0.01	21.5
Experience (years)	9.50±0.81	10	9.50±0.81	10	9.50±0.81	10
Average Heart Rate (bpm)	101.44 ± 5.69	101	106.63 ± 5.09	106.2	110.94 ± 4.83	110.5
Total Distance (m)	4364 ± 223.43	4411.1	4140.81 ± 206.08	4139.5	4505.31 ± 249.66	4506.5
Total Sprint Distance (m)	411.38 ± 18.14	414.5	381.25 ± 17.56	381.5	417.56 ± 17.16	418.5
Maximum Speed (km/h)	25.75 ± 1.983	26	25.25 ± 2.32	25.0	23.94 ± 2.17	23.1
Maximum Heart Rate (bpm)	152.50 ± 5.086	152.2	157.69 ± 4.34	157.1	159.94± 4.49	159.3
Distance per Minute (m/min)	50.89 ± 5.536	50.3	52.74 ± 5.600	53.1	55.99 ± 5.88	55.3
Average Speed (km/h)	4.969±0.4729	4.8	4.856±0.4487	4.86	4.744±0.3966	4.7

Table 2. Comparison of Average Heart Rate Values by Court Surface

Comparison Variables	Mean Difference	Standard Error	95% Confidence Interval Lower Bound	Upper Bound	P
Outdoor – Indoor	-4.062*	0.761	-7.263	-3.112	*0.001
Outdoor – Clay	-8.625*	1.158	-11.897	-7.103	*0.001
Indoor – Clay	-4.562*	1.103	-7.533	-1.592	*0.003

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

According to Table 2, average heart rate values were significantly higher on clay courts compared to both indoor and outdoor courts, and higher on indoor courts compared to outdoor courts ($p<0.05$).

Table 3. Comparison of Maximum Heart Rate Values by Court Surface

Comparison Variables	Mean Difference	Standard Error	95% Confidence Interval Lower Bound	Upper Bound	P
Outdoor – Indoor	-7.750*	0.868	-10.089	-5.411	*0.001
Outdoor – Clay	-8.875*	1.179	-12.052	-5.698	*0.001
Indoor – Clay	-1.125	0.724	-3.075	0.825	0.423

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

According to Table 3, maximum heart rate values were significantly lower on outdoor courts compared to both indoor and clay courts ($p<0.05$). No significant difference was observed between indoor and clay courts ($p>0.05$).

Table 4. Comparison of Total Running Distance Values by Court Surface

Comparison Variables	Mean Difference	Standard Error	95% Confidence Interval Lower Bound	Upper Bound	P
Outdoor – Indoor	223.563*	24.565	157.391	289.734	*0.001
Outdoor – Clay	-140.937*	23.152	-203.303	-78.572	*0.001
Indoor – Clay	-364.500*	37.675	-465.988	-263.012	*0.001

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

According to Table 4, total running distance values were significantly higher on clay courts compared to both outdoor and indoor courts, and higher on outdoor courts compared to indoor courts ($p<0.05$). Thus, players covered the greatest distance on clay, followed by outdoor, and the least on indoor courts.

Table 5. Comparison of Total Sprint Counts by Court Surface

Comparison Variables	Mean Difference	Standard Error	95% Confidence Interval Lower Bound	Upper Bound	P

Outdoor – Indoor	30.125*	6.363	12.984	47.266	*0.001
Outdoor – Clay	-6.187*	1.298	-9.684	-2.691	*0.001
Indoor – Clay	-36.312*	6.269	-53.201	-19.424	*0.001

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

As shown in Table 5, significant differences were found in total sprint counts across all court types ($p<0.05$). Sprint counts were higher on outdoor courts compared to indoor courts, and highest on clay courts compared to both outdoor and indoor courts.

Table 6. Comparison of Maximum Speed Values by Court Surf

Comparison Variables	**Mean Difference**	**Standard Error**	**95% Confidence Lower Bound**	**Interval Upper Bound**	**P**
Outdoor – Indoor	0.500	0.677	-1.324	2.324	1.000
Outdoor – Clay	1.813*	0.485	0.506	3.119	*0.006
Indoor – Clay	1.313*	0.384	0.277	2.348	*0.011

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

As shown in Table 6, no statistically significant difference was found between outdoor and indoor courts in terms of maximum speed values. Although there was a numerical difference between the maximum speed values on outdoor and indoor courts, this difference was not statistically significant. However, a statistically significant difference was found between the maximum speeds on outdoor and clay courts ($p<0.05$). In addition, a significant difference was also observed between the maximum speeds on indoor and clay courts ($p<0.05$).

Table 7. Comparison of Distance Covered per Minute by Court Surface

Comparison Variables	**Mean Difference**	**Standard Error**	**95% Confidence Lower Bound**	**Interval Upper Bound**	**P**
Outdoor – Indoor	-1.858	0.888	-4.251	0.534	*0.001
Outdoor – Clay	-5.099*	0.790	-7.228	-2.970	*0.001
Indoor – Clay	-3.241*	0.687	-5.092	-1.389	*0.001

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

According to Table 7, the distance covered per minute was significantly higher on clay courts compared to both indoor and outdoor courts, and higher on indoor courts compared to outdoor courts ($p<0.05$).

Table 8. Comparison of Average Speed Values Throughout the Match by Court Surface

Comparison Variables	**Mean Difference**	**Standard Error**	**95% Confidence Lower Bound**	**Interval Upper Bound**	**P**
Outdoor – Indoor	0.113	0.099	0.817	-0.153	0.817

Outdoor – Clay	0.225	0.102	0.132	-0.050	0.132
Indoor – Clay	0.113	0.044	0.063	-0.005	0.063

* In this study, a significance level of $p < 0.05$ was considered statistically significant.

According to Table 8, there were no statistically significant differences ($p<0.05$) in the average running speeds during matches played on outdoor, indoor, and clay courts.

Discussion and Conclusion

The average heart rate values recorded during the matches of elite tennis players in this study were as follows: 101.44±5.62 bpm on outdoor courts, 106.63±5.09 bpm on indoor courts, and 110.94±4.83 bpm on clay courts. Martin et al. (2011) and Reid et al. (2013), in their respective studies, found that heart rates were higher on clay courts compared to hard courts. They suggested this could be due to the longer rally durations and shorter recovery periods typically observed on clay surfaces. These findings are consistent with the results obtained in our study.

The maximum heart rate values (HRmax) were observed in this study, as presented in Table 3.3. The recorded data indicated HRmax values of 152.50±5.08 bpm on outdoor courts, 157.69±4.34 bpm on indoor courts, and 159.94±4.49 bpm on clay courts. In similar studies using GPS monitoring on comparable age groups, Mortimer et al. (2006) reported HRmax values of 168 bpm in U17 youth football players. Aşçı (2016), in a study involving young football players with an average age of 17±0.9 years, reported HRmax values of 168 bpm during official matches. Capranica et al., (2001) recorded HRmax values of 170 bpm in youth football players during matches. While previous research in different sports has indicated that physiological demands may vary depending on the sport or player positions, studies tracking heart rate with monitoring devices in young football players have shown variability. This suggests that factors such as playing position and age may not cause significant differences in heart rate. In one report, concerns were raised regarding the use of GPS tracking systems for defining football-specific exercises without considering game pressure, athlete stress, or match intensity (Mendez-Villanueva et al., 2013). Additionally, it has been emphasized that factors such as exercise timing, intensity, duration, weather conditions (hot or cold), epinephrine levels, hydration status, sympathetic nervous system activity, personal variability, medication use, and altitude can significantly affect heart rate outcomes and should be examined in detail (Boressen and Lambert, 2009).

The total running distances performed by elite tennis players during matches were evaluated in meters. The distances covered were 4364±223.43 m on outdoor courts, 4140.25±206.08 m on indoor courts, and 4505.31±249.66 m on clay courts. In his study on competitive loads by playing positions in young football players, Barron (2014) reported that central midfielders covered 5923 m, forwards 5621 m, defenders 5567 m, defensive midfielders 5366 m, and central defenders 4909 m. Murias et al. (2007) and Pereira et al., (2016) concluded that tennis players covered greater distances on clay courts compared to hard courts. Similar results were found in our study, which is thought to be due to the similarity of court surfaces used in both studies.

Accelerations within various speed ranges were observed throughout the study. In tennis, due to the nature and structure of the game, runs exceeding 15 km/h during matches are classified as sprints. The sprint distances obtained in our research were 411.38 ± 18.14 m on outdoor courts, 381.25 ± 17.56 m on indoor courts, and 417.56 ± 17.16 m on clay courts. Reviewing the literature, Harley et al., (2010), in their study on youth football players from U12 to U16 categories, found that older players in the U16 group covered greater sprint distances than those in younger categories. Similarly, Onat (2018), in his evaluation across age categories, indicated that the U19 group covered the greatest sprint distances among U16, U17, and U19 football players. Buchheit et al. (2010), in their study on youth football players aged U13-U18, determined that U18 players reached higher sprint distances during matches. Atan et al. (2016) emphasized that the application of individualized speed thresholds would provide accurate information regarding the personal performance levels of athletes with different maturity levels. Mendez-Villanueva et al., (2012) reported that midfielders, wingers, and forwards covered greater distances at high speed compared to players in other positions. Lovell and Abt, (2013) also highlighted that the use of individualized speed thresholds provides more accurate and valid information when comparing the performance of young football players at different maturity stages. Onat (2018) reported that forwards covered significantly greater sprint distances compared to defenders, although the fastest sprint speeds (reaching 19 km/h) were recorded by defenders in his study.

The maximum speed values recorded on different court surfaces in this study were 25.75±1.98 km/h on outdoor courts, 25.25±2.32 km/h on indoor courts, and 23.94±2.17 km/h on clay courts. Baitel et al., (2018), in their comparative study on training and match performance in Romanian rugby, found that the maximum speed reached during training was 26 km/h, while during matches it was 34 km/h.

The distance covered per minute by elite tennis players aged 12-14 was also evaluated. The results were as follows: 50.89±5.53 m/min on outdoor courts, 52.74±5.60 m/min on indoor courts, and 55.99±5.88 m/min on clay courts. In a study by Baitel et al., (2018) on Romanian rugby, players covered an average of 60 meters per minute during training and 65 meters per minute during matches. Carlos Galé-Ansodi et al., (2016), in their study on the effects of different surfaces on the time-motion characteristics of young elite tennis players, found that the average running distance per minute was 47.1±5.5 m on hard courts and 41.5±6.9 m on clay courts. Their study concluded that players had different physical demands depending on the court surface. On hard courts, there were higher running speeds, greater distances covered at high intensity, and more frequent accelerations and decelerations.

The average speed values of elite tennis players aged 12-14 during matches on different court surfaces were determined as follows: 4.96±0.47 km/h on outdoor courts, 4.85±0.44 km/h on indoor courts, and 4.74±0.39 km/h on clay courts. The literature shows that there are limited studies on this subject. Pilis et al. (2018) reported that the average speed of U19 football players was 6.931 km/h in the first half and 6.26 km/h in the second half of matches. Although this study was conducted in a different sport, it supports our findings. In football, many studies focus on evaluating players by position. Onat (2018) examined the average speeds of U16, U17, and U19 football players and found an overall average speed of 6.52±0.54 km/h, with 6.43±0.53 km/h for U16, 6.64±0.52 km/h for U17, and 6.50±0.55 km/h for U19 players. Dellaserra et al. (2014) found that older football players reached higher speeds than younger players during matches. Hoppe et al. (2016), in their study on tennis matches, reported that winning players ran more often to their forehand side, while losing players ran more to their backhand side, and that their speeds exceeded 5 km/h.

Abade et al., (2014), in their study evaluating the physiological and time-motion profiles of young football players in U15, U17, and U19 categories during training, analyzed running speeds from 0 km/h to >18 km/h by dividing the field into six zones. Bradley et al., (2010), using a multi-camera system in their study, reported that male athletes reached higher speed thresholds than female athletes. McFadden et al., (2020), in their study, found that although men reached higher top speeds than women, both sexes generally stayed below 15 km/h.

This study aimed to determine the extent to which different court surfaces affect athletic performance and how athletes respond to these changes in terms of performance. The statistical findings indicate that matches played on different surfaces result in significant differences in both individual performance and competition outcomes. Tennis is a sport that demands a complete movement chain, starting from the serve and continuing until the final stroke that concludes the point. Therefore, athletes must have a thorough understanding of their structural, motor, and athletic capabilities.

For players to execute the serve and all subsequent shots with maximum quality and consistency, they must be aware of their individual muscle characteristics. It is essential that their muscles work in full coordination. For athletes to achieve peak performance, they must have a strong awareness of their muscular function and apply optimized stroke protocols at the right time and place, which is crucial for personal development and success. To perform the entire kinetic chain at an optimal level, athletes must possess excellent motor and anthropometric attributes.

The aim of this study was to examine the effects of different court surfaces (outdoor hard, indoor hard, and clay) on the physiological and performance parameters of elite junior tennis players using a GPS-based tracking system. The findings confirmed that court surface significantly influences both physiological load and match performance. Average and maximum heart rates were lowest on outdoor courts and highest on clay courts. Total running distance and sprint counts were also highest on clay courts, intermediate on outdoor courts, and lowest on indoor courts. Maximum speed was greater on both outdoor and indoor courts compared to clay, while distance covered per minute was greatest on clay courts. No significant differences were observed in average running speed. These results indicate that surface characteristics directly affect player performance and physical demands, highlighting the importance of designing training and preparation programs that account for the specific requirements of different court surfaces. A limitation of this study is that the sample consisted solely of male tennis players aged 12–14. Therefore, the findings cannot be generalized to athletes of different age groups, competitive levels, or female players. Future research should include female athletes and participants from different age groups to broaden the scope of these findings.

CONCLUSION

This study demonstrated that different court surfaces significantly affect the physiological and performance parameters of elite tennis players. Clay courts increased players’ endurance and strength demands, reflected in higher heart rates, greater running distances, and more sprints. These results highlight the importance of endurance, strength endurance, and speed training in tennis, especially for matches played on high-resistance surfaces. Additionally, appropriate racket and string selection, surface-specific footwear, and sprint drills adapted to different courts are essential for optimizing performance and minimizing injury risk. Future studies should include female athletes and different age groups to broaden the scope of these findings.

This article is derived from the doctoral dissertation titled 'Investigation of Performance Parameters of Elite Level Players in Tennis Competitions Played on Open and Indoor Courts' completed by Sedat Özcan in 2023.

REFERENCES

Abade, E. A., Gonçalves, B. V., Leite, N. M. ve Sampaio, J. E. (2014). Time–motion and physiological profile of football training sessions performed by under-15, under-17, and under-19 elite Portuguese players. International Journal of Sports Physiology and Performance, 9(3), 463-470.

Aktürk, S. (2017). 17-25 yaş grubu gençlerde düzenli tenis çalışmalarının bazı fiziksel ve motorik özelliklere etkisinin araştırılması (Yüksek lisans tezi). Atatürk Üniversitesi Sağlık Bilimleri Enstitüsü, Erzurum.

Aşçı, A. (2016). Heart rate responses during small sided games and official matchplay in soccer. Sports, 4(2), 31.

Baitel, I., Marinescu, G., Stoica, M. ve Dreve, A. (2018). Comparative study between the training effort and the match in Romanian rugby. European Proceedings of Social and Behavioural Sciences, 36, 225-231.

Bradley, P., Di Mascio, M., Peart, D., Olsen, P. ve Sheldon, B. (2010). High intensity activity profiles of elite soccer players at different performance levels. Journal of Strength and Conditioning Research, 111(6), 969–978.

Borresen, J. ve Lambert, M. I. (2009). The quantification of training load, the training response and the effect on performance. Sports Medicine, 39(9), 779-795.

Capranica, L., Tessitore, A., Guidetti, L. ve Figura, F. (2001). Heart rate and match analysis in pre-pubescent soccer players. Journal of Sports Sciences, 19(6), 379-384.

Çamlıbel, T. (2019). Tenis top atma makinası ile yapılan 10 haftalık hedef odaklı dairesel antrenmanın 12-14 yaş performans tenis oyuncularında ITN testine etkisinin incelenmesi (Yüksek lisans tezi). Ankara Yıldırım Beyazıt Üniversitesi Sağlık Bilimleri Enstitüsü, Ankara.

Dellaserra, C. L., Gao, Y. ve Ransdell, L. (2014). Use of integrated technology in team sports: A review of opportunities, challenges, and future directions for athletes. Journal of Strength and Conditioning Research, 28(2), 556-573.

Eren, E. (2019). 12-14 yaş grubu tenisçilerde 8 haftalık core antrenmanının yer vuruş hızlarına ve bazı motorik özelliklere etkisinin incelenmesi (Yüksek lisans tezi). Bartın Üniversitesi Sosyal Bilimler Enstitüsü, Bartın.

Galé-Ansodi, C., Castellano, J. ve Usabiaga, O. (2016). Effects of different surfaces in time-motion characteristics in youth elite tennis players. International Journal of Performance Analysis in Sport, 16(3), 860-870.

Harley, J. A., Barnes, C. A., Portas, M., Lovell, R., Barrett, S., Paul, D. ve Weston, M. (2010). Motion analysis of match-play in elite U12 to U16 age-group soccer players. Journal of Sports Sciences, 28(13), 1391-1397.

Hoppe, M. W., Baumgart, C. ve Freiwald, J. (2016). Do running activities of adolescent and adult tennis players differ during play? International Journal of Sports Physiology and Performance, 11(6), 793-801.

Kabasakal, A. (2006). Tenis nasıl oynanır? İstanbul: Morpa Kültür Yayınları.

Koronas, V. ve Tsigelidou, M. (2018). Anthropometric characteristics, body composition and body type of young tennis players. Gymnasium, 19(2), 98-108.

Lovell, R. ve Abt, G. (2013). Individualization of time–motion analysis: A case-cohort example. International Journal of Sports Physiology and Performance, 8(4), 456-458.

Martin, C., Thevenet, D., Zouhal, H., Mornet, Y., Delès, R., Crestel, T. ve Ben Abderrahman, A. P. J. (2011). Effects of playing surface (hard and clay courts) on heart rate and blood lactate during tennis matches played by high-level players. Journal of Strength and Conditioning Research, 25, 163–170.

McFadden, B. A., Walker, A. J., Bozzini, B. N., Sanders, D. J. ve Arent, S. M. (2020). Comparison of internal and external training loads in male and female collegiate soccer players during practices vs. games. The Journal of Strength and Conditioning Research, 34(4), 969-974.

Mendez-Villanueva, A., Buchheit, M., Simpson, B., Peltola, E. S. A. ve Bourdon, P. (2011). Does on-field sprinting performance in young soccer players depend on how fast they can run or how fast they do run? Journal of Strength and Conditioning Research, 25(9), 2634-2638.

Mendez-Villanueva, A., Buchheit, M., Simpson, B. ve Bourdon, P. C. (2013). Match play intensity distribution in youth soccer. International Journal of Sports Medicine, 34(2), 101-110.

Mortimer, L. A. C. F., Condessa, L., Rodrigues, V., Coelho, D., Soares, D. ve Silami-Garcia, E. (2006). Comparison between the effort intensity of young soccer players in the first and second halves of the soccer game. Revista Portuguesa de Ciências do Desporto, 6(2), 154-159.

Murias, J. M., Lanatta, D., Arcuri, C. R. ve Laiño, F. A. (2007). Metabolic and functional responses playing tennis on different surfaces. Journal of Strength and Conditioning Research, 21(1), 112–117.

Onat, Ç. (2018). Genç erkek futbolcuların resmi maçlardaki iç ve dış yük profillerinin incelenmesi (Doktora tezi). Sakarya Üniversitesi Sağlık Bilimleri Enstitüsü, Sakarya.

Ölçücü, B. (2011). Tenisçilerde pliometrik antrenmanların kol ve bacak kuvveti, servis, forehand, backhand vuruş süratleri ve vurulan hedefe isabet yüzdelerine etkisinin incelenmesi (Doktora tezi). Marmara Üniversitesi Sağlık Bilimleri Enstitüsü, İstanbul.

Pereira, L. A., Freitas, V., Moura, F. A., Aoki, M. S., Loturco, I. ve Nakamura, F. Y. (2016). The activity profile of young tennis athletes playing on clay and hard courts: Preliminary data. Journal of Human Kinetics, 50, 211-218.

Pilis, K., Stec, K., Witkowski, Z., Stanula, A., Gabrys, T. ve Mikołajec, K. (2018, May). Workloads of young soccer players. In Proceedings of the International Scientific Conference, IV (Vol. 199, p. 210).

Reid, M., Duffield, R., Minett, G. M., Sibte, N., Murphy, A. P. ve Baker, J. (2013). Physiological, perceptual, and technical responses to on-court tennis training on hard and clay courts. Journal of Strength and Conditioning Research, 27(6), 1487–1495.

Yıldız, S., Gelen, E., Volkan, S., Akyüz, M., Murat, T., Bakıcı, D. ve Çırak, E. (2018). Çocuk tenisçilerde patlayıcı kuvvet ile sürat arasındaki ilişkinin incelenmesi. Celal Bayar Üniversitesi Sağlık Bilimleri Enstitüsü Dergisi, 5(3), 64-67.