# Comparison of match activity profile and technical-tactical performance in elite women´s doubles tennis on three different surfaces

Marcos Borderias Dominguez

TESI DOCTORAL

# Comparison of match activity profile and technical-tactical performance in elite women's doubles tennis on three different surfaces

# Comparació del perfil d'activitat del partit i del rendiment tècnic-tàctic en el tennis femení de dobles d'elit sobre tres superfícies diferents

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2025

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Memòria presentada per optar al grau de doctor per la Universitat de Barcelona

Programa de Doctorat HDK02 "Activitat Física, Educació Física i Esport"

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# ACKNOWLEDGMENTS

Quiero expresar mi más sincero agradecimiento a todas las personas que han hecho posible la realización de esta tesis doctoral.

En primer lugar, a mi director y amigo, el Dr. Ernest Baiget, no solo quiero agradecerte como mentor académico, sino también como amigo cercano. Desde el inicio de este proyecto, hemos logrado encontrar un equilibrio perfecto entre lo profesional y lo personal. Tu comprensión de mi situación, especialmente en los momentos en los que los viajes y la falta de tiempo hicieron difícil avanzar, ha sido fundamental para que pudiera seguir adelante. Gracias por tu paciencia, por tu orientación experta y por brindarme siempre el espacio necesario para encontrar soluciones. La forma en que hemos trabajado juntos ha sido clave para que este proyecto se haya convertido en una realidad. Este logro, sin duda, es tanto tuyo como mío.

A los doctores Jaime Fernández-Fernández, Rafael Martínez-Gallego, Miguel Crespo y Xavier Iglesias como co-autores. Quiero expresar mi más profundo agradecimiento por su colaboración invaluable en esta investigación. Su experiencia y rigor académico, que son un referente a nivel mundial en el ámbito del tenis, han enriquecido enormemente este trabajo. Gracias por su generosidad al compartir sus conocimientos y por el alto estándar de excelencia que siempre han exigido en cada fase de la investigación. Ha sido un honor aprender de ustedes y contar con su apoyo en este proyecto. Su orientación y compromiso no solo han sido fundamentales para el desarrollo de esta tesis, sino que también me han inspirado a seguir creciendo en la investigación.

Mi más sincero agradecimiento al Institut Nacional d'Educació Física de Catalunya (INEFC), al Grup de Recerca en Ciències de l'Esport INEFC Barcelona y a su coordinador el Dr. Xavier Iglesias por su generoso apoyo, esencial en una publicaciones de este trabajo. Su contribución ha sido fundamental para poder compartir los resultados de esta investigación con la comunidad académica y, de este modo, seguir avanzando en la difusión del conocimiento en el ámbito del tenis. Gracias por creer en el valor de esta investigación y por respaldarla en todo momento.

Quiero agradecer especialmente a la ex jugadora de tenis profesional María José Martínez, a quien tuve el privilegio de entrenar. Su dedicación, esfuerzo y pasión por el tenis no solo me inspiraron a mejorar como entrenador, sino que, de manera inesperada, despertaron en mí la curiosidad por investigar el mundo del dobles femenino. También

por facilitarme el acceso a los partidos y a la web para jugadores y jugadoras profesionales. Gracias por motivarme a explorar nuevas perspectivas.

Agradezco profundamente a todos los jugadores de tenis profesionales y entrenadores con los que he tenido la oportunidad de interactuar y colaborar a lo largo de mi carrera. Su dedicación y exigencia constante en el deporte crean un entorno que me impulsa a seguir ampliando mis conocimientos y a mantener un compromiso constante con el aprendizaje. Este entorno competitivo y dinámico es una fuente continua de motivación para profundizar en nuevas perspectivas y en el desarrollo de un conocimiento más profundo sobre el tenis.

A mi madre, a mis hermanos Carlos y Miguel y al resto de mi familia, quiero agradecerles por su constante interés y apoyo durante todo este proceso, aunque a veces no haya sido tan consciente de ello. Aunque no hayan estado involucrados directamente en mi trabajo, sus preguntas sobre la tesis y su alegría por cada pequeño avance me han dado fuerza y motivación. Aprecio mucho que, aunque no siempre haya dedicado el tiempo que me habría gustado, siempre me hayan mostrado su apoyo y me hayan animado a seguir adelante.

En resumen, este trabajo no habría sido posible sin el apoyo de todas las personas mencionadas, y a todas les estoy profundamente agradecido. A cada uno, por su tiempo, su paciencia y su confianza en mí. Gracias por acompañarme en este viaje, de una u otra manera.

# LIST OF PUBLICATIONS

This thesis is based on the following publications. Studies are presented in chronological order.

**STUDY I**

**Title:** Comparison of the activity profile during Grand Slam women's doubles tennis.

**Authors:** Marcos Borderias, Jaime Fernández-Fernández, Rafael Martínez-Gallego, Ernest Baiget

**Journal:** International Journal of Performance Analysis in Sport

**ISSN:** 2474-8668

**Doi:** 10.1080/24748668.2021.1972611

**Journal Impact factor (JIF):** 2.488

**Quartile:** Q3 (56/88)

**Category:** Sports Sciences

**Citation:** Borderias, M., Fernández-Fernández, J., Martínez-Gallego, R., & Baiget, E. (2021). Comparison of the activity profile during Grand Slam women's doubles tennis. *International Journal of Performance Analysis in Sport*, *21*(6), 1066-1080.

**STUDY II**

**Title:** Comparison of the game structure and point ending during Grand Slam women's doubles tennis

**Authors:** Marcos Borderias, Miguel Crespo, Rafael Martínez-Gallego, Ernest Baiget

**Journal:** International Journal of Sports Science & Coaching

**ISSN:** 1747-9541

**Doi:** 10.1177/17479541221098226

**Journal Impact factor (JIF):** 1.5

**Quartile:** Q3 (85/140)

**Category:** Hospitality, Leisure, Sport & Tourism

**Citation:** Borderias, M., Crespo, M., Martínez-Gallego, R., & Baiget, E. (2023). Comparison of the game structure and point ending during Grand Slam women's doubles tennis. *International Journal of Sports Science & Coaching*, *18*(4), 1248-1255.

**STUDY III**

**Title:** Comparison of the finishing shot and ending zone of points in Grand Slam matches of women's doubles tennis: A cross-sectional study

**Authors:** Marcos Borderias, Xavier Iglesias, Rafael Martínez-Gallego, Ernest Baiget

**Journal:** PLoS One

**ISSN:** 1932-6203

**Doi:** 10.1371/journal.pone.0303437

**Journal Impact factor** (JIF) 2.9

**Quartile:** Q1 (32/134)

**Category:** Multidisciplinary Sciences

**Citation:** Borderias, M., Iglesias, X., Martínez-Gallego, R., & Baiget, E. (2024). Comparison of the finishing shot and ending zone of points in Grand Slam matches of women's doubles tennis: A cross-sectional study. *Plos one*, *19*(5), e0303437.

# ABSTRACT

Many professional tennis tournaments take place every year. These include tournaments by the Women's Tennis Association (WTA), Association of Tennis Professionals (ATP), women's and men's International Tennis Federation (ITF), as well as women's and men's Grand Slams tournaments. Doubles matches are played in all of these professional tournaments and doubles specialists and many singles players participate. However, despite the importance of doubles tennis, there is little research on this modality of the game, especially in women's tennis. All the studies have focused exclusively on analysing men's doubles tennis performance and no research has analysed women's doubles modality.

The professional tennis tournaments take place on different court surfaces, including hard courts, clay courts, and grass courts. Performance characteristics of elite tennis match-play differ depending on the court surface, affecting the physical and physiological responses of players. Therefore, we considered important to analyse doubles matches played on all the various court types used in professional tournaments and differences across playing surfaces were analysed in all the studies. The first aim of the thesis was to describe the activity profile of women´s doubles matches during three different Grand Slam tournaments (study I). Then, we analysed and establish the structural variables of women's doubles matches, determined how points were finished on the three different surfaces and we also studied whether there were differences between the winning teams (WT) and losing teams (LT) in terms of finishing the points (study II). Finally, the last aim was to describe the finishing shot, ending zone, and shot by ending zone (study III). All these variables were analysed in women's doubles matches across three different Grand Slam tournaments.

We conclude that the most common tennis shots are the forehand (F), the backhand (B), the first service (FS) and the volley (V), and more than 50% of the total shots in a match come from the baseline and mid court game (BMC). Also that resting time between games (RTG) and resting time (RT) was longer at the Australian Open (AUS) than at Roland Garros (RG) and Wimbledon (W), and the number of F shots at RG was higher than at W. We found that players played around 2 sets per match (SM), 20 games per match (GM), 130 points per match (PM), 0.2 tie breaks per match (TM), 9.5 games per set (GS), 62 points per set (PS) and 6.5 points per game (PG). About 33% of the points ended with a winner (Wn), about 30% with a forced error (FE) and about 22% with unforced error

(UE), with Wn being the variable that discriminated the most between WT and LT. Lastly, we proved that around 56% of the points were finished from the baseline and mid court zone (BMZ), 36% from the net zone (NZ) and 7.5% from the service zone (SZ). The shot with which the points ended primarily was the forehand volley (FV) (~18%), followed by the F (~17%), the B (~16%) and the backhand volley (BV) (~13%). There was a higher percentage of F played from the BMZ in RG than in W, a higher percentage in overall F in RG than in W, the forehand return (FRT) percentage was higher in the AUS compared to RG and the O shots played from the BMZ were higher in W than RG.

**Key words**: women's tennis, performance analysis; match characteristics; professional players; doubles tennis; descriptive variables; point ending.

# RESUM

Molts tornejos de tennis professionals tenen lloc cada any. Entre ells destaquen els tornejos de la WTA, l'ATP, la ITF, així com els torneigs de Grand Slam femenins i masculins. Els partits de dobles es juguen en tots aquests tornejos professionals i hi participen especialistes en dobles i molts jugadors i jugadores d'individuals. No obstant això, malgrat la importància del tennis de dobles, hi ha poca investigació sobre aquesta modalitat del joc, especialment en el tennis femení. Tots els estudis s'han centrat exclusivament en l'anàlisi del rendiment del tennis de dobles masculins i cap investigació ha analitzat la modalitat de dobles femenins.

Els tornejos de tennis professional tenen lloc en diferents superfícies de la pista, incloent pistes dures, pistes de terra batuda i pistes de gespa. Les característiques del joc de tennis d'elit difereixen segons la superfície de la pista, afectant les respostes físiques i fisiològiques de les jugadores. Per tant, considerem important analitzar els partits de dobles jugats en tots els diferents tipus de pista utilitzats en tornejos professionals i, d'aquesta manera, les diferències entre superfícies de joc van ser analitzades en tots els estudis. El primer objectiu de la tesi va ser descriure el perfil d'activitat dels partits de dobles femenins durant tres tornejos de Grand Slam diferents (estudi I). A continuació, vam analitzar i establir les variables estructurals dels partits de dobles femenins, vam determinar com s'acabaven els punts en les tres superfícies diferents i també vam estudiar si hi havia diferències entre els equips guanyadors i perdedors en termes de finalitzar els punts (estudi II). Finalment, l'últim objectiu era descriure el cop final, la zona de finalització i el cop final per zona de finalització (estudi III). Totes aquestes variables van ser analitzades en els partits de dobles femenins en tres tornejos de Grand Slam diferents.

Concloem que els cops de tennis més habituals són el de dreta (F), el de revés (B), el primer servei i el de volea (V), i més del 50% del total de cops en un partit provenen de la zona de fons (BMC). També que el temps de descans entre jocs (RTG) i el temps de descans (RT) va ser més llarg a l'AUS que a RG i W, i el nombre de F a RG va ser més alt que a W. Vam trobar que les jugadores van jugar al voltant de 2 sets per partit (SM), 20 jocs per partit (GM), 130 punts per partit (PM), 0.2 tiebreaks per partit (TM), 9.5 jocs per set (GS), 62 punts per set (PS) i 6,5 punts per joc (PG). Al voltant del 33% dels punts van acabar amb un cop guanyador (Wn), al voltant del 30% amb un error forçat (FE) i al voltant del 22% amb un error no forçat (UE), sent el Wn la variable que més va discriminar entre equips guanyadors i perdedors. Finalment, vam demostrar que al voltant

del 56% dels punts van acabar des de la zona de fons (BMZ), el 36% de la zona de mitja pista (NZ) i el 7.5% de la zona de servei (SZ). El cop amb el qual van acabar més punts va ser la volea de dreta (FV) (~18%), seguida de la F (~17%), el B (~16%) i la volea de revés (BV) (~13%). Hi va haver un percentatge més alt de F jugat des de la BMZ en RG que en W, un percentatge més alt en general de F en RG que en W, el percentatge de restada de dreta (FRT) va ser més alt en l'AUS comparat amb RG i els cops O jugats des de la BMZ van ser més alts en W que RG.

**Paraules clau:** tennis femení, anàlisi de rendiment, característiques del partit, jugadores professionals, tennis de dobles, variables descriptives, finalització del punt

# RESUMEN

Muchos torneos de tenis profesionales tienen lugar cada año. Entre ellos destacan los torneos de la WTA, la ATP, la ITF, así como los torneos de Grand Slam femeninos y masculinos. Los partidos de dobles se juegan en todos estos torneos profesionales y participan especialistas en dobles y muchos jugadores y jugadoras de individuales. Sin embargo, a pesar de la importancia del tenis de dobles, hay poca investigación sobre esta modalidad del juego, especialmente en el tenis femenino. Todos los estudios se han centrado exclusivamente en el análisis del rendimiento del tenis de dobles masculinos y ninguna investigación ha analizado la modalidad de dobles femeninos.

Los torneos de tenis profesional tienen lugar en diferentes superficies de pista, incluyendo pistas duras, pistas de tierra batida y pistas de hierba. Las características del juego de tenis de élite difieren según la superficie de la pista, afectando a las respuestas físicas y fisiológicas de las jugadoras. Por lo tanto, consideramos importante analizar los partidos de dobles jugados en todos los diferentes tipos de pista utilizados en torneos profesionales y, de esta manera, las diferencias entre superficies de juego fueron analizadas en todos los estudios. El primer objetivo de la tesis fue describir el perfil de actividad de los partidos de dobles femeninos durante tres torneos de Grand Slam diferentes (estudio I). A continuación, analizamos y establecimos las variables estructurales de los partidos de dobles femeninos, determinamos cómo se acababan los puntos en las tres superficies diferentes y también estudiamos si había diferencias entre los equipos ganadores y perdedores en términos de finalización de los puntos (estudio II). Finalmente, el último objetivo era describir el golpe final, la zona de finalización y el golpe final por zona de finalización (estudio III). Todas estas variables fueron analizadas en los partidos de dobles femeninos en tres torneos de Grand Slam diferentes.

Concluimos que los tiros de tenis más habituales son el de derecha (F), el de revés (B), el primer servicio y el de volea (V), y más del 50% del total de golpes en un partido provienen de la zona de fondo (BMC). También que el tiempo de descanso entre juegos (RTG) y el tiempo de descanso (RT) fue más largo en el AUS que en RG y W, y el número de F en RG fue más alto que en W. Encontramos que las jugadoras jugaron alrededor de 2 sets por partido (SM), 20 juegos por partido (GM), 130 puntos por partido (PM), 0.2 tiebreaks por partido (TM), 9.5 juegos por set (GS), 62 puntos por juego (PS) y 6,5 puntos

por juego (PG). Alrededor del 33% de los puntos terminaron con un golpe ganador (Wn), aproximadamente el 30% con un error forzado (FE) y alrededor del 22% con un error no forzado (UE), siendo el Wn la variable que más discriminó entre equipos ganadores y perdedores. Finalmente, demostramos que alrededor del 56% de los puntos terminaron desde la zona de fondo (BMZ), el 36% desde la zona de media pista (NZ) y el 7.5% desde la zona de servicio (SZ). El golpe con el que se acabaron más puntos fue la volea de derecha (FV) (~18%), seguida de la F (~17%), el B (~16%) y la volea de revés (BV) (~13%). Hubo un porcentaje más alto de F jugado desde la BMZ en RG que en W, un porcentaje más alto en general de F en RG que en W, el porcentaje de resto de derecha (FRT) fue más alto en el AUS comparado con RG y los golpes O jugados desde la BMZ fueron más altos en W que en RG.

**Palabras clave:** tenis femenino, análisis de rendimiento, características del partido, jugadoras profesionales, tenis de dobles, variables descriptivas, finalización del punto

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

mid court zone; BV_BMZ, backhand volley baseline and mid court zone; O_BMZ, overhead baseline and mid court zone. †significant differences between RG and W.... 88

# LIST OF ABBREVIATIONS

**ANOVA** - Analysis of variance

**ATP** - Association of Tennis Professionals

**AUS** - Australian Open

**B** - Backhand

**B_BMZ** - Backhand played from the baseline and mid court zone

**BMC** - Baseline and mid court game

**BMZ** - Baseline and mid court zone

**B_NZ** - Backhand played from the net zone

**BRT** - Backhand return

**BV** - Backhand volley

**BV_BMZ** - Backhand volley played from the baseline and mid court zone

**BV_NZ** - Backhand volley played from the net zone

**EPT** - Effective playing time

**F** - Forehand

**F_BMZ** - Forehand played from baseline and mid court zone

**FE** - Forced error

**F_NZ** - Forehand played from the net zone

**FRT** - Forehand return

**FS** - First service

**FV** - Forehand volley

**FV_BMZ** - Forehand volley played from the baseline and mid court zone

**FV_NZ** - Forehand volley played from the net zone

**GM** - Games per match

**GS** - Games per set

**ITF** - International Tennis Federation

**LT** - Losing team

**N** - Net game

**NZ** - Net zone

**O** - Overhead

**O_BMZ** - Overhead from the baseline and mid court zone

**O_NZ** - Overhead played from the net zone

**PG** - Points per game

**PM** - Points per match

**PS** - Points per set

**RD** - Rally duration

**RG** - Roland Garros

**RT** - Resting time

**RTG** - Resting time between games

**RTP** - Resting time between points

**RTS** - Resting time between sets

**SM** - Sets per match

**SPG** - Shots per game

**SPM** - Shots per match

**SPMn** - shot frequency (shots/minute)

**SPR** - Shots per rally

**SPS** - Shots per set

**SPSc** - Shot frequency (shots/second)

**SS** - Second serve

**SZ** - Service zone

**TM** - Tie breaks per match

**TMT** - Total match time

**UE** - Unforced error

**V** - Volley

**W** - Wimbledon

**Wn** - Winner

**W:R** - Work-to-rest ratio

**WT** - Winning team

**WTA** - Women's Tennis Association

# 1. INTRODUCTION

## 1.1. Specific characteristics of the doubles game

### 1.1.1. Relevance of the doubles tennis

Each year, numerous professional tennis tournaments are held, including events organized by the WTA, the ATP, and the ITF for both men and women, along with the Grand Slam tournaments (International Tennis Federation, 2023; Women's Tennis Association, 2023; Association of Tennis Professionals, 2023). All of these tournaments feature doubles matches, with each Grand Slam hosting its own doubles competitions. Over the years, many exceptional players have dedicated their careers to excelling in doubles (Breknik, 2015; Martínez-Gallego, Vives, et al., 2021). The importance of doubles is longstanding, as the first doubles event occurred in 1884, just seven years after the inaugural singles tournament at W in 1877. Both doubles specialists and singles players often take part, as the dynamics of doubles can help improve essential skills for singles play, such as serving, returning serves, net play, reaction time, and court awareness (Carboch et al., 2014). Additionally, professional players might be drawn to participate in doubles for various reasons, including the potential for prize money (Martínez-Gallego et al., 2019) and the need for preparation for team competitions like the Davis Cup, Billie Jean King Cup, and ATP Cup, where doubles matches are highly valued (Martínez-Gallego et al., 2019).

Throughout the history of doubles, certain players and teams have distinguished themselves by dominating the field, leaving a lasting legacy on the sport. On the men's side, legendary pairs such as the Bryan brothers, Bob and Mike Bryan, have set the gold standard in doubles, holding the record for the most Grand Slam doubles titles in history with 16 titles (ATP, 2023). Their synergy on the court, tactical intelligence, and consistency made them an unbeatable force for nearly two decades, and their contributions to the doubles game have been monumental.

In women's doubles, one of the most successful and influential teams in recent decades has been the pairing of Martina Navratilova and Pam Shriver. Together, they won 20 Grand Slam women's doubles titles in the 1980s and were known for their remarkable coordination and powerful net play. More recently, the team of Tímea Babos and Kristyna Pliskova has been a dominant force in women's doubles, with multiple Grand Slam titles and a strong competitive presence on the WTA Tour. The partnership between Barbora

Krejcikova and Katerina Siniakova has also been groundbreaking, with the duo winning several major titles, including W and the French Open, and securing their place as one of the top women's doubles teams in recent years. Elise Mertens and Aryna Sabalenka have also had significant success in doubles, with both having earned Grand Slam titles and consistently ranking among the best in the world

Among the men, current players such as Nikola Mektic and Mate Pavic have taken the doubles scene by storm, clinching numerous titles together and achieving the world No. 1 ranking in doubles. Their combination of tactical skill, physicality, and exceptional teamwork has earned them widespread recognition.

These players have contributed immensely to the evolution of doubles tennis, demonstrating that the specialty requires not only physical prowess but also a deep understanding of strategy, communication, and court positioning. The top doubles players continue to inspire future generations, showcasing the beauty and importance of teamwork in the sport of tennis.

### 1.1.2. Specific rules and technical-tactical characteristics

Certain elements of the rules in doubles tennis are distinct from those in singles tennis, including the lines, court space, and scoring systems. Doubles is played in pairs, and the court is wider due to the addition of alleys on each side (10.97 m in total). As a result, shot precision and direction are essential since the space available per player is reduced. This influences training, movement, positioning, timing, and physiological demands when compared to singles play (Martínez-Gallego et al., 2019). Moreover, doubles involves more complex tactics and decision-making, as having two players per team creates more stimuli to consider (Carboch et al., 2014; Carboch & Kocib, 2015). Regarding scoring, doubles matches typically use a best of two tiebreak set format without advantage sets. In contrast, Grand Slam doubles matches are played as best of three tiebreak sets with advantage sets, similar to singles (International Tennis Federation, 2023; Women's Tennis Association, 2023). These different match formats affect the overall duration of the games. Furthermore, effective communication between doubles partners is vital; both verbal and non-verbal communication help teams tackle challenges and make decisions during and between points (Lausic et al., 2009). Overall, these various

differences lead to shorter match times compared to singles (Martínez-Gallego et al., 2019).

## 1.2. Tennis activity profile and physiological demands in doubles tennis

### 1.2.1. Activity profile in singles tennis

The activity profile on various surfaces have been extensively examined in singles tennis. Research indicates that the duration of most rallies (RD) is roughly 6 s (Kilit et al., 2016; Martin et al., 2011; Morante & Brotherhood, 2006). The number of shots per rally (SPR) ranges from 2.5 to 6 (Mendez-Villanueva et al., 2010; Torres-Luque, Sánchez-Pay, et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017). The work-to-rest ratio (W: R) typically falls between 1:2 and 1:3 (Torres-Luque, Sánchez-Pay, et al., 2011; Kilit & Arslan, 2017; Kilit et al., 2016), and the effective playing time (EPT) is estimated to be around 20% to 30% (Mendez-Villanueva et al., 2010; Martin et al., 2011; Torres-Luque, Sánchez-Pay, et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017; Kilit et al., 2018). In addition, there have been some studies focusing on women's singles tennis. These studies show that women experience a longer RD and fewer SPR than men, with an average of 2.5 SPR (Fernandez-Fernandez et al., 2009).

### 1.2.2. Doubles' activity profile and physiological demands

The double's activity profile compared to singles has shorter real playing time (4.40 vs 4.16 min) and the real RT is longer (15.42 vs 15.67 min). The resting time between points (RTP) is also shorter in doubles than in singles (14.8 vs 16.9 s). The EPT in singles is about 22.2% and 21.0% in doubles. The percentage of points lasting <5s are higher in doubles, the percentage of points between 5-10 s is the same in doubles than singles, and the percentage of points lasting >10s is higher in singles than in doubles (Armstrong et al., 2023). It has been noted that the RD in doubles is shorter compared to singles (Martínez-Gallego, Vives et al., 2021; Armstrong et a., 2023), and that the SPR in men's doubles are 3.41 shots per point (Martínez-Gallego et al., 2019). In doubles, rallies tend to be shorter due to the faster pace of play. Doubles players focus more on quick strategies and net play, which makes the exchange of shots end more quickly. Moreover, team

coordination allows players to avoid unnecessarily prolonging points, which results in shorter rallies compared to singles. Additionally, in men's doubles, there are fewer sets, PM, and PG than in singles, although there are more games played per set (Martínez-Gallego et al., 2019).

In doubles, the dynamic of the game allows players to support each other, which helps resolve points more quickly, especially during service games. This results in fewer total points played in doubles matches. Additionally, it is harder to break the opponent's serve in doubles compared to singles, as the player-to-space ratio is smaller and team coordination is more important. This contributes to having more GS in doubles. The W:R in men's doubles is also lower than the one observed in singles (Martínez-Gallego, Vives et al., 2021). Since players cover a smaller portion of the court and are positioned closer to the net, rallies tend to be shorter. Additionally, they typically use all their rest time between points to prepare their strategy, which contributes to the lower W:R. The distance covered (1074 vs 903 m), player load (102 vs 82 au), acceleration density (0.434 vs 0.348 au) and acceleration load (523 vs 439 au) for singles are higher compared with doubles (Armstrong et al., 2023). In singles tennis, players are responsible for covering the entire court on their own, which requires more movement and physical exertion. In contrast, in doubles, players share the court and work together to cover less ground individually, leading to less overall distance travelled. Furthermore, the physical demands are higher in singles due to the increased intensity of movement, as players have to cover a larger area without assistance. The player load, acceleration density, and acceleration load are all higher in singles because the player has to move more frequently, change directions faster, and generate more force to cover the court, whereas in doubles, these demands are split between the two players. However, the match-play characteristics for professional women's doubles tennis remains largely unexplored. As for the types of strokes, the number of FS, second services (SS), F and B was greater for singles compared with doubles. The number of V and lobs were higher in doubles than singles (Armstrong et al., 2023). Therefore, the activity profile that characterizes tennis is primarily shaped by singles play, with doubles having a lesser influence. Furthermore, many of these studies focus solely on men's singles, highlighting the urgent need for research specifically addressing women's tennis.

From a physiological perspective, there is little scientific evidence regarding intensity in doubles. A single study found that average heart rates (157 vs. 139 beats·min$^{-1}$) and blood lactate (1–2 mmol·L$^{-1}$) concentrations are higher at all time intervals in singles compared to doubles (Armstrong et al., 2023). Consistent with this, values for overall perceived exertion (13.7 vs 11.4), breathing difficulty (11.0 vs 8.4), and limb discomfort (9.0 vs 6.4) are also higher for singles compared with doubles (Armstrong et al., 2023).

### 1.3. Types of studies conducted in doubles tennis

The existing body of literature on doubles tennis encompasses a range of topics, reflecting the complexity and multifaceted nature of the sport. Key areas of research include the following:

- **Game structure and scoring system:** Studies have examined the fundamental structure of doubles tennis, including how points are scored and the implications of the scoring system on gameplay (Martínez-Gallego et al., 2019; Pollard & Pollard, 2010).
- **Temporal analysis and match dynamics:** Research has explored the time structure of matches, highlighting differences based on the experience levels of competing teams (Martínez-Gallego, Vives et al., 2021).
- **Serve performance:** The serve, as a critical component of doubles tennis, has been analyzed in terms of its effectiveness and impact on match outcomes (Martínez-Gallego, Crespo et al., 2021; Martínez-Gallego, Salvador et al., 2021).
- **Positioning and tactics:** Studies have investigated player positioning, particularly the "V positions," and their strategic implications (Martínez-Gallego, Ramón-Llin et al., 2021). Additionally, tactical approaches in doubles tennis have been extensively studied, with contributions spanning from early works (Talbert & Old, 1957) to more recent analyses (Carboch & Kocib, 2015; Carboch et al., 2014; Cayer, 2004; Kočíb et al., 2020).
- **Communication and coordination:** Effective communication and implicit coordination between partners have been identified as crucial factors for success in doubles tennis (Blickensderfer et al., 2010; Lausic et al., 2009, 2015).

- **Gender differences:** Research has also addressed gender differences in doubles tennis, exploring variations in play styles, performance, and strategies (Anderson, 1982).
- **Match load and physical demands:** Recent studies have focused on the physical demands of doubles tennis, including match load and its implications for player performance and recovery (Armstrong et al., 2023).
- **Player analysis and typologies:** The identification and analysis of the best players in doubles tennis, as well as the categorization of player types, have been explored to understand the characteristics of successful competitors (Breznik, 2015).

## 1.4. Observational methodology in tennis

Observational methodology is a research approach that involves systematically recording observable behaviours as they naturally occur in real-life settings. This methodology relies on specific instruments or tools designed for the precise capture and analysis of behaviours, ensuring the quality and reliability of the data (Anguera & Hernández-Mendo, 2013, 2014). The key advantage of observational methodology is that it allows researchers to study subjects in their natural or habitual environments without altering or controlling the context. This makes it an effective approach for studying human behaviour in complex, dynamic situations, such as sports, where athletes' actions are influenced by real-time factors like opponents, environmental conditions, and strategies.

The observational method can be both qualitative and quantitative, depending on the research objectives. In sports research, particularly in team and individual sports, it enables an in-depth analysis of athlete performance, tactics, and physical interactions that might not be captured in experimental settings (Anguera & Hernández-Mendo, 2013, 2014, 2015, 2016). For example, observational data can include not just the outcomes of events (e.g., wins or losses) but also the process of interaction, such as player positioning, decision-making, or movement patterns. By understanding these behaviours, coaches and practitioners can better tailor training regimens and improve strategic planning (Hughes & Franks, 2004). The non-intrusive nature of observational methodology is especially useful in sports, where the environment and flow of the game cannot be easily replicated in a controlled laboratory setting.

In tennis, observational methodology has been widely used to analyze a broad range of factors that contribute to player performance. One of the most common applications is match and notational analysis, where researchers observe and record specific aspects of a match, such as the success of certain techniques or tactical patterns, to derive conclusions about effective play. Studies have examined various performance metrics, including stroke types, success rates, and efficiency, providing valuable insights into which actions lead to successful points or games (Djurovic et al., 2009; Katic et al., 2011; Cui et al., 2018). Additionally, the effectiveness of key aspects of the game, such as serves and returns, has been thoroughly analyzed using observational tools to determine how certain serve types, placement, or return strategies impact match outcomes (Gillet et al., 2009; Hizan et al., 2011; Martin et al., 2016).

Tactical analysis in tennis also heavily relies on observational methodology. By closely observing match dynamics, researchers have been able to identify patterns in strategies, such as when and how players use different shot types or adjust their positioning during rallies (Over & O'Donoghue, 2010; Cross & Pollard, 2011; Reid et al., 2016). These findings help inform training strategies that target specific areas of a player's game. Another key area of tennis research using observational methods is the analysis of player movements and positioning on the court. Studies have shown that players' court coverage, their positioning during rallies, and their ability to anticipate the opponent's next move can significantly impact their performance (Martínez-Gallego et al., 2013; Pereira et al., 2017). By tracking these elements, researchers can highlight areas for improvement and optimize player positioning during matches.

In summary, the observational methodology is an invaluable tool in tennis research, offering detailed insights into various facets of the game. It allows for the study of player behaviours in real match conditions and provides a foundation for developing strategies and improving performance, both in training and competitive settings. The application of this methodology across different aspects of the game, such as performance metrics, tactics, and movement analysis, contributes to a deeper understanding of tennis and the factors that determine success on the court.

# 2. AIMS AND HYPOTHESIS

## 2.1. General objective

The general aim of this doctoral thesis was to determine the activity profile and technical and tactical performance of professional women's doubles players, and to analyse the differences between playing surfaces.

## 2.2. Specific objectives

The general objective has been divided into specific objectives, which are addressed in specific papers:

**Study I: Comparison of the activity profile during Grand Slam women's doubles tennis:**

- To describe the activity profile of women´s doubles matches during three different Grand Slam tournaments.
- To analyse the differences between playing surfaces in relation to the activity profile of women's doubles matches.

**Study II: Comparison of the game structure and point ending during Grand Slam women's doubles tennis:**

- To analyse and establish whether there were differences in the structural variables of women's Grand Slam doubles matches.
- To determine how points were finished in women's doubles matches at three Grand Slam played on three different surfaces and analyse the differences between these surfaces.
- To study whether there were differences between the winning and LT in terms of finishing the points.

**Study III: Comparison of the finishing shot and ending zone of points in Grand Slam matches of women's doubles tennis: A cross-sectional study:**

- To describe the finishing shot, ending zone, and shot by ending zone in women's doubles matches across three different Grand Slam tournaments.
- To analyse the differences across playing surfaces in relation to the finishing shot and ending zone of the women's doubles tennis matches.

## 2.3. Hypothesis

In accordance with the general and specific objectives, the following hypothesis were established:

**Study I:**

- There would be significant differences between surfaces in the duration and time parameters, and also in the number of shots, being the clay with longer durations and higher number of shots, and the grass with shorter durations and lower number of shots.
- The F and V shots would be very frequent and important shots in all three surfaces.

**Study II:**

- There would be significantly more points (PM, PS and PG) on clay than on the other surfaces, with no other significant differences in the rest of descriptive variables.
- The FE would be the way in which more points finish, followed by the Wn and UE, with no significant differences between surfaces.
- The variable that most discriminates between the winning and LT is the UE.

**Study III:**

- The percentage of points that finish from the NZ and with a V would be very high, even if the V was not the most frequent shot.
- There would be more points that finish in the NZ in W and AUS than in RG.

# 3. METHODS

## 3.1. Matches

Three studies were carried out to tackle the general and specific objectives and to test the proposed hypothesis. The Clinical Research Ethics Committee of the Sports Administration of Catalonia, Spain (23/CEICGC/2020), approved the research project. Performance characteristics of 21 matches were analysed. According to the Ethical Principles of Psychologists and the Code of Conduct from the American Psychological Association (American Psychological Association, 2017), since the tennis matches took place in public venues and public images were recorded, obtaining informed consent from the participants was not necessary. The videos were sourced from a publicly accessible platform for all Grand Slam players known as the Match Analysis Department. The matches analysed were from three Grand Slam of the 2019 season, played on different surfaces: AUS (hard court, n = 7), RG (clay, n = 7), and W (grass, n = 7). The study adhered to all ethical guidelines set forth in the Declaration of Helsinki. In total, 22 doubles pairs and 42 professional female players were observed, with an average age of 30.1 ± 5.6 years, weight of 65.4 ± 6.5 kg, and height of 170.1 ± 27.8 cm, and a median WTA ranking of 24.5 (range: 1–481). The analysis included matches from the first round (n = 2), third round (n = 3), quarter-finals (n = 9), semi-finals (n = 4), and finals (n = 3).

## 3.2. Procedures

For the observational data collection, LINCE PLUS v.1.4 (Soto-Fernández et al., 2022) was utilized. An observational instrument was specifically developed *ad hoc* based on scientific literature regarding the analysis of external load parameters in singles tennis (Fernandez-Fernandez et al., 2008; Smekal et al., 2001; Torres-Luque et al., 2011). This instrument consisted of 11 criteria and 25 categories, capturing data on the player, type of shot, outcome, and shot location. Additionally, points scored in each game, set, and match were recorded (Table 1).

***Table 1.*** *Observational Instrument.*

| ***Criteria*** | ***Categories*** | ***Description*** |
|---|---|---|

| | | |
|---|---|---|
| Player who hits | J1 | Player in the right of the winning pair |
| | J2 | Player in the left of the winning pair |
| | J3 | Player in the right of the losing pair |
| | J4 | Player in the left of the losing pair |
| Duration of points | SP | Start of point (moment in which the serving player starts the movement of the first service) |
| | EP | End of point (the linesman determines that the ball crosses the limits of the court, the ball touches the net and does not pass to the opposite side or the ball makes the second bounce after having touched the opposite side) |
| Resting time between points | SRP | Start of rest between points (the linesman determines that the ball crosses the limits of the court, the ball touches the net and does not pass to the opposite side or the ball makes the second bounce after having touched the opposite side) |
| | ERP | End of rest between points (moment in which the serving player starts the movement of the first service) |
| Hitting place | G | Groundstroke (between the baseline and the service line) |
| | AB | Attacking balls (between the service line and the net) |
| Type of shot I | F | Forehand |
| | B | Backhand |
| Type of shot II | V | Volley |
| | O | Overhead |
| Type of service | 1 | First service in |
| | 10 | First service out |
| | 2 | Second service in |
| | 20 | Second service out |
| | L | Let |
| Point ending | FE | Forced error |
| | UE | Unforced error |
| | W | Winner |
| Score | X-X | Game score (15, 30, 40, Ad, game) |
| Games | X-X | X takes values from 0 to 7 |
| Set | X | 1, 2 o 3 |

## 3.3. Validity and reliability testing

Construct validity was established through the consistency of the conceptual framework evaluated by six tennis experts (graduates of the RFET; Real Federación Española de Tenis – Royal Spanish Tennis Federation), who achieved 100% consensus on each category. The validation process involved a virtual questionnaire that allowed experts to either agree or disagree with the categorization of each criterion. Reliability was assessed after the observers underwent training on how to use the registration instrument and reached an agreement (Anguera, 1990). This was measured by interobserver and intraobserver agreement on 200 actions during the matches. The kappa coefficients for all criteria indicated substantial to almost perfect agreement (Cohen, 1968). All three studies were cross-sectional observational studies. Study I analysed duration and time parameters, and number and type of shots. Study II was to determine the descriptive variables and point ending. Finally, in the Study III the type of shot that ends the points and the location from which they end were analysed (Figure 1).

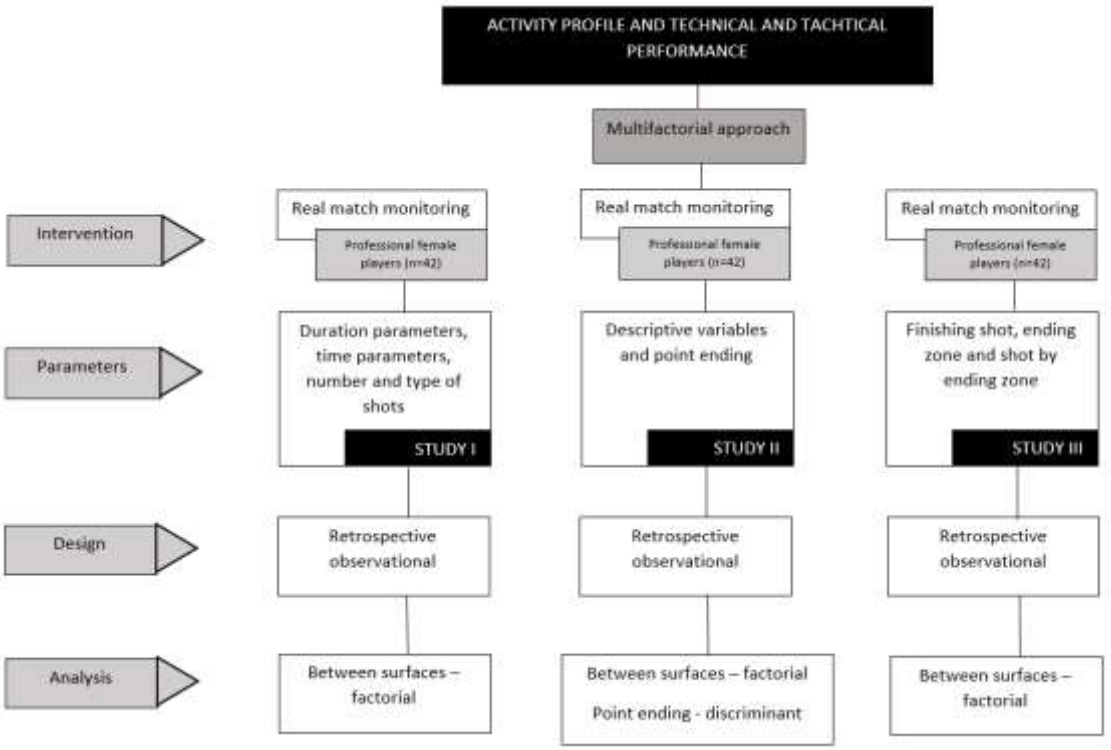


***Figure 1.*** *General study design.*

# 4. RESULTS

## 4.1. Study I

**Comparison of the activity profile during Grand Slam women's doubles tennis**

*by*

Borderias M, Fernández-Fernández J, Martínez-Gallego R, Baiget E

### 4.1.1. ABSTRACT

There is little information on the female doubles tennis. The aim of this study was to describe the activity profile of women's doubles tennis, and to analyse the differences between playing surfaces. Twenty-one matches of three Grand Slams tournaments and played on 3 different surfaces, were analysed. Activity profile included rally duration (RD), RTP, RTG, resting time between sets (RTS), RT, EPT, total match time (TMT), W: R, SPR, shots per game (SPG), shots per set (SPS), shots per match (SPM), shot frequency (shots/second) (SPSc), and type of shots. Results showed that RTG and RT was longer at the AUS than at RG and W, and the number of F shots at RG was higher than at W. The most common tennis shots are the F, the B, the FS and the V, and more than 50% of the total shots in a match come from the BMC. These results show that in women's doubles the stimuli are short and intense and that net game (N) is very important.

**Keywords:** Racquet sports; performance analysis; match characteristics; profile; professional players

### 4.1.2. INTRODUCTION

Tennis tournaments are celebrated throughout the year at professional level (555 women's ITF, 542 men's ITF, 60 WTA, 72 ATP, 158 Challenger in 2019) (International Tennis Federation, 2019; Women's Tennis Association, 2019; Association of Tennis Professionals, 2019). All Grand Slam tournaments hold a doubles competition, and both, male and female players contest for the economic contribution and sporting advantages it entails (Martínez-Gallego et al., 2019).

Technical, tactical and conditional differences between players influence performance of each player. In tennis, sport-specific technical skills are predominant factors, although a complex profile of physical performance factors is also required (Fernandez-Fernandez et al., 2014). Moreover, performance characteristics of elite tennis match-play differ depending on court surface (Filipčič & Filipčič, 2006), affecting therefore the physical and physiological responses of players (Filipčič & Filipčič, 2006).

The activity profile on different surfaces has been widely described in singles tennis. It has been observed that the RD of most of the rallies is approximately 6 s (Kilit et al., 2016; Martin et al., 2011; Morante & Brotherhood, 2006). The SPR are between 2.5 and 6 s (Mendez-Villanueva et al., 2010; Torres- Luque, Sánchez-Pay, et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017). The W: R is 1:2 to 1:3 (Torres-Luque, Sánchez-Pay, et al., 2011; Kilit & Arslan, 2017; Kilit et al., 2016), and the EPT is 20% to 30% (Mendez-Villanueva et al., 2010; Martin et al., 2011; Torres-Luque, Sánchez-Pay, et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017; Kilit et al., 2018). On the other hand, there are also some studies on women's singles tennis. These studies show a longer RD and fewer SPR in women's tennis compared to men's tennis, the average being 2.5 SPR (Fernandez-Fernandez et al., 2009).

In doubles tennis, unlike singles tennis, the matches play best of two tie-break sets and a super tie-break, and the advantage set is not played, except in Grand Slam tournaments, where they play best of three tie-break sets in women's and best of five tie-break sets in men's, like W, and the advantage set is also played, facts that determine the total time of the matches. In addition, it is played in pairs and the dimensions of the court are different, thus affecting the training system, movements, positions, temporal structure, and the physiological profile of the players (Martínez- Gallego et al., 2019). Regarding the activity profile in men's doubles, it has been observed that the RD is shorter than in singles (Martínez-Gallego, Vives et al., 2021) and that the SPR are 3.41 shots per point (Martínez-Gallego et al., 2019). In males' doubles, too, fewer sets, PM and PG are played than in singles, but there are more GS (Martínez-Gallego et al., 2019). The RD and W:R present lower values than in single tennis in males' doubles, too (Martínez- Gallego, Vives et al., 2021). However, in women's tennis doubles the activity profile of the matches are unknown.

Thus, the activity profile of the matches which defines tennis is fundamentally determined in singles tennis, and to a lesser extent in doubles. Besides, a large number of these studies are referred only to men's singles, thus becoming even more necessary the conduction of studies referred to women. Existing literature on doubles tennis refers to the structure of the game and the way in which the points are scored (Martínez- Gallego et al., 2019), the time structure depending on the experience of the teams (Martínez-Gallego, Vives et al., 2021), the serve performance (Martínez-Gallego, Crespo et al., 2021; Martínez-Gallego, Salvador et al., 2021), the V positions (Martínez- Gallego, Ramón-Llin et al., 2021) , the tactics (Carboch & Kocib, 2015; Carboch et al., 2014; Cayer, 2004; Kočíb et al., 2020; Talbert & Old, 1957), the communication (Lausic et al., 2015, 2009), the implicit coordination (Blickensderfer et al., 2010), the scoring system (Pollard & Pollard, 2010), the gender differences (Anderson, 1982) and the best players of different types of tennis (Breznik, 2015). Although some of these studies included female players in the sample (Anderson, 1982; Martínez-Gallego, Crespo et al., 2021; Martínez- Gallego, Ramón-Llin et al., 2021), no mention is made of the activity profile of the matches, especially in the female category.

Since there is a lack of studies describing the characteristics of women's doubles, the aim of the present study was to describe the activity profile of women´s doubles matches during three different Grand Slam tournaments, and to analyse the differences between playing surfaces.

## 4.1.3. METHODS

### *4.1.3.1.* Matches

With the approval of institutional ethics (23/CEICGC/2020), the performance characteristics of 21 matches were analysed. The matches were selected according to convenience among women's tennis matches belonging to 3 Grand Slams of the 2019 WTA Tour, played on the three types of surfaces on which the vast majority of professional tournaments are played: AUS (hard court, n = 7), RG (clay, n = 7) and W (grass, n = 7). A total of 42 professional female players were observed (age 30.1 ± 5.6; weight 65.4 ± 6.5 kg; height 170 ± 0.1 cm), and WTA ranking 51.3 ± 82. 7 (1– 481).

Matches in the first (n = 2) and third round (n = 3), quarter-finals (n = 9), semi-finals (n = 4) and final (n = 3) were analysed.

#### *4.1.3.2.* Procedures

We had online access to the footage of the tennis matches on the web for Grand Slam players, which we were able to access through the account of a professional player from the 2019 Grand Slams. From these accounts the videos of the matches can be downloaded free of charge for their analysis in MP4 format with a frame size of 1280 × 720 pixels high and a frame rate of 25.00 frames per second. The videos did not need processing. For the observational recording, the Lince v.1.4 (Gabín et al., 2012) was used. A categorisation system was created *ad hoc* based on scientific literature related to the analysis of external load parameters in singles tennis (Fernandez-Fernandez et al., 2007; Smekal et al., 2001; Torres-Luque et al., 2011), composed of 11 criteria and 25 categories collecting data on the duration of the playing and rest time intervals, and the number, types, result and location of the shots (Table 2). Points scored in each game, set and match, and the actions performed by each player were also recorded. The analysis of the duration parameters included: a) RD (start – end). For this calculation, if the FS was an error or service let, it did not count, and neither did the time between the first and second services. For the duration of the points in a double fault, the time between the beginning movement of the second service and the moment when the line umpire determined that the ball had crossed the limits of the court or that the ball had touched the net without crossing was counted; b) RTP (start of RTP – end of RTP); c) RTG (time between the end of the last point of the game and the beginning of the technical movement of the service of the first point of the next game after switching sides; d) RTS (time between the end of the last point of the set and the beginning of the technical movement of the service of the first point of the next set). The temporal analysis included: a) RT: the result of the time consumed between points, games and sets (divided into the total playing time and multiplied by 100 for the percentage); b) EPT: the result of the duration of all the points (divided into the total playing time and multiplied by 100 for the percentage); c) TMT: from the moment the first server begins the technical movement of the FS of the match until the end of the last point of the match; d) W: R: rest ratio divided into the EPT. The analysis of the shots included: a) SPR: number of shots from the FS of the point to the end of the point; b) SPG: number of shots from the FS of the game to the end of the game;

c) SPS: number of shots from the FS of the set to the end of the set; d) SPM: number of shots from the FS of the match to the last shot of the match; e) shot frequency (shots/second) (SPSc): duration of the point divided into SPR; f) shot frequency (shots/minute) (SPMn): duration of the point divided into SPR and multiplied by 60; g) base line and mid court game (BMC): area comprised from the back of the court to the service line); h) N: area comprised between the service line and the net; i) V: number of shots without a bounce other than overheads (O), j) O: number of overheads; k) F: number of F shots;1) B: number of B shots; m) FS: number of first services in; n) second serve (SS): number of second services in.

***Table 2.*** *Observational instrument.*

| ***Criteria*** | ***Categories*** | ***Description*** |
|---|---|---|
| Player who hits | J1 | Player in the right of the winning pair |
| | J2 | Player in the left of the winning pair |
| | J3 | Player in the right of the losing pair |
| | J4 | Player in the left of the losing pair |
| Duration of points | SP | Start of point (moment in which the serving player starts the movement of the FS) |
| | EP | End of point (the linesman determines that the ball crosses the limits of the court, the ball touches the net and does not pass to the opposite side or the ball makes the second bounce after having touched the opposite side) |
| Resting time between points | SRP | Start of rest between points (the linesman determines that the ball crosses the limits of the court, the ball touches the net and does not pass to the opposite side or the ball makes the second bounce after having touched the opposite side) |
| | ERP | End of rest between points (moment in which the serving player starts the movement of the FS) |
| Hitting place | G | Groundstroke (between the baseline and the service line) |
| | AB | Attacking balls (between the service line and the net) |
| Type of shot I | F | Forehand |
| | B | Backhand |
| Type of shot II | V | Volley |
| | O | Overhead |

| | | |
|---|---|---|
| | 1 | FS in |
| | 10 | F out |
| Type of service | 2 | Second service in |
| | 20 | Second service out |
| | L | Let |
| Point ending | FE | Forced error |
| | UE | Unforced error |
| | W | Winner |
| Score | X-X | Game score (15, 30, 40, Ad, game) |
| Games | X-X | X takes values from 0 to 7 |
| Set | X | 1, 2 o 3 |

#### *4.1.3.3.* Validity and reliability testing

The construct validity was obtained from the consistency of the conceptual framework by 6 tennis experts (graduates of the RFET; Real Federación Española de Tennis – Royal Spanish Tennis Federation), who reached 100% agreement for each of the categories. The validation was carried out using a virtual questionnaire, where the experts could agree or disagree with the categorisation of each criterion. The reliability was determined after the observers had received a period of training in the application of the registration instrument and after reaching an agreement (Anguera, 1990). It was established by interobserver and intraobserver agreement on 200 actions in the game. The kappa coefficients for all the criteria showed substantial or almost perfect agreement (Cohen, 1968) (Table 3).

***Table 3.*** *Interobserver and intraobserver Kappa values of every criteria.*

| **Criteria** | **Interobserver** | **Intraobserver** |
|---|---|---|
| Player who hits | 0.849 | 0.945 |
| RD (s) | 0.869 | 1.0 |
| RTP (s) | 0.861 | 1.0 |
| RTG (s) | 0.825 | 1.0 |
| Hitting place | 0.879 | 0.982 |
| Type of shot 1 | 0.893 | 1.0 |
| Type of shot 2 | 0.897 | 1.0 |
| Type of service | 0.926 | 1.0 |
| Mean | 0.875 | 0.991 |

RD, rally duration; RTP, resting time between points; RTG, resting time between games.

#### *4.1.3.4.* Statistical analyses

The mean and standard deviation were presented as statistical descriptors. To establish the differences between Grand Slam tournaments, one-way ANOVA was used after verifying the adjustment to the normality of the variables by using the Shapiro-Wilk test. When the ANOVA confirmed the existence of significant differences, the contrasts were calculated post hoc with the Bonferroni correction method and partial eta squared ($\eta 2$) was used as the effect size estimate, small effect values were considered 0.01 – < 0.06, moderate effect values were considered 0.06 – < 0.14 and large effect values were considered ≥ 0.14. The level of statistical significance was $p < 0.05$. The programme used for the statistical analysis was the SPSS Statistics, version 26.0. The reliability was measured with the kappa coefficient (Cohen, 1968).

### 4.1.4. RESULTS

#### *4.1.4.1.* Duration parameters

Table 4 presents the duration parameters in the three Grand Slam tournaments. Significant differences ($F = 6.3$; $p = 0.009$; $\eta 2 = 0.411$) were found in the RTG between hard court and clay ($p = 0.049$), and between hard court and grass ($p = 0.01$), but not between clay and grass. No significant differences were identified between the different surfaces for RD ($F = 2.9$; $p = 0.082$; $\eta 2 = 0.242$), RTP ($F = 0.19$; $p = 0.826$; $\eta 2 = 0.021$), and RTS ($F = 3.0$; $p = 0.078$; $\eta 2 = 0.247$).

Figure 2 presents the interval distribution of RD on the three surfaces. The RD of most of the points (~60%) ranged from 1 to 6 s, and when combined with the points ranging from 6 to 9 s (~20%) they represented 80% of the total points played during the tournaments. Figure 3 presents the interval distribution of RTP on the three surfaces. More than 80% of the RTP were between 18 and more than 30 s.

***Table 4.*** *Duration parameters in the three Grand Slams.*

| Variable | AUS | RG | W |
|---|---|---|---|

| | | | |
|---|---|---|---|
| RD (s) | 6.5 ± 0.7 | 7.3 ± 0.7 | 6.4 ± 0.8 |
| RTP (s) | 26.3 ± 1.2 | 26.1 ± 0.8 | 25.7 ± 3.1 |
| RTG (s) | 91.3 ± 4.7*# | 85.3 ± 3.2* | 83.7 ± 4.6# |
| RTS (s) | 133 ± 20.2 | 155.9 ± 37.3 | 121.8 ± 18.4 |

RD, rally duration; RTP, resting time between points; RTG, resting time between games; RTS, resting time between sets; AUS, Australian Open; RG, Roland Garros; W, Wimbledon.
*significant difference between Australian Open and Roland Garros.
#significant difference between Australian Open and Wimbledon.
Results are expressed as Mean ± Standard Deviation (M ± SD).

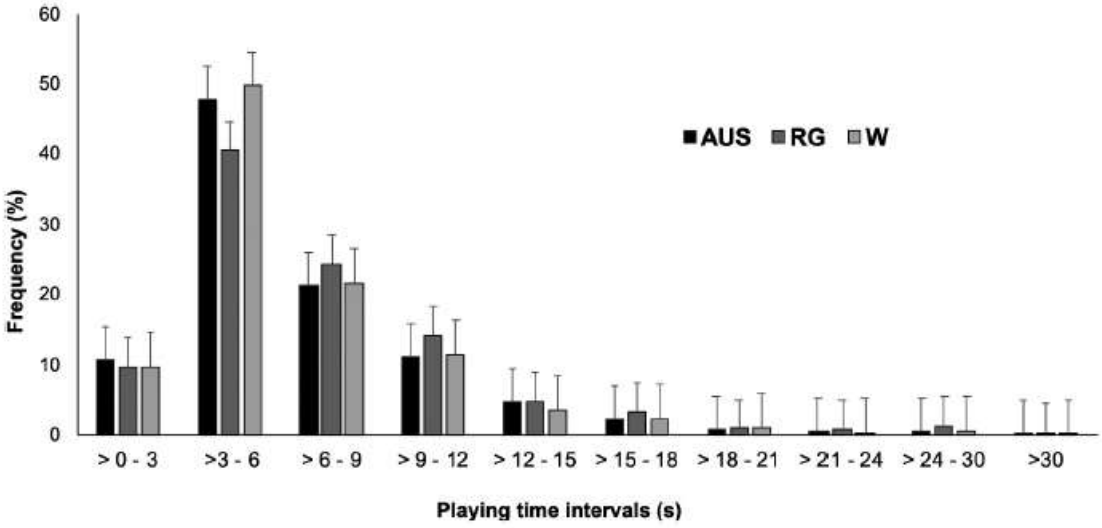


***Figure 2.*** *Mean percentage of playing time intervals (rally duration) of all the matches.*

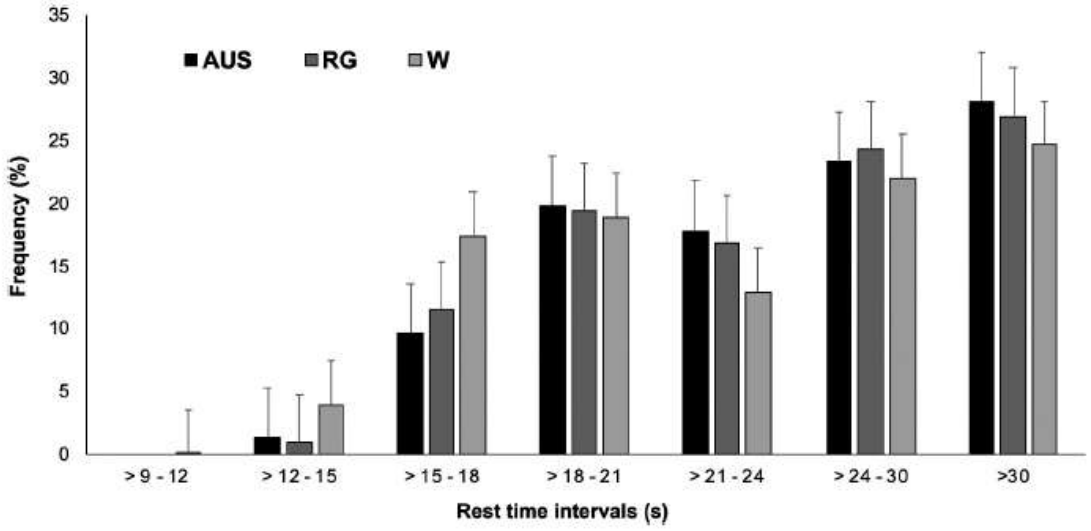


***Figure 3.*** *Mean percentage of recovery (rest time between rallies) of all the matches.*

#### *4.1.4.2.* Time parameters

Table 5 presents the absolute frequencies of the time parameters. No significant differences were identified between the different surfaces for EPT ($F = 1.0$; $p = 0.381$; $\eta2 = 0.102$), RT ($F = 1.0$; $p = 0.374$; $\eta2 = 0.104$), TMT ($F = 1.0$; $p = 0.388$; $\eta2 = 0.100$), and W: R ($F = 1.4$; $p = 0.266$; $\eta2 = 0.137$).

***Table 5.*** *Time parameters in the three Grand Slams.*

| Variable | AUS | RG | W |
|---|---|---|---|
| EPT (s) | 921.5 ± 214.5 | 923.8 ± 232.9 | 790.9 ± 137.4 |
| RT (s) | 4420.1 ± 751.3 | 3997.9 ± 951.6 | 3794.7 ± 766.1 |
| TMT (s) | 5341.6 ± 950.8 | 4921.7 ± 1170.3 | 4585.5 ± 864.90 |
| W: R (s) | 1:4.83 | 1:4.33 | 1:4.74 |

EPT, effective playing time; RT, resting time; TMT, total match time;
W: R, work-to-rest ratio; AUS, Australian Open; RG, Roland Garros; W, Wimbledon.
Results are expressed as Mean ± Standard Deviation (M ± SD).

#### ***4.1.4.3.*** Number of shots

Table 6 presents the absolute frequencies of SPM. No significant differences were found between the different surfaces in SPR ($F = 1.4$; $p = 0.268$; $\eta2 = 0.136$), SPG ($F = 1.1$; $p = 0.362$; $\eta2 = 0.107$), SPS ($F = 3.4$; $p = 0.056$; $\eta2 = 0.274$), SPM ($F = 1.3$; $p = 0.289$; $\eta2 = 0.129$), SPSc ($F = 1.4$; $p = 0.281$; $\eta2 = 0.132$), and SPMn ($F = 1.4$; $p = 0.281$; $\eta2 = 0.132$).

Figure 4 presents the average distribution of the SPR. SPR were 1 to 4 in ~60% of the cases, which combined with 5 to 6 SPR account for ~80% of the total.

***Table 6.*** *Number of shots in the three Grand Slams.*

| Variable | AUS | RG | W |
|---|---|---|---|
| SPR (n) | 4.7 ± 0.5 | 5.0 ± 0.5 | 4.5 ± 0.6 |
| SPG (n) | 33.1 ± 7.0 | 32.7 ± 6.1 | 29.1 ± 3.1 |
| SPS (n) | 336.6 ± 73.7 | 299.7 ± 40.4 | 263.0 ± 36.1 |
| SPM (n) | 665.6 ± 144.9 | 634 ± 158.0 | 550.9 ± 97.4 |
| SPSc (n) | 1.4 ± 0.1 | 1.5 ± 0.2 | 1.4 ± 0.1 |
| SPMn (n) | 82.7 ± 3.6 | 88.0 ± 9.3 | 86.1 ± 3.6 |

SPR, shots per rally; SPG, shots per game; SPS, shots per set SPM, shots per match; SPSc, strokes per second; SPMn, strokes per minute; AUS, Australian Open; RG, Roland Garros; W, Wimbledon

Results are expressed as Mean ± Standard Deviation (M ± SD).

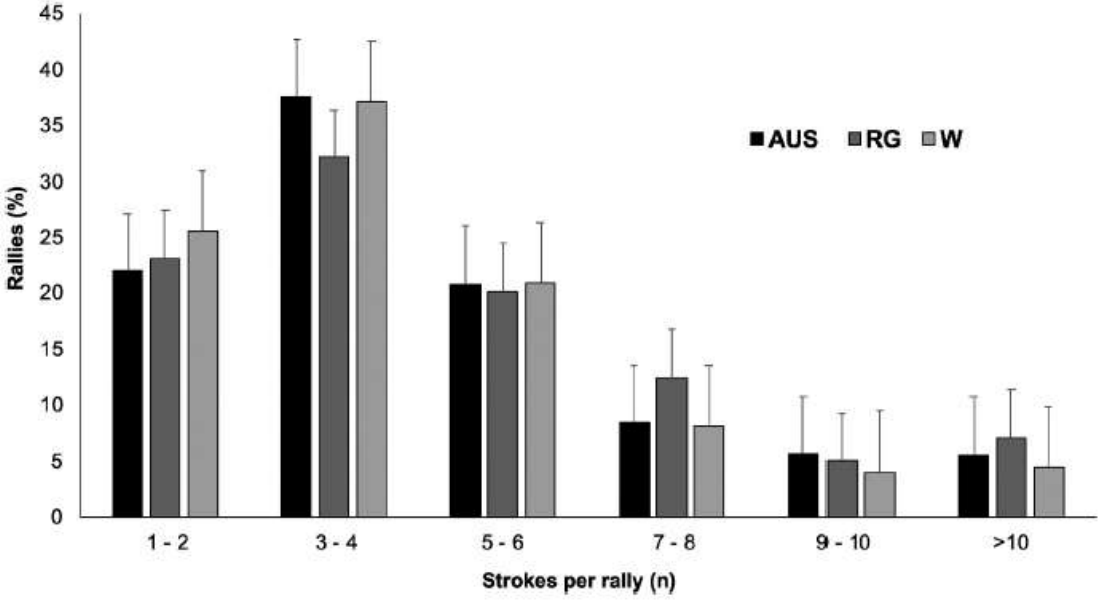


***Figure 4.*** *Mean percentage of strokes per rally in all the matches.*

#### *4.1.4.4.* Type of shots

Table 7 presents the absolute and relative frequencies of the types of SPM. Significant differences (F = 4.4; p = 0.029; η2 = 0.326) were found in F in absolute values between clay and grass (p = 0.047). No significant differences were found in the other variables.

***Table 7.*** *Stroke characteristics.*

| | AUS | | RG | | W | |
|---|---|---|---|---|---|---|
| **Variable** | **n** | **%** | **n** | **%** | **n** | **%** |
| GS | 350.3 ± 110.1 | 51.8 ± 4.9 | 361.7 ± 110.9 | 56.3 ± 5.8 | 273.6 ± 55.4 | 49.5 ± 4.2 |
| AB | 119.7 ± 24.8 | 18.3 ± 3.4 | 102.1 ± 28.0 | 16.5 ± 4.6 | 105.1 ± 26.7 | 19.0 ± 2.8 |
| V | 109.1 ± 19.7 | 16.8 ± 3.2 | 91.9 ± 23.8 | 14.9 ± 4.4 | 95.0 ± 24.6 | 17.2 ± 3.2 |
| FV | 59.9 ± 9.8 | 9.2 ± 1.7 | 50.7 ± 10.3 | 8.3 ± 2.4 | 46.6 ± 10.5 | 8.5 ± 1.5 |
| BV | 49.3 ± 10.6 | 7.6 ± 1.7 | 41.1 ± 14.0 | 6.6 ± 2.1 | 48.4 ± 15.0 | 8.7 ± 1.9 |
| O | 11.4 ± 5.6 | 1.7 ± 0.7 | 11.3 ± 4.2 | 1.9 ± 0.9 | 12.3 ± 6.3 | 2.2 ± 1.0 |
| F | 188.1 ± 54.0 | 28.0 ± 2.9 | 194.9 ± 65.5ɨ | 30.2 ± 4.0 | 122.3 ± 23.1ɨ | 22.4 ± 3.3 |
| B | 160.9 ± 62.4 | 23.5 ± 4.2 | 165.7 ± 53.9 | 25.8 ± 4.2 | 149.1 ± 45.2 | 26.7 ± 5.5 |
| FS | 118.6 ± 24.3 | 17.9 ± 2.0 | 113.6 ± 28.6 | 18.2 ± 3.1 | 113.0 ± 19.8 | 20.7 ± 2.8 |
| SS | 48.3 ± 9.6 | 7.5 ± 2.0 | 39.6 ± 12.0 | 6.4 ± 1.9 | 40.4 ± 10.3 | 7.4 ± 1.7 |

GS, groundstrokes; AB, attacking balls; V, volleys; FV, forehand volleys; BV, backhand volleys; O, overhead; F, forehands; B, backhands; FS, first service; SS, second serve; AUS, Australian Open; RG, Roland Garros; W, Wimbledon.
ɨ significant differences between Roland Garros and Wimbledon.
Results are expressed as Mean ± Standard Deviation (M ± SD).

### 4.1.5. DISCUSSION

This study is the first one to describe the activity profile of elite women's doubles tennis on different playing surfaces. These results indicate that women's doubles tennis is characterised by a series of short duration efforts, alternated with short rest periods between points, games and sets, besides requiring a good technical performance of different quick movements, with scarce differences found regarding surfaces. The RD is approximately 7 s and RTP is around 26 s, most of the points have a duration of 3 to 6 s and most of the RT exceeds 30 s. The EPT is approximately 18% of the total playing time, with a W: R of approximately 1: 4.4. The SPR are approximately 4.7 and ~80% of the points comprise 1 to 5 shots. The SPMn are over 80 shots per minute. The most frequent shots in women's doubles tennis are the F, B, FS and V, and more than 50% of the total shots in a match come from the baseline.

#### *4.1.5.1.* Duration parameters

The results indicate that the activity of the best players in women's doubles tennis during matches consists of short periods of exercise (around 80% from 0 to 9 s), and short periods of recovery (around 80% from 18 to 30 s), alternating with several longer periods of recovery (91.3 ± 4.7 s – 83.7 ± 4.6 s) between games and switching sides. Thus, although no significant differences are found, a longer RD is observed on clay (7.3 s), with grass being the surface with the shortest RD (6.4 s). The RD in women's doubles coincides with both men's and women's individuals on clay, which is between 7 and 10 s (Smekal et al., 2001; Mendez-Villanueva et al., 2007, 2010; Murias et al., 2007; Hornery et al., 2007; Fernandez-Fernandez et al., 2008; Martin et al., 2011), and more specifically with women's individuals, which is 7.2 s (Fernandez-Fernandez et al., 2009). On hard court, it is much longer compared to a study carried out on male doubles (Martínez-Gallego, Vives et al., 2021), with a RD of 3.5 ± 2.9 s. It is slightly longer compared with a study carried out with female players (Martin et al., 2011), with a duration of 5.9 ± 0.5 s, and shorter when compared with other studies carried out with male players (Christmass et al., 1998; Fernandez-Fernandez et al., 2009; Torres- Luque et al., 2011; Kilit & Arslan, 2017). The values are also slightly lower for the hard court compared with other studies which refer only to women's individuals (Morante & Brotherhood, 2006; Torres-Luque et al., 2011), with a RD of 7.0 ± 1.3 s and 9 ± 0.5 s, respectively. There are also other studies that coincide with the values in the present study, but instead, carried out on men (Hornery et al., 2007; Kilit et al., 2016; Smekal et al., 2001). On grass, it can only be compared with one other existing study. The RD observed in the present study is longer when compared with the other study of the same tournament (W) but in women's individuals (5.6 ± 0.6 s) (Morante & Brotherhood, 2006). Therefore, the trend indicated in the study by Martínez-Gallego et al. (2019) stating that the RD in men's doubles is shorter than in individuals is not confirmed, since dissimilar values are found, having some studies higher values, others lower and others equal to those found in the present study. Probably, the lower shot speed of female tennis players and the resulting greater control and response on each shot implies that the RD is not shorter than in individuals. The RD of most of the points (~40–50%) is 3 to 6 s on the three different surfaces, followed by 6 to 9 s (~22%), 9 to 12 s (~12%) and 0 to 3 s (~10%). As a result, 60% of the points have a duration of 0 to 6 s, and ~80% of 0 to 9 s. Therefore, differences with other studies are found in women's individuals (Fernandez-Fernandez et al., 2008), with a higher percentage of points having a duration of 0 to 3 s (17%) and 6 to 9 s (25%), and a lower

percentage having a duration of 3 to 6 s (25%), probably because it was carried out with junior female players. No significant differences were found regarding surfaces in the mean of RTP (~26 s), being longer, in all the cases, than the RT registered in studies on men's and women's individuals (Christmass et al., 1998; Fernandez-Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007, 2010; Hornery et al., 2007; Torres- Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017) and longer than the regulation 20 s (International Tennis Federation, 2012). This fact is probably due to the need to talk about and tactically prepare the point or the performance with the partner and, also, because the time spent on the failed FS or lets were not counted as playing time, nor was the time between FS and SS. Additionally, the signals given between the first and second services and the auditory information between partners probably mean an even bigger time increase. More than 80% of RTP is between 18 s and more than 30 s. Most of the RTP on the three different surfaces exceeds 30 s, followed by 24 to 30 s, 18 to 21 s, 21 to 24 s and 15 to 18 s, except on grass, where 17.4% of the RT is between 15 and 18 s, and 12.9% between 21 and 24 s. The RTG is 91.3 s on hard court, 85.3 s on clay and 83.7 s on grass. This is the only duration parameter with significant differences, which are found between the hard court and clay, and the hard court and grass. This is probably due to the tournament conditions. The AUS is characterised by its high temperatures (Smith et al., 2018), making players spend more time between games refreshing and cooling themselves. No significant differences are found between clay and grass. The RTG includes the RT between the first and the second game of each set, which is possibly the reason why the time is slightly shorter than the regulation 90 s (International Tennis Federation, 2012), although the time between the first and the second services when it was a fault or a service let was also counted as RTG. The RTS is 133.0 s on hard court, 155.7 s on clay and 121.8 s on grass. The time is longer on clay, followed by hard court and grass, although no significant differences are found. In all the cases it is longer than the regulation 120 s (International Tennis Federation, 2012), probably because the time of the fault FS or lets at the beginning of the set were not counted, nor was the time between FS and SS of the FS of each set. It might also be due to the need to reach a tactical agreement between the partners after each let or between the first and second services.

#### *4.1.5.2.* Relation between playing and resting time

According to time parameters, ~82% is RT and ~18% is EPT. No significant differences are identified between the different surfaces. The EPT is shorter than in individuals and the RT is longer. This fact is probably due to the tactical preparation of the points and, therefore, to the longer time spent between points (Christmass et al., 1998; Smekal et al., 2001; Fernandez- Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007, 2010; Martin et al., 2011; Morante & Brotherhood, 2008; Torres-Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017; Kilit et al., 2018; Kilit & Arslan, 2018). A W: R of ~1: 4.6 s is established and no significant differences are found regarding different surfaces. Compared with men's doubles on hard courts, the ratio is slightly lower (RT per second is shorter) (Martínez- Gallego, Vives et al., 2021). However, compared with other studies, on the three different surfaces the ratio is higher (RT per second is longer) than in individuals, both men's and women's (Christmass et al., 1998; Smekal et al., 2001; Fernandez-Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007; Martin et al., 2011; Torres-Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017), the reason might probably be because the shots are performed in longer units of time than in men's doubles where the points finish sooner, but in shorter units of time than in individuals where the points are longer. The W: R provides an objective means of quantifying the physiological requirements of an activity, and this information could be used for the development of interval training protocols for female doubles professional players. The TMT is 5341.6 ± 950.8 s (89.0 ± 15.8 min) on hard court, 4921.7 ± 1170.3 s (82.0 ± 19.5 min) on clay and 4585.5 ± 864 s (76.4 ± 14.4 min) on grass. No significant differences are identified regarding the different surfaces. The duration values on hard and clay courts are slightly shorter than those obtained in men's doubles on hard court (79.4 ± 7.2 min), and longer on grass (Martínez-Gallego, Vives et al., 2021). Compared with individuals, the TMT is shorter than in men's singles Grand Slam matches on any of the surfaces, probably because the matches are played to the best of five sets, it is also shorter in women's singles on hard court, and longer on grass in women's individuals (Morante & Brotherhood, 2008).

#### *4.1.5.3.* Number of shots

Regarding the SPR, the values contrast with another study carried out on doubles (Martínez-Gallego et al., 2019), where the SPR were 3.4 shots, although that study was carried out among male players (ATP) and on hard court, so the results were probably

influenced by the faster hitting speed of the male players. They also contrast with other studies carried out on women's and men's individuals, both on hard court (Kilit et al., 2016; Torres-Luque et al., 2011; Kilit & Arslan, 2017), and on clay (Mendez-Villanueva et al., 2007; Fernandez-Fernandez et al., 2008, 2009). However, values similar to those in the present study were are also found on hard court (~4.7 SPR) Christmass et al., 1998; Hornery et al., 2007) and on clay (~4.9 SPR) (Hornery et al., 2007), although both studies were carried out among men. Regarding the intervals of SPR, the values contrast with other studies carried out on women's individuals (Fernandez-Fernandez et al., 2008), where more than 50% (50.8%) of the total points required between 1 and 2 shots (~23% in the present study), more than 30% (32.4%) between 3 and 4 shots (~35% in the present study) and when adding both it resulted in more than 80% (83.2 %). No significant differences were found between the different surfaces in SPG, SPS, and SPM. Regarding SPSc and SPMn, the values in the present study (~85 shots per minute) contrast with others on the frequency of shots in individuals also in a Grand Slam tournament (Morante & Brotherhood, 2006), where the shots per minute in women's individuals were 42.2 ± 3.1 in the AUS (hard court) and 44.1 ± 1.0 in W (grass). It also contrasts with another study carried out among male players (Smekal et al., 2001) which divides players into attackers (those who preferred to play near the net) and defenders (those who preferred to play from the baseline), with defenders performing 42.6 ± 9.6 shots per minute and attackers 47.1 ± 6.9. It can be seen that when the game is offensive, the frequency of the shots increases (Smekal et al., 2001). In this way, we find a much greater frequency of the shots in doubles than in individuals, probably due to the offensive game in doubles. The player near the net is actively involved with a high percentage of V played very close to the net (Martínez-Gallego, Ramón-Llin et al., 2021), and so, the number of V increase and the playing space is reduced.

#### *4.1.5.4.* Types of shots

Regarding the different types of shots, previous studies have studied the frequency of the use of tennis strokes (Martin-Lorente et al., 2017; Takahashi et al., 2008) and have shown differences depending on the quality and experience of the players (Cui et al., 2017) and the playing surface (Cui et al., 2018). In this study, significant differences were found only in the F shots between clay and grass in the absolute values, not in the percentages, possibly due to having more time to hit on the desired side owing to a lower speed of the

bounce. Also, possibly because of the greater number of shots on clay in absolute terms. Besides, when a ball goes towards the centre it is usually a F. With regard to the position in the area where the shot is performed and taking into account the total shots in the matches, approximately 50% of the shots in doubles come from the BMC, around 18% from the N and the rest from the service line because they are services. The number of shots in the N is much higher than in singles, probably because in most of the points the player starts near the net and the space to send the ball to the back of the court is limited. In addition, the player who starts from the back of the court also gets closer to the net, both after the service and after the first shot. Regarding the types of shots, on the three different surfaces, the most frequent are the F (~26%) and B (~25%), followed by FS (~18%), V (~16%), SS (~7%) and O (~2%), except F and B on grass, where B rank first and F second. Compared with individuals, in another study also carried out in a Grand Slam tournament (AUS) with male and female players, it was established that, in terms of percentage, the most frequent shots are the F (28%) and the B (23%), followed by the FS (19%), the returns of B (12%) and F (9%), and the SS (7%) (Whiteside & Reid, 2017). Therefore, the order of the most frequent shots is the same on the three different surfaces in the first three (F, B and service), but different in the others, since in doubles the V is more important (in this study, the returns were not registered), probably because in most of the points the player starts near the net and a V is easier. Although no significant differences are found, the percentage of FV is slightly higher than BV on hard court and clay, and the percentage of BV is slightly higher on grass.

Some limitations to the study should be noted. Although the reliability of data collection was very high, there was no access to automatic data collection systems that would allow for greater precision in the positions of the players or in the time. On the other hand, as this was an observational study of competitive matches, analyses of physiological variables that could have complemented the results shown in the study were not carried out as the use of electronic devices is not permitted during matches.

### 4.1.6. CONCLUSIONS

The activity profile of the female players is characterised by a RD of approximately 7 s and an RTP of approximately 26 s, most of the points lasting between 3 s and 6 s, and most of the RT exceeding 30 s. The EPT is approximately 18% of the total playing time,

with a W: R of approximately 1:4.4. The SPR is approximately 4.7 and ~80% of the points perform 1 to 5 shots. The SPMn exceeds 80 shots per minute. The most frequent shots in women's doubles are the F, B, FS and V, and more than 50% of the total shots in a match are ground-strokes. The only significant differences regarding surfaces are found in the RT between games between AUS and RG, and AUS and W. These results suggest that in women's doubles the stimuli are short and intense, the N is very important, it requires a good technical performance of different quick movements, and each point is tactically prepared. Consequently, they could be used to develop specific training protocols for professional doubles female players.

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## 4.2. Study II

**Comparison of the game structure and point ending during Grand Slam women's doubles tennis**

*by*

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### 4.2.1. ABSTRACT

Despite the importance of doubles tennis, there is little research on this modality of the game, especially as per women play. The aim of this study was to analyse the structural variables and the way points ended in women's doubles, as well as to observe the differences between surfaces and between winning and LT. Twenty-one WTA doubles matches from three Grand Slams played on three different surfaces were analysed. Players played 2.0 ± 0.3 sets, 19.9 ± 3.2 games, 130.4 ± 25.3 points, 0.2 ± 0.6 TM, 9.5 ± 1.0 games and 62.6 ± 7.9 PS, and 6.6 ± 0.6 PG. 33.5% of the points ended with a Wn, 43.6% with a FE and 22.8% with an UE, with the Wn shot being the variable that most discriminated between WT and LT. It was also shown that the way more points were finished was with FE, followed by Wn and UE. There were no significant differences between surfaces in structural variables or point ending. These results showed that in women's doubles playing Wn shots and avoiding UE is crucial to successful performance, so that aggressive play and taking the initiative in the game has a positive influence in the result.

**Keywords:** Doubles tennis, performance analysis, descriptive variables, point ending, professional players, playing surface, racket sport

### 4.2.2. INTRODUCTION

In tennis, the doubles game has always had a considerable relevance, in fact, the first doubles competition took place in 1884, just 7 years after the first singles tournament played in 1877 at W. On the other hand, throughout the years there have been great players who have focused their careers and have been especially known for their outstanding performance in doubles (Breznik, 2015; Martínez-Gallego, Vives et al., 2021). In addition, it is common to see players who are not specialists in doubles playing this discipline, as the characteristics of the doubles game allow them to develop and improve some skills that are crucial for successful singles play, such as the serve, the return of serve, the N, the reaction speed or perception (Carboch, 2014). The doubles game also helps players to make extra income at professional level (Martínez-Gallego et al., 2019). Currently, doubles events are played in all professional tournaments, both in the men's and women's events, which is a clear indicator that the doubles game is considerably relevant in the professional tours (Carboch, 2014; Martínez-Gallego et al., 2019). On the other hand, in team competitions (i.e., Davis Cup, Billie Jean King Cup, ATP Cup), doubles matches are often decisive for the results of the ties, which is why this discipline is particularly relevant in this type of competition (Martínez-Gallego et al., 2019).

As per the specific rules of the doubles game, the court dimensions are different to those of the singles game since the two alleys are added to both sides of the court. In addition, due to the fact that it is played in pairs, the precision and the direction of the shots is very important, as the space is reduced as compared to the singles game. The tactical and decision-making aspects are also more complex than in singles, as the number of players is greater and, therefore, a higher number of stimuli should be considered (Carboch, 2014; Carboch and Kočíb, 2015). Thus, communication between players, both verbal and non-verbal, becomes particularly important as teams should communicate effectively to solve problems and take decisions between and during points (Lausic et al., 2009). The scoring system also has some differences as compared to singles. Except in Grand Slam doubles events, where matches are played to the best of three tie-break sets, in all other tournaments on the professional circuits, matches are played to the best of two tie-break sets and a super tiebreak. In addition, the No-Ad rule also applies, whereby in the event of a tie-break, the match is decided on the next point (International Tennis Federation, 2021; Association of Tennis Professionals, 2020; Women's Tennis Association, 2019).

These differences mean that match times are shorter than those of the singles game (Martínez-Gallego et al., 2019).

Despite the importance of the doubles game, it has not received excessive interest from researchers. Previous research that have studied doubles have analysed aspects such as the tactics used by the teams (Carboch, 2014; Carboch and Kočíb, 2015; Cayer, 2004; Kočíb et al., 2020; Talbert and Old, 1957), the communication between team members (Lausic et al., 2009; Lausic et al., 2015), the players' coordination (Blickensderfer et al., 2010), scoring systems (Pollard and Pollard, 2010), gender differences (Anderson 1982), the best doubles players (Breznik, 2015), the structure of the game and the way in which points are finished (Martínez-Gallego et al., 2019), the time characteristics according to the experience of the teams (Martínez-Gallego, Vives et al., 2021), the performance of the serve (Martínez-Gallego, Crespo et al., 2021; Martínez-Gallego, Salvador et al., 2021), the V positions (Martínez-Gallego, Ramón Llin et al., 2021) and the activity profile in women's doubles tennis (Borderias et al., 2021).

The specific characteristics of the doubles game presented above imply that the demands of the game are substantially different from those of the singles matches. With regards to the activity profile in men's, it has been observed that the duration of points (DR) is shorter than in singles (Martínez-Gallego, et al., 2019). However, this is not the case in women's doubles, where no differences have been found as compared to the men's singles in terms of DR (Borderias et al., 2021). The work-rest ratio (W: R) also shows lower values in doubles than in singles (Martínez-Gallego, Vives et al., 2021). The rest time between points (RTP) is higher in women's doubles than in the singles game, the EPT is shorter in women's doubles as compared to the singles game, and the rest time (RT) is longer in women's doubles (Borderias et al., 2021). In terms of structural characteristics, less sets, less PM and less PG are played in men's doubles than in singles, although more games are played per set (Martínez-Gallego, et al., 2019). Regarding the differences between men's and women's doubles at professional level, it has been shown that the W: R is slightly lower in women's doubles than in men's doubles, the TMT in women's doubles on hard and clay courts is slightly longer than in men's doubles on hard courts, and shorter on grass (Borderias et al., 2021).

To the authors knowledge, there is only one previous study that analysed the point ending and the structure of the professional doubles game and, moreover, it studied the men's game (Martínez-Gallego, et al., 2019), and only another previous study that analysed the women's professional doubles game (Borderias et al., 2021). As per the singles game, there are several studies that have analysed Wn and errors, and some of them related them to the players' style of play and the probability of winning or losing matches (Djurovic et al., 2009; Filipcic et al., 2009; Katic et al., 2011), as well as to the time spent in different zones of the court (Martínez-Gallego et al., 2013). As it can be concluded, there is no previous literature that have analysed the variables that describe the structure of matches and the way in which points are finished in women's doubles. Thus, the objectives of this study were to analyse and establish whether there were differences in the structural variables of women's doubles matches, and to determine how points were finished in women's doubles matches of three Grand Slams which were played on three different surfaces. In addition, it was also studied whether there were differences between the winning and LT in terms of finishing the points.

## 4.2.3. METHODS

### *4.2.3.1. Matches*

With the approval of institutional ethics (23/CEICGC/2020), the performance characteristics of 21 matches were analysed. The matches were played at 3 Grand Slams of the 2019 season, which were played on three different surfaces: AUS (hard court, n=7), RG (clay, n = 7) and W (grass, n = 7). One of the two hard court Grand Slams was randomly selected and therefore only the AUS matches on this surface were analysed. A total of 42 professional female players were observed (age 30.1 ± 5.6; weight 65.4±6.5 kg; height 170 ± 0.1 cm), with a mean Woman Tennis Association (WTA) ranking of 51.3±82. 7 at the time matches were played (minimum = 1 – maximum = 481). Matches in the first round (n = 2), third round (n = 3), quarter-finals (n = 9), semi-finals (n = 4) and final (n = 3) were analysed.

### *4.2.3.2. Procedures*

Online access to the footage of the tennis matches available on the web for Grand Slam players was obtained from a professional player. From these accounts the videos of the matches can be downloaded free of charge for their analysis in MP4 format with a frame

size of 1280×720 pixels high and a frame rate of 25.00 frames per second. The videos did not need processing. For the observational recording, the Lince v.1.425 was used. A categorisation system was created ad hoc based on scientific literature related to the analysis of external load parameters in singles tennis (Fernandez-Fernandez et al., 2007; Smekal et al., 2001; Torres-Luque et al., 2011), composed of 6 criteria and 12 categories which collected data on the player, score, point outcome and shot placement (Table 8) (Borderias et al., 2021). Points scored in each game, set and match, and the point ending were also recorded. The analysis of the descriptive variables included SM, GM, PM, TM, GS, PS and PG. The analysis of the point ending included Wn (when the rally outcome was caused by a forcing shot that could not be reached), FE (when the rally outcome was caused by a forcing shot that could not be played back) and UE (when the rally outcome was an error caused by a wrong tactical decision or technical execution by the player, or a poor hitting technique) (Martínez-Gallego et al., 2013; Brody, 2006). For the percentage, Wn, FE and UE shots were divided into the total number of shots and multiplied by 100.

***Table 8.*** *Observational instrument.*

| ***Criteria*** | ***Categories*** | ***Description*** |
|---|---|---|
| Player who hits | J1 | Player in the right of the winning pair at the start of the match |
| | J2 | Player in the left of the winning pair at the start of the match |
| | J3 | Player in the right of the losing pair at the start of the match |
| | J4 | Player in the left of the losing pair at the start of the match |
| Hitting place | G | Groundstroke (between the baseline and the service line) |
| | AB | Attacking balls (between the service line and the net) |
| Point ending | FE | Forced error |
| | UE | Unforced error |
| | W | Winner |
| Score | X-X | Game score (15, 30, 40, Ad, game) |
| Games | X-X | X takes values from 0 to 7 |
| Set | X | 1, 2 o 3 |

#### *4.2.3.3.* Validity and reliability testing

The construct validity was obtained from the consistency of the conceptual framework by 6 tennis experts (certified coaches by the Real Federación Española de Tenis – Royal Spanish Tennis Federation- RFET), who reached 100% agreement for each of the categories. The validation was carried out using a virtual questionnaire, in which the experts could agree or disagree with the categorisation of each criterion. The reliability was determined after the observers had received a period of training in the application of the registration instrument and after reaching an agreement (Anguera, 1990). It was established by interobserver and intraobserver agreement on 200 actions in the game, with values of 0.798 and 0.940 respectively in the kappa coefficient. These values represent a very good reliability (Table 9).

***Table 9.*** *Interobserver and intraobserver Kappa values of every criteria.*

| Criteria | Interobserver | Intraobserver |
|---|---|---|
| **Player who hits** | 0.849 | 0.945 |
| **Hitting place** | 0.879 | 0.982 |
| **Point ending** | 0.666 | 0.895 |
| **Mean** | 0.798 | 0.940 |

#### *4.2.3.4.* Statistical analyses

The mean and standard deviation were presented as statistical descriptors. To establish the differences between Grand Slam tournaments, one-way ANOVA was used after verifying the adjustment to the normality of the variables by using the Shapiro-Wilk test When the ANOVA confirmed the existence of significant differences, the contrasts were calculated post hoc with the Bonferroni correction method and partial eta squared ($\eta 2$) was used as the effect size estimate, small effect values were considered 0.01 - < 0.06, moderate effect values were considered 0.06 - < 0.14 and large effect values were considered >=0.14. Data for PS, SM, TM, UE (n) and FE (n) was not normally distributed and comparison of variables was done using the Kruskal-Wallis and Mann-Whitney tests (for independent samples). Comparisons between the teams (winners vs. losers) and surfaces (AUS, RG and W) were performed using factorial analysis of variance (ANOVA) (2×3 design, winners and losers' teams x surface). If significant effects were

found, Bonferroni post hoc test were performed to locate significant differences. Stepwise discriminant analysis was used for selected point ending parameters, with team as the dependent variable (winners vs. losers). The reliability was measured with the kappa coefficient (Cohen, 1968). The level of statistical significance was $p < 0.05$. The programme used for the statistical analysis was the SPSS Statistics, version 26.0.

### 4.2.4. RESULTS

#### *4.2.4.1.* Descriptive variables

Table 10 shows the absolute frequencies per match of the variables which describe the characteristics of the women's doubles matches.

No significant differences were identified between the different surfaces for PG ($F = 0.74$; $p = 0.491$; $\eta^2 = 0.076$), GM ($F = 3.64$; $p = 0.809$; $\eta^2 = 0.023$), PM ($F = 0.71$; $p = 0.507$; $\eta^2 = 0.073$), and GS ($F = 2.29$; $p = 0.130$; $\eta^2 = 0.203$). In the same way, no significant differences between surfaces (Kruskal-Wallis) were found in PS ($x^2 = 5.77$, $df = 2$, $p = 0.056$), SM ($x^2 = 0.855$, $df = 2$, $p = 0.652$) and TM ($x^2 = 0.54$, $df = 2$, $p = 0.765$).

***Table 10.*** *Descriptive variables of women's doubles Grand Slam matches.*

| VARIABLE | AUS | RG | W |
|---|---|---|---|
| **SM (n)** | 2.0 ± 0 | 2.1 ± 0.4 | 2.1 ± 0.4 |
| **GM (n)** | 20.4 ± 1.9 | 20.0 ± 4.6 | 19.3 ± 3.0 |
| **PM (n)** | 140.0 ± 20.9 | 127.3 ± 29.6 | 124.0 ± 25.5 |
| **TM (n)** | 0.3 ± 0.8 | 0.1 ± 0.4 | 0.3 ± 0.5 |
| **GS (n)** | 10.2 ± 1.0 | 9.3 ± 1.2 | 9.0 ± 0.9 |
| **PS (n)** | 70.1 ± 10.4 | 59.4 ± 5.4 | 58.5 ± 8.1 |
| **PG (n)** | 6.9 ± 0.9 | 6.5 ± 0.7 | 6.4 ± 0.4 |

AUS, Australian Open; RG, Roland Garros; W, Wimbledon; SM, sets per match; GM, games per match; PM, points per match; TM, tie breaks per match; GS, games per set; PS, points per set; PG, points per Game. Results are expressed as Mean ± Standard Deviation (M ± SD).

#### *4.2.4.2.* Point ending

Table 11 shows the absolute and relative frequencies per match of the way in which points ended in women's doubles matches. No significant differences were identified between the different surfaces for UE (%) ($F = 1.64$; $p = 0.221$; $\eta^2 = 0.154$), Wn (n) ($F = 0.08$; $p = 0.926$; $\eta^2 = 0.009$), Wn (%) ($F = 0.97$; $p = 0.398$; $\eta^2 = 0.097$), and FE (%) ($F = 0.46$; $p = 0.639$; $\eta^2 = 0.0.049$). In the same way, no significant differences (Kruskal-Wallis) were found in UE (n) ($x^2 = 4.26$, $df = 2$, $p = 0.119$) and FE (n) ($x^2 = 1.01$, $df = 2$, $p = 0.604$).

***Table 11.*** *Point ending of women's doubles Grand Slam matches.*

| VARIABLE | AUS | RG | W |
|---|---|---|---|
| **Wn (n)** | 43.4 ± 9.8 | 40.1 ± 9.8 | 41.0 ± 9.1 |
| **FE (n)** | 53.0 ± 12.7 | 54.4 ± 14.8 | 54.1 ± 15.9 |
| **UE (n)** | 38.6 ± 13.7 | 25.4 ± 9.8 | 22.1 ± 4.2 |
| **Wn (%)** | 32.0 ± 4.3 | 33.8 ± 5.5 | 34.9 ± 3.4 |
| **FE (%)** | 39.8 ± 10.7 | 45.3 ± 4.1 | 45.7 ± 5.1 |
| **UE (%)** | 28.3 ± 8.3 | 20.9 ± 6.3 | 19.4 ± 4.9 |

AUS, Australian Open; RG, Roland Garros; W, Wimbledon; Wn, winner; FE, forced error; UE, unforced error. Results are expressed as Mean ± Standard Deviation (M ± SD).

#### *4.2.4.3.* Differences between point ending and winners and losers

Table 12 shows the absolute frequencies of the differences between the way in which points ended and the teams that win or lose the matches.

The Figure 5 shows the differences between the Wn, FE and UE by surfaces with the WT or LT.

A significant main effect of teams (losers and winners) was found for Wn ($F = 11.2$; $p = 0.002$; $\eta^2 = 0.238$). Specifically, WT shows more Wn than LT in RG ($p = 0.031$; 32.9%). A significant main effect of surface was found for UE ($F = 7.3$; $p = 0.002$; $\eta^2 = 0.289$), AUS shows more UE than W in WT ($p = 0.008$; 55.6%). No significant interaction effect (group x surface) was found (Table 12).

The results of the stepwise discriminant analysis are summarized in Table 13. The predictive model that best discriminated WT included the 3 point ending variables, and correctly classified 90.5% of the players. The most discriminating factor was the Wn followed by UE and FE.

***Table 12.*** *Point ending differences between winners and losers.*

| VARIABLE | WT | | | LT | | |
|---|---|---|---|---|---|---|
| | **AUS** | **RG** | **W** | **AUS** | **RG** | **W** |
| **Wn (n)** | 24.7 ± 5.2 | 24.0 ± 8.0$^{\$}$ | 23.7 ± 5.7 | 18.7 ± 7.2 | 16.1 ± 3.8 | 17.3 ± 8.1 |
| **FE (n)** | 24.0 ± 5.7 | 24.9 ± 10.7 | 26.7 ± 9.0 | 29.0 ± 7.7 | 29.6 ± 4.8 | 27.4 ± 8.2 |
| **UE (n)** | 18.7 ± 5.9* | 11.0 ± 5.0 | 8.3 ± 3.0 | 19.9 ± 9.1 | 14.4 ± 6.3 | 13.9 ± 4.9 |

AUS, Australian Open; RG, Roland Garros; W, Wimbledon; WT, winning team; LT, losing team; Wn, winner; FE, forced error; UE, unforced error. Results are expressed as Mean ± Standard Deviation (M ± SD).
$^{\$}$Significantly greater than RG LT ($p < 0.05$).

*Significantly greater than W WT ($p < 0.01$).

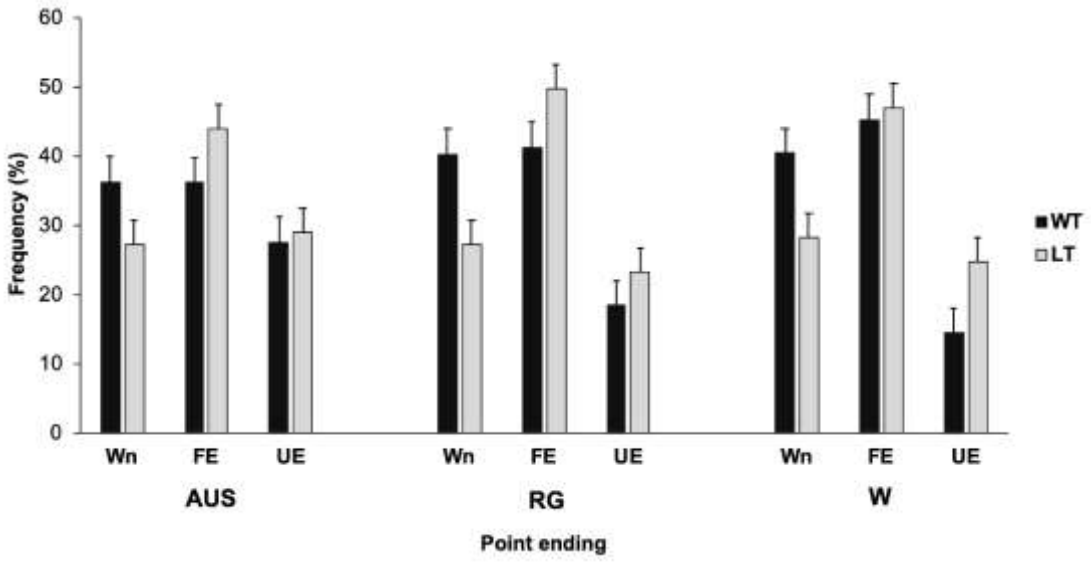


**Figure 5.** Comparison between point ending and winners and losers in different surfaces. Abbreviations: WT, winning team; LT, losing team; Wn, winner; FE, forced error; UE, unforced error; AUS, Australian Open; RG, Roland Garros; W, Wimbledon.

***Table 13.*** *Point ending variables included in the stepwise discriminant analysis procedure.*

| Step* | Entered | Wilk's lambda | | | | | |
|---|---|---|---|---|---|---|---|
| | | Statistic | df1 | df2 | df3 | Statistic | p-value |
| 1 | Wn | 0.766 | 1 | 1 | 40.000 | 12.251 | 0.001 |
| 2 | UE | 0.617 | 2 | 1 | 40.000 | 12.088 | <0.001 |
| 3 | FE | 0.446 | 3 | 1 | 40.000 | 15.734 | <0.001 |

Wn, winner; UE, unforced error; FE, forced error. At each step, the variable that minimizes the overall Wilk's lambda is entered. *Maximum number of steps is 6; minimum partial F to enter is 3.84; maximum partial F to remove is 2.71.

### 4.2.5. DISCUSSION

Knowing the structure of the game and the way in which points are won is important for designing training sessions and understanding the women's doubles game. This study is the first one that provides data on the variables that describe the game, as well as on how points are won in women's doubles matches. In addition, differences are analysed between the three main surfaces in three Grand Slam tournaments, and between the point ending and the winning and LT. As per the descriptive variables about 2 SM, 20 GM, 130 PM, 0.2 TM, 9.5 GS, 62 PS and 6.5 PG are played. Regarding point ending, about 33% were Wn, about 30% FE and about 22% UE, with Wn being the variable that discriminated the most between WT and LT. As mentioned above, there are just a few studies on doubles tennis, and just one of them has analysed the structure of the game and the point ending. Therefore, in the discussion, reference will also be made to the research conducted on singles tennis.

#### *4.2.5.1.* Descriptive variables

Results have shown that the best women doubles teams play around 2 SM, 20 GM, 130 PM, 0.2 TM, 9.5 GS, 62 PS and 6.5 PG. As per SM, the number was lower (2.0 or 2.1) on all three surfaces as compared to SM in men's doubles (2.44) (Martínez-Gallego et al., 2019). In this study the matches were played to the best of 3 sets (with match tie break), although all were played on hard surfaces. It was also lower compared to the results of a study of men's singles matches played at the 4 Grand Slams, where the number of SM varied from 3.55 to 3.85 SM (Cross and Pollard, 2009). These results are due to the fact that men's Grand Slam doubles matches are played to the best of 5 sets (best of 3 in the women's draw) and therefore the number of sets played per match is higher.

Regarding the number of GM, the highest number was obtained on hard court, being 20.4 (20.0 and 19.3 on clay and grass, respectively). The values on the three surfaces were lower compared to those of men's doubles on hard court (21.65), with matches played to the best of 3 sets with match tie break (Martínez-Gallego et al., 2019).

Although no significant differences were found, the highest number of PM was obtained on hard courts (140.0), followed by clay (127.3) and grass (124.0). Compared to a study in men's doubles, with mean values of 123.18 PM, the results were higher on all three surfaces (Martínez-Gallego et al., 2019). This is possibly due to the higher effectiveness of the serve in men's doubles, being 10% higher than in women's doubles (Carboch and Kočíb, 2015), possibly due to the higher speed of the serve and the reduced court space to hit the ball back in doubles (Borderias et al., 2021). Thus, in women's doubles, games are possibly won more slowly and less easily when serving and more points are played as compared to the men's game. Compared to singles and in the same Grand Slams than that in this study, in women's singles there was a lower number of PM than in women's doubles on hard courts (129), whereas on grass the number was slightly higher (130) and on clay it was the highest (133) (Kovalchik and Reid, 2017). In both studies the matches were played to the best of 3 sets. In men's singles and in the same Grand Slams, the PM values were higher than those found in our study on women's doubles on all three surfaces. On hard courts the number of PM was 216 (140 in women's doubles), on clay 213 (127.3 in women's doubles) and on grass 221 (124 in women's doubles) (Kovalchik and Reid, 2017). These results are consistent considering that men's singles Grand Slam matches are played to the best of 5 sets and women's doubles matches are played to the best of 3 sets. Compared to singles but in the junior category, where matches are played to the best of 3 sets in girls and boys, the PM values in girl's juniors were smaller than in women's doubles, being 122 on hard court and clay and 115 on grass (Kovalchik and Reid, 2017). This is possibly because junior players have not yet fully developed their technical-tactical skills and physical capacity and, therefore, the number of errors they make is higher. In junior boys the values were 130 on hard court (lower than women's doubles), 131 on clay and 137 on grass (higher than women's doubles). In comparison with the PM in another article on to men's and women's singles, where the matches were played to the best of 3 sets, the number of PM in singles was lower in all cases, being 123.3 on hard courts, 119.1 on clay and 121.0 on grass for the men's, and 115.5 on hard

courts, 111.2 on clay and 113.5 on grass for the women's (Carboch and Kočíb, 2015). Finally, as compared to another study in men's singles, the values are lower on all three surfaces, being 177 PM (Kovacs, 2004). Therefore, no clear trend can be established with respect to the singles game, as there are PM values below and above those found in this study, both in women's and men's singles.

In terms of TM, there were 0.3 on hard and grass courts and 0.1 on clay. No significant differences were observed, although the results show that it is more difficult to break serve on hard and grass courts than on clay courts and, therefore, there were more tie breaks on these surfaces than on clay. Compared to men's doubles on hard courts, where 0.53 TM were played, fewer TM were played on all three surfaces (Martínez-Gallego et al., 2019). This fact may be due to the higher service speeds of male players and, therefore, also to the greater difficulty in winning games when they are returning, which leads to a higher number of TM. Furthermore, in the doubles game, the fact that the server's partner is usually at the net means that following a good serve, even if the serving team does not win the point directly, they still have a considerable advantage to win it on the following shots, which further reduces the chances of the receiving team to win the points and, therefore, it is also more difficult to make breaks.

As per the variables related to a set, the number of GS in women's doubles is below the 10.51 GS in men's doubles on hard courts (Martínez-Gallego et al., 2019), probably because, as noted above, it is more difficult to break serve in men's doubles than in the women's game. The closest value to this was 10.2 on hard courts, followed by 9.3 on clay and 9.0 on grass courts. In comparison with a study in men's singles in Grand Slams, at the AUS, values between 9.5 and 9.8 GS were found, both lower than the 10.2 GS observed in this study, possibly because in singles there are more breaks than in doubles. In RG between 9.3 and 9.7 GS were played, so in women's doubles similar values were found. And in W the GS values were between 9.9 and 10.1, both higher than the 9.0 observed in women's doubles (Cross and Pollard, 2009). It can thus be concluded that on hard courts the sets were more even in doubles than in singles and more GS had to be played. On clay courts, they were similar in singles and doubles. Finally, on grass courts the sets were closer in singles than in doubles and, therefore, in singles matches players had to play more GS.

In terms of PS, the highest value was obtained on hard courts (70.1), followed by 59.4 on clay and 58.6 on grass courts. In all three surfaces more points were played than in men's doubles on hard courts, where mean values of 57.94 PS were observed (Martínez-Gallego et al., 2019). It can be observed that there is greater equality in women doubles, possibly, as indicated above, due to a greater difficulty in winning points on serve as compared to the men's game.

The PG were also higher in women's doubles on all three surfaces compared to men's doubles on hard courts, where 5.51 PG were played (Martínez-Gallego et al., 2019), possibly for the reason mentioned above. Compared to the PG played in men's singles, values between 6.27 and 6.35 were observed at the AUS (Cross and Pollard, 2009), both slightly below the 6.9 PG found in our study. In RG the PG in the singles game were between 6.3 and 6.5 (Cross and Pollard, 2009), which is similar to the 6.5 observed in this study. In W, 6.25 and 6.02 PG were observed (Cross and Pollard, 2009), also close to the 6.4 found in this study.

#### *4.2.5.2.* Point ending

In relation to point ending results, in men's doubles on hard courts, the percentage of FE was 48%, of Wn 38% and of UE 18% (Martínez-Gallego et al., 2019). In women's doubles on hard courts, the percentage of FE was 39.8%, 32.0% in Wn and 28.3% in UE. Therefore, the percentage of FE and Wn was lower and that of UE higher. On clay courts, FE percentages of 45.3%, 33.8% in Wn and 20.9% in UE were observed. Thus, the percentage of FE, Wn and UE was very similar to the men's doubles. On grass courts, the percentage of FE was 45.7%, that of Wn 34.9% and that of UE 19.4%, also very similar to the percentages observed in the men's doubles on hard courts. In women's doubles, the same results were found as in the men's doubles on the three surfaces, with the FE being the way in which most points are finished, followed by the Wn and the UE. Possibly these results are due to the level of the players observed in this study, being the best in the world and, therefore, those who make the fewest errors, as in the men's doubles (Martínez-Gallego et al., 2019).

Compared to the results found in women's singles in the same Grand Slams as in this study, the percentage of points ending with UE at the AUS was 37.0%, in RG it was 34.08% and in W it was 30.72% (Carboch, 2016). On all three surfaces the percentage of

UE in women's singles was higher than that found in our study (22.8%) and the order of findings by surface was the same, with the highest number of UE occurring on hard courts and the lowest on grass courts. In men's singles, points ending with UE at the AUS accounted for 30.35%, in RG there were 30.76% and at W 24.85% (Carboch, 2016). The values were higher on all three surfaces than those found in the women's doubles, with the hard courts having the most even value (28.3%). These results are probably due to the greater complexity of doubles tennis, which makes errors less likely to be UE. The low number of UE found is probably due to the high level of the players participating in the sample, all of whom were among the best in the world. The percentage of points that ended in Wn in Grand Slam women's singles matches was 28.62% at the AUS, 32.49% in RG and 30.05% in W (Carboch, 2016). On all three surfaces the values are very similar to those of women's doubles, with percentages of 32.0% on hard courts, 33.8% on clay and 34.9% on grass. In men's singles the percentages of points finished in Wn were also very similar to the results found in this study, with values of 31.45% on hard courts, 33.53% on clay and 34.57% on grass. In comparison with another study in men's singles matches at Grand Slams, where the UE percentages were 35.96% in RG, 22.79% in W and 24.81% at the US Open (hard court) (Barbaros et al., 2014), it can be observed how in women's doubles the UE value is higher in hard courts and lower on clay and grass courts. As per Wn in men's singles, the percentage found in RG was 34.95%, in W 38.19% and at the US Open 23.86% (Barbaros et al., 2014). The number of Wn was thus very similar to the women's doubles on clay and grass courts, and lower on hard courts, albeit in a different Grand Slam to that observed in our study.

In summary, in terms of the point ending variable it can be concluded that the percentages of UE, Wn and FE found are very similar to those in the men's doubles and that in both cases the order of point ending is the same on all three surfaces, with FE being the way in which most points are finished, followed by Wn and UE. Compared to the singles game, there are fewer UE in women's doubles than in men's and women's singles, and the number of Wn is very similar on all three surfaces in both men's and women's doubles.

Finally, regarding the differences in point ending between WT and LT, it was observed that the variable that most discriminates between the winning and LT is Wn, followed by UE and FE. Therefore, it can be concluded that the most important variable and the one

that differentiates the most between the winning and LT is Wn. This may be because in doubles the percentage of shots that are hit at the net is higher than in singles (Borderias et al., 2021) and, therefore, as they are hit in offensive positions, it is easier to finish the points with winning shots (Martínez-Gallego et al., 2019). The second variable that differentiates the most between the winning and LT is the UE, although it represents the lowest percentage of point completion. Therefore, in high-level women's doubles it is important not to make errors caused by poor decision making or bad execution. At the highest level of tennis, the number of Wn is comparable to the number of UE. Players lose more points due to UE than due to the opponent's Wn, therefore, if the number of UE is reduced, the number of points won increases (Brody, 2006).

In terms of the relationships between point ending and the winning and losing player in the singles game, the matches won differ from those lost, also due to the number of UE (Djurovic et al., 2009). In singles, differences between winners and losers are shown with respect to the number of Wn, just as in women's doubles. Winners, therefore, hit more Wn than losers and, therefore, it can be concluded that aggressive play and taking the initiative in the game has a positive influence in tennis results (Filipcic et al., 2009; Katic et al., 2011).

As per differences by team (WT and LT) and surface in absolute values, at RG more Wn were observed in WT than in LT. More UE in WT were also observed at the AUS (18.7) than in W (8.3).

### 4.2.6. CONCLUSIONS

The structural variables of the female doubles tennis teams found in our study consisted of values of about 2 SM, 20 GM, 130 PM, 0.2 TM, 9.5 GS, 62 PS and 6.5 PG. Less SM, GM, TM and GS were played in the women's doubles as compared to the men's doubles found in another study. More PM, PS and PG were played in the women's doubles compared to the men's doubles of another study. The percentages of UE, Wn and FE were 22.8%, 33.6% and 43.6% respectively, thus very similar to the men's doubles. In both women's and men's doubles the order of point ending alternatives is the same on all three surfaces, with FE being the most usual, followed by Wn and UE. The variable that discriminates the most between the winning and LT was Wn, followed by UE and FE. There were no significant differences between surfaces in structural variables or point

ending. These results can be used to develop technical-tactical, conditioning and mental training programmes for professional doubles players based on data regarding what actually occurs on court.

### 4.2.7. DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### 4.2.8. FUNDING

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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## 4.3. Study III

**Comparison of the finishing shot and ending zone of points in Grand Slam matches of women's doubles tennis: A cross-sectional study**

*by*

Borderias M, Iglesias X, Martínez-Gallego R, Baiget E

### 4.3.1. ABSTRACT

Despite the importance of doubles tennis, there is little research on this modality of the game, especially in women's tennis. The aim of this study was to analyse the finishing shot, the ending zone and shot by ending zone of women´s doubles matches during three Grand Slams, and to observe the differences among surfaces. Twenty-one women's doubles matches from three Grand Slams, each played on a different surface were analysed. 56.4 ± 2.3% of the points were finished from the BMZ, 36.1 ± 2.3% from the NZ and 7.5 ± 4.2% from the SZ. The shot with which the points ended primarily was the FV (18.2 ± 3.5%), followed by the F (17.4 ± 4.2%), the B (15.8 ± 4.8%), BV (12.8 ± 3.6%), the FRT (11.7 ± 2.7%), backhand return (BRT) (11.4 ± 2.6%), the service (7.5 ± 4.2%) and the O (5.2 ± 3.0%). The results showed a higher percentage of F played from the BMZ in RG than in W ($p = 0.011$). In addition, the results also showed a higher percentage in overall F in RG than in W ($p = 0.023$). The FRT percentage was higher in the AUS compared to RG ($p = 0.026$), and the O shots played from the BMZ were higher in W than RG ($p = 0.038$). These results suggest that in professional women's doubles tennis the N is a determinant factor, as well as the V and F shots. Playing aggressive and close to the net may have a positive effect on the result.

### 4.3.2. INTRODUCTION

Many professional tennis tournaments take place every year. These include tournaments by the WTA, ATP, ITF, as well as women's and men's Grand Slams tournaments (International Tennis Federation, 2023; Women's Tennis Association, 2023; Association of Tennis Professionals, 2023). Doubles matches are played in all of these professional tournaments and doubles specialists and many singles players participate (Breznik, 2015).

Professional tennis players' participation in doubles matches is likely motivated by several factors. These include, but not limited to, the prize money being offered (Martínez-Gallego et al., 2019), the desire to improve various skills (service, return, reaction speed and perception) (Carboch et al., 2014), and the preparation for team competitions such as the Davis Cup, Billie Jean King Cup, and ATP Cup, which place high importance on doubles tennis (Martínez-Gallego et al., 2019). These professional tennis tournaments take place on different court surfaces throughout the year, including hard courts, clay courts, and grass courts. Performance characteristics of elite tennis match-play differ depending on the court surface, affecting the physical and physiological responses of players (Filipcic et al., 2009). Given these differences across surfaces, it is important to analyse doubles matches played on all the various court types used in professional tournaments.

Certain aspects of the rules in doubles tennis differ from singles tennis, such as lines, spaces or scoring systems. Doubles is played in pairs, and the court dimensions are different, with added alleys on each side. Consequently, the precision and the direction of the shots is very important, as the space-to-player ratio is smaller. This affects the training, movements, positions, timing, and physiological demands compared to singles (Martínez-Gallego et al., 2019). Doubles also involves greater tactical and decision-making complexity. With two players per team, there are more stimuli to process (Carboch et al., 2014; Carboch and Kocib, 2015). In terms of scoring format, doubles matches often utilize a best of two tiebreak set system, without advantage sets. However, Grand Slam doubles contests differ by playing best of three tiebreak sets with advantage sets, similar to singles (International Tennis Federation, 2023; Women's Tennis Association, 2023). These varied match formats impact total match duration. Additionally, communication between doubles partners is crucial. Verbal and non-verbal communication allows teams to effectively solve problems and make decisions during points (Lausic et al., 2009). In general, the numerous differences result in shorter match times compared to singles (Martínez-Gallego et al., 2019).

Despite the importance of doubles tennis, literature on the topic is limited. Existing research has examined elements such as doubles tactics (Carboch et al., 2014; Carboch and Kocib, 2015; Cayer, 2004; Lausic et al., 2015), match structure and scoring (Martínez-Gallego et al., 2019), communication between partners (Lausic et al., 2009;

Lausic et al., 2015), player coordination (Blickensderfer, 2010), the best doubles players (Breznik, 2015), sex differences (Anderson, 1982), scoring systems (Pollard and Pollard, 2010), time characteristics based on team experience (Martínez-Gallego, Vives et al., 2021), serve performance (Martínez-Gallego, Salvador et al., 2021; Martínez-Gallego, Crespo et al., 2021) and V positions (Martínez-Gallego, Ramón-Llin et al., 2021). However, the majority of the aforementioned studies have focused exclusively on analysing men's doubles tennis performance. While some compare men's and women's doubles (Carboch et al., 2014; Carboch and Kocib, 2015; Anderson, 1982; Martínez-Gallego, Crespo et al., 2021; Martínez-Gallego, Ramón-Llin et al., 2021), none have centered solely on elite women's doubles play. To date, only three studies have exclusively examined women's professional doubles, investigating the team communication (Lausic et al., 2009), activity profile (Borderias et al., 2021) and game structure and point ending (Borderias et al., 2022).

Regarding the match external load differences between men's and women's doubles at a professional level, if we observe the work-rest ratio of one study in women's doubles (Borderias et al., 2021) and another one in men's doubles (Martínez-Gallego, Vives et al., 2021), the work-rest ratio seems slightly lower in the women's one. Additionally, the TMT was slightly longer in women's doubles matches played on hard and clay courts, but shorter on grass surfaces (Martínez-Gallego, Vives et al., 2021; Borderias et al., 2021). When examining differences between singles and doubles, it has been observed that RD is shorter in men's doubles than singles (Martínez-Gallego, Vives et al., 2021). However, the rally time in women's doubles seems longer on the three surfaces compared to men's singles and with no differences compared to women's singles (Borderias et al., 2022; Pluim et al., 2023). In terms of other timing variables, the work-rest ratio was lower in men's and women's doubles versus singles as well (Martínez-Gallego, Vives et al., 2021; Borderias et al., 2021; Pluim, 2023) and rest time between points and total rest time were higher in women's doubles compared to singles (Borderias et al., 2022). Finally, looking at structural differences, it was noted that men's doubles involved fewer sets, PM, and PG compared to women's doubles, though more games were played per set (Martínez-Gallego et al., 2019; Borderias et al., 2022).

To the authors' knowledge, no research has analysed the specific shots and court zones with which points end in either doubles or singles tennis matches. Thus, the aim of this

study was to address this gap by describing the finishing shot, ending zone, and shot by ending zone in women's doubles matches across three different Grand Slam tournaments. Differences across playing surfaces were also analysed.

## 4.3.3. MATERIALS AND METHODS

### *4.3.3.1.* Matches

The study was approved by the Clinical Research Ethics Committee of the Sports Administration of Catalonia, Spain (23/CEICGC/2020). The performance characteristics of 21 matches were analysed. The imaging recruitment period for this study began on March 3, 2020 and ended on April 24, 2020. According to the Ethical Principles of Psychologists and Code of Conduct of the American Psychological Association (American Psychological Association, 2017), given that the tennis matches were held in public settings and records of observation of public images were made, it was not necessary to request informed consent from the participants.

The videos were obtained from a public platform available to all Grand Slam players called Match Analysis Department. The matches were played at three Grand Slams of the 2019 season, which were played on three different surfaces: AUS (hard court, n = 7), RG (clay, n = 7) and W (grass, n = 7). The observational record was made between April 28 and May 15, 2020. The study follows all the ethical guidelines of the Declaration of Helsinki. A total of 22 doubles pairs and 42 professional female players were observed (age 30.1 ± 5.6 years; weight 65.4 ± 6.5 kg; height 170.1 ± 27.8 cm), with a median WTA ranking of 24.5 (range: 1–481). Matches in the first round (n = 2), third round (n = 3), quarter-finals (n = 9), semi-finals (n = 4) and final (n = 3) were analysed.

### *4.3.3.2.* Procedures

Online access to the footage of the tennis matches available on the web for Grand Slam players was obtained from a professional player. As we were part of the technical team of one of them, we could download the videos from the public platform for all the players and coaches. From these accounts the videos of the matches can be downloaded free of charge for their analysis in MP4 format with a frame size of 1280 x 720 pixels high and a frame rate of 25.00 frames per second. The videos did not need processing. For the

observational recording, the LINCE PLUS v.1.4 (Soto-Fernández et al., 2022) was used. An observational instrument was created *ad hoc* based on scientific literature related to the analysis of external load parameters in singles tennis (Fernandez-Fernandez, 2008; Smekal, 2001; Torres-Luque, 2011), composed of 6 criteria and 18 categories collecting data on player, type of shot, outcome and location of the shots (Table 14). Points scored in each game, set and match were also recorded (Table 14) (Borderias et al., 2021, 2022). The analysis of the finishing shot, defined as the last shot played regardless of its outcome (Wn, UE, FE), included F, B, FV, BV, FRT, BRT, service and O shots. The analysis of the ending zone included the BMZ (a shot that takes place behind the service line), the NZ (a shot that takes place between the service line and the net) and the SZ (only serves) (Figure 6). The analysis of the finishing shot by zone included the F played from BMZ (F_BMZ), F played from the NZ (F_NZ), B played from the BMZ (B_BMZ), B played from the NT (B_NZ), FV played from the BMZ (FV_BMZ), FV played from the NZ (FV_NZ), BV played from the BMZ (BV_BMZ), BV played from the NZ (BV_NZ), O from the BMZ (O_BMZ) and O played from the NZ (O_NZ).

***Table 14.*** *Observational instrument.*

| Criteria | Categories | Description |
|---|---|---|
| Player who hits | J1 | Player in the right of the winning pair |
| | J2 | Player in the left of the winning pair |
| | J3 | Player in the right of the losing pair |
| | J4 | Player in the left of the losing pair |
| Hitting place | G | Groundstroke (between the baseline and the service line) |
| | AB | Attacking balls (between the service line and the net) |
| Type of shot I | F | Forehand |
| | B | Backhand |
| Type of shot II | V | Volley |
| | O | Overhead |
| Type of service | 1 | FS in |
| | 10 | FS out |
| | 2 | Second service in |
| | 20 | Second service out |
| | L | Let |

| | | |
|---|---|---|
| Score | X-X | Game score (15, 30, 40, Ad, game) |
| Games | X-X | X takes values from 0 to 7 |
| Set | X | 1, 2 or 3 |

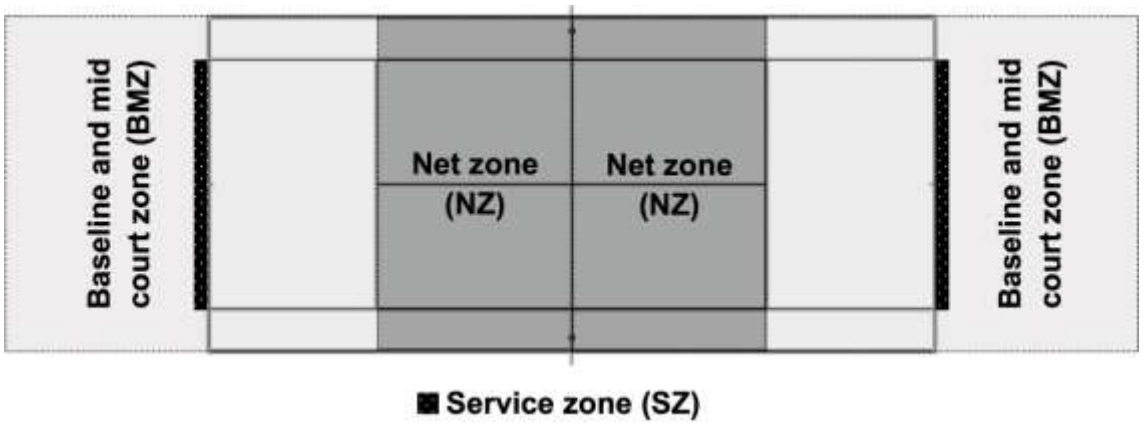


***Figure 6.*** *Ending zones. NZ, net zone; BMZ, baseline and mid court zone; SZ, service zone.*

#### *4.3.3.3.* Validity and reliability testing

The construct validity was obtained from the consistency of the conceptual framework by 6 tennis experts (certified coaches by the *Real Federación Española de Tenis*—Royal Spanish Tennis Federation- RFET), who reached 100% agreement for each of the categories. The validation was carried out using a virtual questionnaire, in which the experts could agree or disagree with the categorisation of each criterion. The reliability of the players who hit, hitting place, type of shots and type of service was determined after the observers had received a period of training in the application of the registration instrument and after reaching an agreement (Anguera, 1990). It was established by interobserver and intraobserver agreement on 200 actions in the game, with values of 0.888 and 0.985 respectively in the kappa coefficient. These values represent a very good reliability (Cohen, 1968) (Table 15).

***Table 15.*** *Interobserver and intraobserver Kappa values of every criteria.*

| Criteria | Interobserver | Intraobserver |
|---|---|---|
| Player who hits | 0.849 | 0.945 |
| Hitting place | 0.879 | 0.982 |
| Type of shot 1 | 0.893 | 1.0 |
| Type of shot 2 | 0.897 | 1.0 |

| | | |
|---|---|---|
| Type of service | 0.926 | 1.0 |
| **Mean** | **0.888** | **0.985** |

#### *4.3.3.4.* Statistical analyses

Statistical descriptors including mean and standard deviation were presented for relative frequencies. The Shapiro-Wilk test was used to verify normality of the variables. One-way ANOVA was used to compare differences among Grand Slam tournaments when variables were normally distributed. When significant differences were found, post-hoc tests using Bonferroni correction were performed and partial eta squared calculated effect sizes, small effect values were considered 0.01 –< 0.06, moderate effect values were considered 0.06 –< 0.14 and large effect values were considered ≥ 0.14. Data for percentage of F played from NZ, FRT played from BMZ, FV played from BMZ, B played from NZ, BV played from BMZ, and O played from BMZ showed non-normal distributions and were compared using Kruskal-Wallis and Mann-Whitney U tests. The level of significance was set at $p < 0.05$ for all analyses. Analyses were conducted using SPSS Statistics, version 26.0. The reliability was measured with the kappa coefficient (Cohen, 1968).

### 4.3.4. RESULTS

#### *4.3.4.1.* Type of finishing shot

Figure 7 shows the relative frequencies per match of the type of shots with which the points end in women's doubles matches in the three Grand Slam tournaments. The most frequent shot was the FV (18.2%). Statistical significant differences were found for percentage of F ($F = 4.566$; $p = 0.025$; $\eta^2 = 0.337$). Specifically, RG shows higher values than W in percentage of F ($p = 0.023$). Moreover, significant differences among surfaces (Kruskal-Wallis) were found in percentage of FRT ($x^2 = 6.38$, $df = 2$, $p = 0.041$). Specifically, AUS shows higher values than RG in percentage of FRT ($p = 0.026$). No significant differences were identified among the different surfaces for the rest of type of finishing shots.

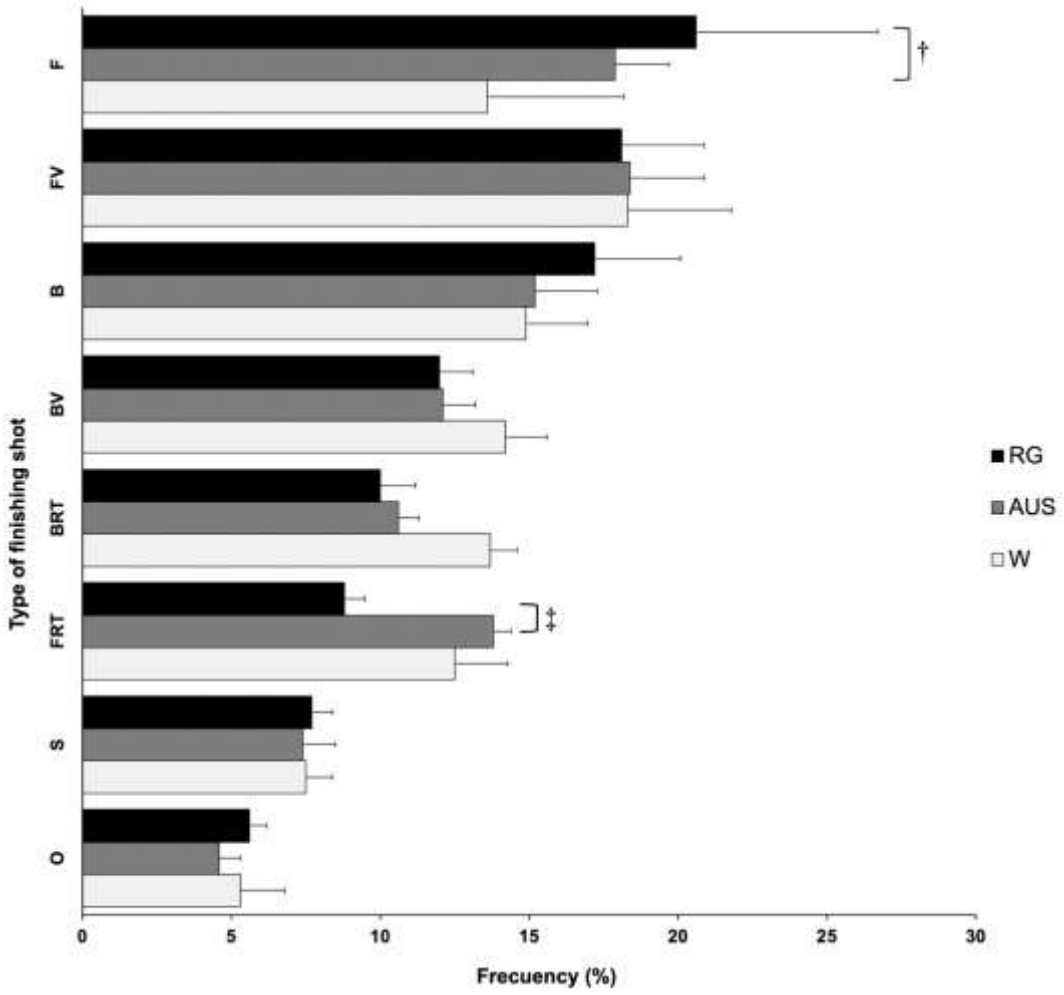


***Figure 7.*** *Finishing shots in the three Grand Slams. F, forehand; FV, forehand volley; B, backhand; BV, backhand volley; BRT, backhand return; FRT, forehand return; S, service; O, overhead; AUS, Australian Open; RG, Roland Garros; W, Wimbledon. † significant differences between RG and W; ‡ significant differences between AUS and RG.*

#### *4.3.4.2.* Finishing zone

Figure 8 shows no significant differences among the different surfaces in the relative frequencies per match of the finishing zone with which the points end (Figure 8). On all surfaces, the most frequent area where the points end is BMZ (56.4%), followed by NZ (36.1%), while the least frequent is SZ (7.5%).

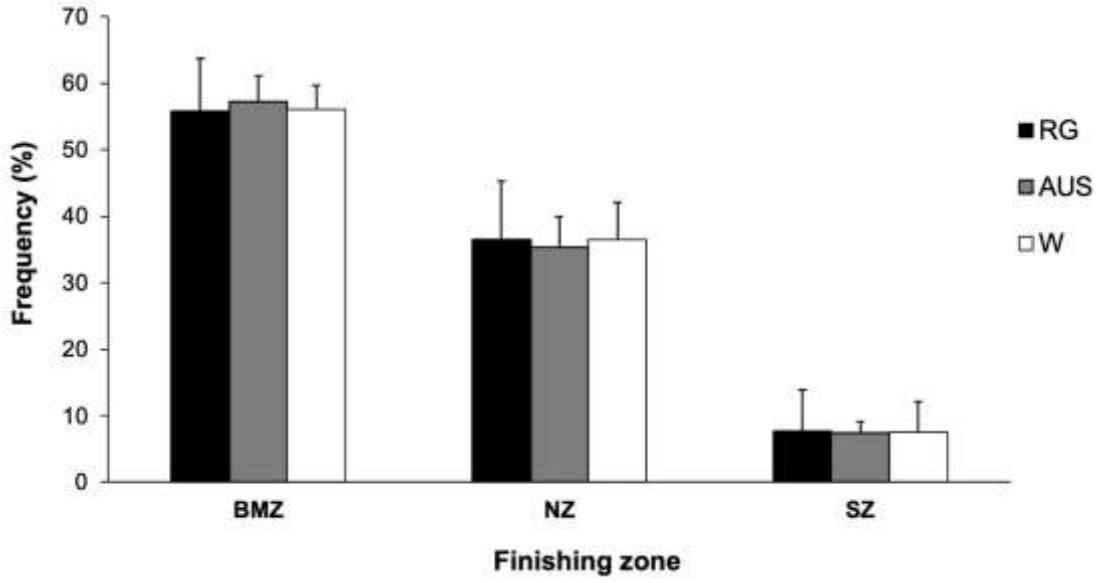


***Figure 8.*** *Mean percentage of the finishing zone of all the matches. NZ, net zone; BMZ, baseline and mid court zone; SZ, service zone; AUS, Australian Open; RG, Roland Garros; W, Wimbledon.*

#### *4.3.4.3.* Finishing shot by zone

Figure 9 shows the relative frequencies per match of the finishing shots by zone with which the points ends. Statistical significant differences were found for percentage of F_BMZ ($F = 5.625$; $p = 0.013$; $\eta^2 = 0.385$). Concretely, RG shows higher values than W in percentage of F_BMZ ($p = 0.011$). Significant differences among surfaces (Kruskal-Wallis) were found in percentage of O_BMZ ($x^2 = 6.19$, $df = 2$, $p = 0.045$), specifically, W shows higher values than RG ($p = 0.038$). No significant differences were identified among the different surfaces for the rest of finishing shots by zone.

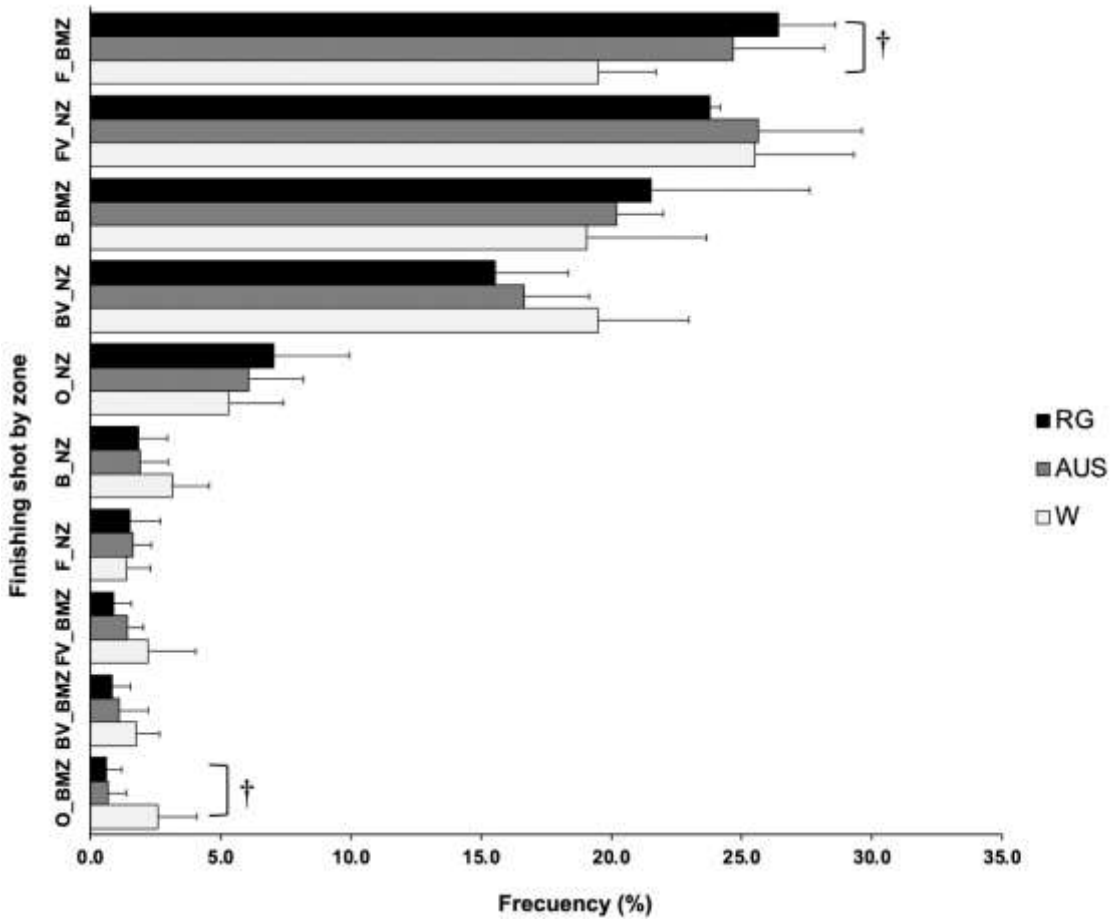


***Figure 9.*** *Finishing shots by zone in the three Grand Slams. F_BMZ, forehand baseline and mid court zone; FV_NZ, forehand volley net zone; B_ BMZ, backhand baseline and mid court zone; BV_NZ, backhand volley net zone; O_NZ, overhead net zone; B_NZ, backhand net zone; F_NZ, forehand net zone; FV_BMZ, forehand volley baseline and mid court zone; BV_BMZ, backhand volley baseline and mid court zone; O_BMZ, overhead baseline and mid court zone. †significant differences between RG and W.*

### 4.3.5. DISCUSSION

Understanding the shots and court zones with which points end, provides valuable insights into professional women's doubles tennis and can aid in structuring the practice accordingly. To the authors' knowledge, this is the first study to describe the ending shot and ending zone of elite women's doubles tennis on different playing surfaces of three different Grand Slam tournaments. Results showed the most frequent finishing shots were FV (18.2%), F (17.4%), B (15.8%), BV (12.8%), FRT (11.7%) and BRT (11.4%), while the most common ending zones were BMZ (56.4%) and NZ (36.1%). These findings highlight the importance in women's doubles of mastering net play and efficient V and F to finish points decisively. With limited prior research examining point endings in doubles tennis, particularly women's doubles, these results provide unique descriptive data to build from. Additionally, due to the limited research available on point endings,

specifically in women's doubles tennis, references to studies examining singles tennis will be made to provide additional context.

#### *4.3.5.1.* Finishing shot

The results showed that the top women's doubles tennis players finish most points with FV (18.2%), followed by F (17.4%), B (15.8%), BV (12.8%), FRT (11.7%) and BRT (11.4%). The finishing shot was defined as the last shot played regardless of its outcome (Wn, UE, FE). A study (Carboch et al., 2014) in 2014 found that women's doubles teams frequently use a classical formation, with the server's partner standing at the net on the opposite side. This results in most V occurring near the net and on the sides, away from the centre of the court (Martínez-Gallego, Ramón-Llin et al., 2021). Additionally, the doubles female players, especially using their FS, attempt to move the returner by serving to the sides, even though they are not as effective in doing so as male players (Martínez-Gallego, Crespo et al., 2021; Black, 2012). This leads to less aggressive returns, allowing the players volleying, to attack with their best shot, which could explain the percentage of FV point endings observed in the current study. Both women's and men's players try to move the receiver by serving to zones wide and T (area located in the middle of the court formed by the union of the service lines and the center line) with the FS to take the initiative of the point, while with the SS both take lower risks and mainly serve to zone body (to the center lane of the service box). The effectiveness of the FS in men's doubles match is higher in all the directions inside the service box (i.e. wide, T and body), while there are only differences in the effectiveness of the SS in the zone body of the advantage service box. In general, the effectiveness of the serve in women's matches may not have the same efficacy of that found in the men's matches, but does show a similar tactical approach (Martínez-Gallego, Crespo et al., 2021).

If we take in account the most frequent shots in women's doubles, we find the F in first place (26%) (Borderias et al., 2021), but it's the second shot with which points finish the most (17.4%). Thus, the percentage of F shots during rallies is likely higher than the percentage of points ending with F. Additionally, more points are finished with F in RG than in W, but the F is hit more frequently at W. This discrepancy is likely because the slower clay courts allow more time for players to get in position and execute the F shot better. Overall, while the F is a common rally shot for women, other shots like the V are more frequent point-enders.

The B is the third most common shot to finish points at 15.8% and is the second most frequent rally shot at around 25% in women's doubles (Borderias, 2021). Similar to F, fewer points end with B compared to the frequency of B shots during rallies. This seems to indicate the lower offensive potential and effectiveness of the B compared to the F in women's doubles. Players seem to prefer hitting F when possible and utilize the B more during rallies rather than to finish points. Around 16% of shots in women's doubles are V (Borderias, 2021). However, taking into account FV and BV, approximately 31% of points end with a V. Despite V being the fourth most frequent shot (Borderias, 2021), it is used to finish points more than any other shot, except the F and B together. This is likely because V are more definitive than other shots, frequently ending the point when hit. This shot, apart from being more definitive, is much more frequent in doubles than in singles tennis (Borderias, 2021; Whiteside and Reid; 2017). Comparing FV and BV, around 8.6% of shots in women's doubles are FV and 7.6% are BV (Borderias, 2021). The order is the same for finishing shots, with 18.2% of points ending with FV and 12.8% with BV. Though no significant differences were found, the FV percentage is slightly higher on hard courts and clay, while the BV percentage is slightly higher on grass (Borderias, 2021). However, similar to rally shots, more points end with FV than BV on all three surfaces. Furthermore, although no significant differences were found, it is interesting that there are more FV played from NZ in RG than in W, but more BVs played from NZ in W than in RG. This finding suggests that playing on slower surfaces, such as RG, may offer players more time at the net to play FV.

The S is the second most frequent shot at around 25% when including first and second S (Borderias, 2021). However, only 7.5% of points end with a S. This aligns with findings of previous studies that have shown a lower effectiveness of S in women's doubles compared to men's doubles (Martínez-Gallego, Crespo et al., 2021). Additionally, if the S does not immediately end the point, playing a V will likely finish it instead, as it is the most common ending shot. In this study, return errors did not count as S points. Finally, regarding O, they are only used by players around 2% of the time (Martínez-Gallego, Ramón-Llin et al., 2021; Borderias et al., 2021). However, 5.2% of points end with O, probably because it is the most definitive shot and when it's used there are few possibilities of returning the ball. The finishing shot values for FRT (11.7%) and BRT (11.4%) are similar. This is likely because modern S variety provides fewer repeated serve

locations, especially with first S (Martínez-Gallego, Crespo et al., 2021). Thus, both FRT and BRT are utilized. The high frequency of V highlights how players are actively involved at the net, leading to more V rallies and points ending with V as the most definitive shot along with O. F is the second most common ending shot given that over 25% of shots in women's doubles are F. Consequently, many FE, UE, and Wn occur from this shot. In summary, V finish points most often due to being offensive and close to the net play. However, F and B remain the most common ending shots given their prevalence during baseline rallies.

#### *4.3.5.2.* Ending zone

The results showed that approximately 56.4% of points ended in the BMZ, while 36.1% ended in the NZ and just 7.5% ended in the SZ. This aligns with previous research indicating around 50% of shots in doubles come from the BMZ, 18% from the NZ, and the remainder from serves in the SZ (Borderias et al., 2021). The higher frequency of net play compared to singles is likely because there is always two of the four players at the net for the beginning of each point (Borderias et al., 2021, 2022). Given the prevalence of net play, it's logical that over one third of points conclude in the NZ with aggressive V, the second most common ending shot per the current study's results. Specifically, FV ended 18.2% of points, followed by BV at 12.8%. 33.2% ended with groundstrokes from the baseline, including 17.4% with F and 15.8% with B. This further highlights the importance of net play, V, and F in finishing points decisively in professional women's doubles.

### 4.3.6. LIMITATIONS AND PROSPECTS FOR FUTURE STUDIES

The study's methodology, while robust, is limited by its observational design, as it focuses exclusively on high-level women's doubles matches at Grand Slam touraments. This constraint may not capture the full diversity of strategies and outcomes present at different competitive levels. Future studies should consider analysing matches from a broader range of tournaments and levels to provide a more comprehensive understanding of the dynamics in women's doubles tennis. Another significant limitation is the lack of consideration for player limb dominance, which could influence the effectiveness of certain shots and the set up of the players. Incorporating limb dominance and the relationship between shot speed and finishing shots into future research could offer deeper insights into match play dynamics.

### 4.3.7. PRACTICAL APLICATIONS

From a tactical standpoint, this study highlights the importance of net play and the strategic selection of finishing shots in women's doubles tennis. Coaches and players should focus on developing skills that enable aggressive net play, such as effective volleying and O shots, to dominate the NZ. Emphasizing the practice of specific shots that were found to be more prevalent in successful point endings, like the FV and F from the baseline and mid-court zone, could be beneficial. Tailoring training to simulate match conditions across different surfaces can also prepare players to adapt their game strategically to the unique demands of each Grand Slam surface, enhancing their competitiveness at the highest level of the sport.

### 4.3.8. CONCLUSIONS

In women's doubles tennis the most frequent finishing shots were the F and B together, followed by the V, FRT, BRT, S and O, while the most common ending zones were BMZ and NZ. Despite V not being used as often when compared to groundstrokes over the entire match, V are more likely to end points in women's double's tennis. These results suggest that in women's doubles tennis, controlling the game in the net area, as well as being efficient with V and F shots, is very important and can be decisive in the outcome of the match. Consequently, this study may be useful for coaches from both a tactical and technical standpoint when designing practices for professional doubles women's players.

### 4.3.9. ACKNOWLEDGMENTS

The authors would like to thank the support of the National Institute of Physical Education of Catalonia (INEFC) of the Generalitat of Catalonia.

### 4.3.10. AUTHOR CONTRIBUTIONS

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**Visualization:** Marcos Borderias, Xavier Iglesias, Rafael Martínez-Gallego, Ernest Baiget.

**Writing – original draft:** Marcos Borderias, Ernest Baiget.

**Writing – review & editing:** Marcos Borderias, Xavier Iglesias, Rafael Martínez-Gallego, Ernest Baiget.

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# 5. DISCUSSION

As noted before, the main aim of this doctoral thesis was to determine the activity profile and technical and tactical performance of professional women's doubles players, and to analyse the differences between playing surfaces. Thus, the discussion will be structured around these parameters and will aim to summarize the key topics addressed in the studies presented.

## 5.1. Duration parameters

The results suggest that the activity of the best female doubles players during matches consists of short periods of exercise (1–9 s) and recovery (18–30 s), alternating with several longer recovery periods (91.3 s – 83.7 s) between games and side changes. Although no significant differences are observed, a longer RD is noted on clay (7.3 ± 0.7 s), with grass being the surface with the shortest RD (6.4 ± 0.8 s). The RD in women's doubles is similar to that of both men's and women's individual players on clay, which ranges from 7 to 10 s (Smekal et al., 2001; Mendez-Villanueva et al., 2007, 2010; Murias et al., 2007; Hornery et al., 2007; Fernandez-Fernandez et al., 2008; Martin et al., 2011), and more specifically with women's individuals, which is 7.2 s (Fernandez-Fernandez et al., 2008). On hard court, the RD is much longer compared to a study conducted on male doubles players (Martínez-Gallego, Vives et al., 2021), with an RD of 3.5 ± 2.9 s. It is slightly longer compared to a study with female players (Martin et al., 2011), with a duration of 5.9 ± 0.5 s, and shorter when compared to other studies on male players (Christmass et al., 1998; Fernandez-Fernandez et al.; Torres-Luque et al., 2011; Kilit & Arslan, 2017). The values are also slightly lower for hard court compared with other studies that focus only on female individuals (Morante & Brotherhood, 2006; Torres-Luque et al., 2011), with an RD of 7.0 ± 1.3 s and 9 ± 0.5 s, respectively.

Other studies, conducted on men, have reported values that align with those of the present study (Hornery et al., 2007; Kilit et al., 2016; Smekal et al., 2001). On grass, it can only be compared with one other existing study. The RD observed in this study is longer when compared to another study from the same tournament (W), but with women's individuals (5.6 ± 0.6 s) (Morante & Brotherhood, 2006). Thus, the trend suggested by Martínez-Gallego et al. (2019), which stated that the RD in men's doubles is shorter than in individuals, is not confirmed, as the values vary, with some being higher, some lower,

and others matching those of the present study. This is likely because the lower shot speed of female tennis players and the resulting greater control and response on each shot implies that the RD is not shorter than in individual play.

The RD for most points (~40–50%) is between 3 and 6 s on the three surfaces, followed by 6 to 9 s (~22%), 9 to 12 s (~12%), and 0 to 3 s (~10%). As a result, 60% of points have a duration of 0 to 6 s, while approximately 80% fall within 0 to 9 s range. Therefore, differences with other studies on women's individuals (Fernandez-Fernandez et al. 2009) are found, where a higher percentage of points lasts 0 to 3 s (17%) and 6 to 9 s (25%), and a lower percentage lasts 3 to 6 s (25%), likely because it was conducted with junior female players. No significant differences were found regarding surfaces in the mean RTP (~26 s), which was longer, in all cases, than the RT recorded in studies on men's and women's individuals (Christmass et al., 1998; Fernandez-Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007, 2010; Hornery et al., 2007; Torres-Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017) and longer than the regulation 20 s (International Tennis Federation, 2012). This is likely due to the need to discuss and tactically prepare the point or performance with the partner, and also because the time spent on missed FS or lets was not counted as playing time, nor was the time between FS and SS. Additionally, the signals given between the first and second services and the auditory communication between partners likely lead to an even greater time increase.

More than 80% of RTP is between 18 s and >30 s. Most of the RTP on the three surfaces exceeds 30 s, followed by 24 to 30 s, 18 to 21 s, 21 to 24 s, and 15 to 18 s, except on grass, where 17.4% of RT is between 15 and 18 s, and 12.9% is between 21 and 24 s. The RTG is 91.3 ± 4.7 s on hard court, 85.3 ± 3.2 s on clay, and 83.7 ± 4.6 s on grass. This is the only duration parameter that shows significant differences, which are observed between hard court and clay, as well as between hard court and grass. This is probably due to the tournament conditions. The AUS is characterized by its high temperatures (Smith et al., 2018), causing players to spend more time between games refreshing and cooling down. No significant differences were found between clay and grass. The RTG includes the RT between the first and second game of each set, which is likely the reason why the time is slightly shorter than the regulation 90 s (International Tennis Federation,

2012), although the time between the first and second services when it was a fault or a service let was also counted as RTG. The RTS is 133.0 ± 20.2 s on hard court, 155.9 ± 37.3 s on clay, and 121.8 ± 18.4 s on grass. The time is longer on clay, followed by hard court and grass, although no significant differences are found. In all cases, it is longer than the regulation 120 s (International Tennis Federation, 2012), probably because the time for fault FS or lets at the beginning of the set was not counted, nor was the time between FS and SS of the FS of each set. It may also be due to the need for partners to reach a tactical agreement after each let or between the first and second services.

### 5.2. Relation between playing and resting time

Based on the time parameters, approximately 82% of the time is spent in RT and around 18% is EPT. No notable differences are observed across various surfaces. The EPT is shorter than in individual matches, while the RT is longer. This difference is likely attributed to the tactical preparation between points, leading to more time spent between points (Christmass et al., 1998; Smekal et al., 2001; Fernandez-Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007, 2010; Martin et al., 2011; Morante & Brotherhood, 2008; Torres-Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017; Kilit et al., 2018; Kilit & Arslan, 2018). A W: R ratio of approximately 1:4.6 s is found, with no significant surface-related differences. When compared to men's doubles on hard courts, the ratio is slightly lower, indicating a shorter RT per second (Martínez-Gallego, Vives et al., 2021). However, when compared to other studies, the ratio is higher across the three surfaces, meaning the RT per second is longer than in individual matches (both men's and women's) (Christmass et al., 1998; Smekal et al., 2001; Fernandez-Fernandez et al., 2008, 2009; Mendez-Villanueva et al., 2007; Martin et al., 2011; Torres-Luque et al., 2011; Kilit et al., 2016; Kilit & Arslan, 2017). This could be because shots are executed in longer intervals than in men's doubles, where points finish quicker, but shorter intervals than in individual matches, where points are more prolonged. The W: R ratio provides an objective measure of the physiological demands of the activity, which could be useful in creating interval training programs for professional female doubles players.

The TMT is 5341.6 ± 950.8 s (89.0 ± 15.8 minutes) on hard courts, 4921.7 ± 1170.3 s (82.0 ± 19.5 minutes) on clay, and 4585.5 ± 864 s (76.4 ± 14.4 minutes) on grass. No

significant differences across surfaces are found. The duration on hard and clay courts is slightly shorter than in men's doubles on hard courts (79.4 ± 7.2 minutes), while it is longer on grass (Martínez-Gallego, Vives et al., 2021). Compared to singles matches, the TMT is shorter than in men's Grand Slam singles matches on any surface, likely due to the best-of-five-set format. It is also shorter than in women's singles on hard courts but longer on grass in women's singles (Morante & Brotherhood, 2008).

## 5.3. Number of shots

In terms of the SPR, the values in this study differ from those found in another doubles study (Martínez-Gallego et al., 2019), which reported an average of 3.4 SPR. However, that study focused on male ATP players on hard courts, so the results were likely influenced by the faster hitting speeds of the male athletes. These values also contrast with those from studies on both women's and men's singles, played on hard courts (Kilit et al., 2016; Torres-Luque et al., 2011; Kilit & Arslan, 2017) and clay (Mendez-Villanueva et al., 2007; Fernandez-Fernandez et al., 2008, 2009). Nonetheless, similar values to the ones found in this study were also reported on hard courts (around 4.7 SPR) (Christmass et al., 1998; Hornery et al., 2007) and on clay (around 4.9 SPR) (Hornery et al., 2007), although these studies focused on male players.

When examining shot intervals, the values in this study differ from those found in other studies on women's singles (Fernandez-Fernandez et al. 2008), where slightly over 50% of points consisted of 1 to 2 shots (compared to about 23% in this study), and somewhat more than 30% (32.4%) consisted of 3 to 4 shots (compared to about 35% here). When combined, over 80% (83.2%) of the points in those studies were made up of 1 to 4 shots, while this study shows a different distribution. No significant differences were found between the various surfaces in SPG, SPS, and SPM.

Regarding shots per second (SPSc) and shots per minute (SPMn), the values in this study (around 85 SPMn) differ from those reported in individual Grand Slam tournaments (Morante & Brotherhood, 2006), where women's singles had 42.2 ± 3.1 SPMn at the AUS (hard court) and 44.1 ± 1.0 SPMn at W (grass). The results also contrast with a study on male players (Smekal et al., 2001) that categorized players as attackers (those who

preferred to play near the net) and defenders (those who preferred baseline play). Defenders performed 42.6 ± 9.6 SPMn, while attackers hit 47.1 ± 6.9 SPMn. This shows that when the game is more offensive, the frequency of shots tends to increase (Smekal et al., 2001). Therefore, the frequency of shots in doubles is much higher than in singles, likely due to the offensive nature of doubles play. Players at the net are actively engaged, with a high percentage of V played very close to the net (Martínez-Gallego, Ramón-Llin et al., 2021). This results in an increased number of V and a more confined playing space.

## 5.4. Types of shots

Previous research has examined the frequency of tennis strokes (Martin-Lorente et al., 2017; Takahashi et al., 2008), highlighting differences based on player experience and skill level (Cui et al., 2017) as well as the playing surface (Cui et al., 2018). In this study, significant differences were only found in the absolute values of F shots between clay and grass, not in the percentages. This could be due to more time available to hit on the desired side on clay, due to the slower bounce. Additionally, the greater number of shots on clay in absolute terms may contribute to this finding. Balls that go towards the center are often hit with a F.

Regarding shot location, approximately 50% of the shots in doubles come from the baseline and mid-court areas, around 18% come from the net, and the remaining shots are from the service line, primarily due to serves. The number of net shots is significantly higher in doubles than in singles, likely because players in doubles often start near the net, reducing the space to send the ball to the back of the court. Moreover, players starting from the baseline typically move toward the net after the serve or first shot.

As for the types of shots, across all three surfaces, the most common are the F (around 26%) and B (around 25%), followed by the first FS (around 18%), V (around 16%), SS (around 7%), and O (around 2%). On grass, however, B shots ranked higher than F shots. When compared to singles play, a similar study conducted at the AUS (Whiteside & Reid, 2017) found that the most common shots in terms of percentage were F (28%) and B (23%), followed by FS (19%), BRT (12%), FRT (9%), and SS (7%). Thus, while the order of the most frequent shots is consistent for F, B, and service across surfaces, it differs for the others, with V being more prominent in doubles (note that this study did not register returns). This is likely because players in doubles often start closer to the net,

making V more frequent. Although no significant differences were found, the percentage of FV was slightly higher than BV on hard and clay courts, while the reverse was true on grass.

## 5.5. Structural variables

Results indicate that the top women's doubles teams typically play around 2 SM, 20 GM, 130 PM, 0.2 TM, 9.5 GS, 62 PS, and 6.5 PG. For SM, the figure was lower (2.0 or 2.1) across all surfaces compared to the SM in men's doubles (2.44). In this study, matches were played in the best of 3 sets format (with a match tie break), and all were on hard courts. The number was also lower compared to a study of men's singles matches at the four Grand Slam tournaments, where SM ranged from 3.55 to 3.85. These findings can be attributed to the fact that men's Grand Slam doubles matches are played in the best of 5 sets (as opposed to 3 sets for women), meaning more sets are played per match.

Regarding GM, the highest value was recorded on hard courts, at 20.4 ± 1.9 (with values of 20.0 ± 4.6 and 19.3 ± 3.0 on clay and grass, respectively). These figures were lower than those for men's doubles on hard courts, where the GM averaged 21.65, with matches also played in the best of 3 sets format with match tie breaks. Although no significant differences were noted, the highest number of PM was observed on hard courts (140.0 ± 20.9), followed by clay (127.3 ± 29.6) and grass (124.0 ± 25.5). Compared to a study on men's doubles, where the average PM was 123.18, the results for women were higher on all three surfaces. This could be due to the greater effectiveness of the serve in men's doubles, which is about 10% more effective than in women's doubles, possibly because of the faster serve speeds and smaller court space in doubles play, leading to more points being played and slower, less frequent service wins in women's doubles.

When comparing these results to singles in the same Grand Slam tournaments, the PM in women's singles was lower than in women's doubles on hard courts (129), while the values on grass were slightly higher (130) and on clay, the highest (133). The matches in both studies were played in the best of 3 sets format. In men's singles at the same tournaments, the PM values were higher than those observed in women's doubles on all surfaces. On hard courts, the PM in men's singles was 216 (compared to 140 ± 20.9) in

women's doubles), on clay it was 213 (127.3 ± 29.6 in women's doubles), and on grass it was 221 (124 ± 25.5 in women's doubles). These results align with the fact that men's singles matches are played to the best of 5 sets, while women's doubles are played in the best of 3 sets.

When considering junior categories, where matches are also played in the best of 3 sets for both girls and boys, the PM values for girls were lower than in women's doubles, with 122 on hard courts and clay, and 115 on grass. This could be due to junior players still developing their technical, tactical, and physical skills, leading to more errors. For junior boys, the PM was 130 on hard courts (lower than in women's doubles), 131 on clay, and 137 on grass (higher than in women's doubles). In comparison with singles, the PM in both men's and women's singles was lower, with values of 123.3 on hard courts, 119.1 on clay, and 121.0 on grass for the men, and 115.5 on hard courts, 111.2 on clay, and 113.5 on grass for the women. In a study of men's singles, the PM values were lower across all surfaces, with an average of 177. Therefore, no clear trend emerged when comparing singles with women's doubles, as the PM values were sometimes higher and sometimes lower than those found in this study.

For TM, values were 0.3 ± 0.8 on hard, 0.1 ± 0.4 on clay and 0.3 ± 0.5 on grass courts. Although no significant differences were observed, the data suggests it is harder to break serve on hard and grass courts than on clay, leading to more tie breaks on these surfaces. Compared to men's doubles on hard courts, where the average TM was 0.53, fewer tie breaks occurred on all surfaces in women's doubles. This could be due to the higher serve speeds in men's doubles, making it harder to win points when returning serves, which increases the likelihood of tie breaks. Additionally, the presence of the server's partner at the net in doubles can create an advantage for the serving team, even if they don't win the point directly.

Looking at set-related variables, the number of GS in women's doubles was lower than in men's doubles (10.51 GS on hard courts), likely due to the greater difficulty in breaking serve in men's doubles. The closest value was 10.2 ± 1.0 on hard courts, followed by 9.3 ± 1.2 on clay and 9.0 ± 0.9 on grass. In comparison to men's singles at the Grand Slams, GS values at the AUS ranged from 9.5 to 9.8, which were lower than the 10.2 GS in this study, possibly because there are more breaks in singles than doubles. At RG, the GS values ranged from 9.3 to 9.7, similar to those in women's doubles. At W, GS values

ranged from 9.9 to 10.1, which were higher than the 9.0 observed in women's doubles. Thus, it can be concluded that, on hard courts, sets were more competitive in doubles than in singles, requiring more GS. On clay, the numbers were similar for both singles and doubles, while on grass, singles sets were closer, requiring more GS.

In terms of PS, the highest value was found on hard courts (70.1 ± 10.4), followed by 59.4 ± 5.4 on clay and 58.6 ± 8.1 on grass. On all three surfaces, more points were played in women's doubles than in men's doubles on hard courts, where the average was 57.94 PS. This suggests a greater balance in women's doubles, likely due to the increased difficulty in winning points on serve compared to men's doubles. PG values were also higher in women's doubles on all surfaces compared to men's doubles on hard courts (5.51 PG). This is likely attributable to the factors previously discussed. Compared to PG in men's singles, the values at the AUS ranged from 6.27 to 6.35, both slightly lower than the 6.9 PG in this study. At RG, PG in singles was between 6.3 and 6.5, similar to the 6.5 ± 0.7 found in this study. At W, PG values were between 6.25 and 6.02, close to the 6.4 ± 0.4 observed in this study.

## 5.6. Point ending

Regarding point-ending results, in men's doubles on hard courts, 48% of points ended with FE, 38% with Wn, and 18% with UE. In women's doubles on hard courts, the percentages were 39.8% for FE, 32.0% for Wn, and 28.3% for UE. Thus, women's doubles had lower percentages of FE and Wn but a higher percentage of UE. On clay courts, the percentages were 45.3% for FE, 33.8% for Wn, and 20.9% for UE, showing a close similarity to the men's doubles results. On grass courts, the FE percentage was 45.7%, Wn was 34.9%, and UE was 19.4%, which was also very similar to the men's doubles on hard courts. Overall, in women's doubles, the pattern of point endings closely mirrored that of men's doubles on all surfaces, with FE being the most common way to finish points, followed by Wn and UE. These results could be attributed to the high skill level of the players in the study, who, like in men's doubles, tend to make fewer errors.

In comparison with women's singles in the same Grand Slams, the percentage of points ending in UE was higher. At the AUS, it was 37.0%, at RG 34.08%, and at W 30.72%.

In women's singles, the UE percentage was higher compared to women's doubles in this study (22.8%), with the order of percentages by surface remaining consistent: the highest percentage on hard courts and the lowest on grass. In men's singles, the UE percentages were 30.35% at the AUS, 30.76% at RG, and 24.85% at W. These values were all higher than those found in women's doubles, with the closest match being on hard courts, where the UE percentage was 28.3%. This might be because doubles, being a more complex game, tends to result in fewer UE. The low number of UE found in this study can also be attributed to the high caliber of players involved.

The percentage of points ending in Wn in women's singles at the Grand Slams was 28.62% at the AUS, 32.49% at RG, and 30.05% at W. These values are very similar to those found in women's doubles, with 32.0% on hard courts, 33.8% on clay, and 34.9% on grass. In men's singles, the Wn percentages were also close to those in women's doubles: 31.45% on hard courts, 33.53% on clay, and 34.57% on grass. In comparison with another study of men's singles at Grand Slams, which reported UE percentages of 35.96% at RG, 22.79% at W, and 24.81% at the US Open (hard court), it can be seen that the UE percentage in women's doubles was higher on hard courts and lower on clay and grass. Regarding Wn in men's singles, the percentages were 34.95% at RG, 38.19% at W, and 23.86% at the US Open, showing similarities with women's doubles on clay and grass, but a lower percentage on hard courts. To summarize, the point-ending patterns observed in women's doubles are very similar to those in men's doubles. In both, the FE was the most common way to finish points, followed by Wn and UE. When compared to singles, women's doubles saw fewer UE than both men's and women's singles, and the Wn percentage was almost identical across both men's and women's doubles on all surfaces.

Regarding differences between winning and LT, the variable that most differentiates the winners from the losers is Wn, followed by UE and FE. Therefore, Wn is the most important factor that separates winning and LT. This could be because doubles players are more often at the net, and as the shots are typically more offensive, they are more likely to end points with Wn. The second most significant variable in determining the outcome is UE, although it accounts for the smallest percentage of point endings. In high-level women's doubles, avoiding errors, such as poor decisions or bad execution, is crucial. At the highest level, the number of Wn is comparable to the number of UE.

Players generally lose more points due to their own errors than from the opponent's Wn, so reducing UE leads to more points won. In singles, differences between winners and losers also stem from the number of UE. Winners in singles typically hit more Wn than losers, which suggests that aggressive play and taking the initiative in the match positively impacts results. Regarding differences by team and surface in absolute values, more Wn were observed in the WT than in the LT at RG. Additionally, at the AUS, LT had more UE (18.7) compared to W (8.3).

## 5.7. Finishing shot

The results showed that the top women's doubles tennis players most commonly finish points with FV (18.2%), followed by F (17.4%), B (15.8%), BV (12.8%), FRT (11.7%), and BRT (11.4%). A finishing shot was defined as the last shot played, regardless of its outcome (Wn, UE, or FE). A 2014 study found that women's doubles teams often use a classical formation, with the server's partner positioned at the net on the opposite side. This typically leads to more V occurring near the net and on the sides of the court, away from the center. Additionally, female players, especially when serving their FS, tend to move the returner by aiming for the sides, although they are less effective at this compared to male players. As a result, returns are often less aggressive, giving the volleying player an opportunity to attack with their best shot, which could explain the higher percentage of FV point endings observed in this study. Both women's and men's players try to move the receiver with their FS, serving wide or to the T (the center of the court). On SS, both genders tend to take fewer risks, primarily serving to the body. While the effectiveness of the FS is generally higher in men's doubles across all serve directions, women's doubles shows a similar tactical approach, even if not as effective overall.

When considering the most frequent shots in women's doubles, the F shot ranks first at 26%, but it's the second most common point-ending shot at 17.4%. This suggests that while the F shot is common during rallies, it doesn't end points as frequently as other shots like V. Furthermore, more points tend to end with F in RG than in W, although F shots occur more often in W. This discrepancy may be due to the slower clay courts in RG, which provide more time for players to position themselves and execute the F shot

better. While the F shot is a frequent rally shot in women's doubles, V are more common as point enders.

The B shot is the third most common point-ending shot, at 15.8%, and it's also the second most frequent rally shot at around 25%. Similar to the F shot, fewer points end with a B compared to its frequency in rallies, suggesting that B have lower offensive potential and effectiveness in women's doubles. Players appear to prefer using the F when possible and rely on the B more during rallies. V, including FV and BV, make up about 31% of point endings. Despite V being the fourth most frequent shot, they are more commonly used to finish points than any other shot except for F and B combined. This is likely because V are more definitive and often end points when executed. V are also more common in doubles than in singles tennis. The percentage of FV is 8.6% and BV is 7.6%, with the same order for point endings, where 18.2% of points end with FV and 12.8% with BV. No significant differences were found, but FV is slightly more common on hard courts and clay, while BV is slightly higher on grass. On all three surfaces, more points end with FV than BV, and interestingly, there are more FV shots from net positions in RG than in W, while more BV shots are played from net positions in W than in RG. This suggests that slower surfaces like RG give players more time at the net to execute FV shots.

The serve shot is the second most frequent shot in women's doubles, making up about 25% of all shots (including both FS and SS). However, only 7.5% of points end with a serve, indicating lower effectiveness compared to other shots. This finding aligns with previous studies showing that serves in women's doubles are generally less effective than in men's doubles. If the serve doesn't immediately end the point, it is likely that a V will finish the point, as V are the most common point-ending shot. It is important to note that return errors were not considered as serving points in this study.

Finally, the O shot is executed around 2% of the time, yet it contributes to 5.2% of point endings. This likely duet to the fact the O is a highly definitive shot, leaving little opportunity for the opponent to return the ball. The percentages of point endings with FRT (11.7%) and BRT (11.4%) are quite similar, possibly because the variety in serving techniques today means players are less likely to stick to one serving location. The frequent use of V highlights how actively players engage at the net, making V rallies and point-ending V more common. The F shot remains the second most common point-ending shot, with over 25% of shots in women's doubles being F. Consequently, many points are

concluded by FE, UE, or Wn from F. In conclusion, while V are the most common point-enders due to their offensive nature and proximity to the net, F and B still remain the most frequent finishing shots due to their prevalence during baseline rallies.

## 5.8. Ending zone

The results indicated that around 56.4% of points concluded in the BMZ, while 36.1% ended in the NZ, and only 7.5% finished in the SZ. These findings are consistent with those from the same thesis, which reported that approximately 50% of shots in doubles come from the BMZ, 18% from the NZ, and the rest from serves in the SZ. The higher frequency of net play in doubles compared to singles is likely due to the presence of two players at the net at the start of each point. With net play being so prevalent, it makes sense that over a third of points end in the NZ, often with aggressive V, which is the second most common way points are finished in this study. Specifically, FV shots ended 18.2% of points, followed by BV shots at 12.8%. A total of 33.2% of points ended with groundstrokes from the baseline, with 17.4% of those coming from F and 15.8% from B. These results further emphasize the significant role of net play, V, and F in ending points effectively in professional women's doubles.

# 6. CONCLUSIONS

The following section will examine the specific objectives of this doctoral thesis, providing answers that reflect the project's outcomes.

**Objective I:** To describe the activity profile of women´s doubles matches during three different Grand Slam tournaments.

- The activity profile of the female players is characterised by a RD of approximately 7 s and an RTP of approximately 26 s, most of the points lasting between 3 s and 6 s, and most of the RT exceeding 30 s. The EPT is approximately 18% of the total playing time, with a W: R of approximately 1:4.4.
- The SPR is approximately 4.7 and ~80% of the points perform 1 to 5 shots. The SPMn exceeds 80 shots per minute. The most frequent shots in women's doubles are the F, B, FS and V, and more than 50% of the total shots in a match are ground-strokes.
- These results suggest that in women's doubles the stimuli are short and intense, the N is very important, it requires a good technical performance of different quick movements, and each point is tactically prepared.

**Objective II:** To analyse the differences between playing surfaces in relation to the activity profile of women's doubles matches.

- The only significant differences across surfaces are observed in the RTG between hard court and clay, as well as between hard court and grass. Additionality, significant differences are found in the absolute values of F between clay and grass.

**Objective III:** To analyse whether there were differences in the structural variables of women's Grand Slam doubles matches.

- The structural variables of the female doubles tennis teams consisted of values of about 2 SM, 20 GM, 130 PM, 0.2 TM, 9.5 GS, 62 PS and 6.5 PG.
- There were no significant differences between surfaces in structural variables.

**Objective IV:** To determine how points were finished in women's doubles matches at three Grand Slams played on three different surfaces and analyse the differences between these surfaces.

- The percentages of UE, Wn and FE were 22.8%, 33.6% and 43.6% respectively. The order of point ending alternatives is the same on all three surfaces, with FE being the most usual, followed by Wn and UE.
- There were no significant differences between surfaces in point ending.

**Objective V:** To study whether there were differences between the winning and LT in terms of finishing the points.

- The variable that discriminates the most between the winning and LT was Wn, followed by UE and FE.

**Objective VI:** To describe the finishing shot, ending zone, and shot by ending zone in women's doubles matches across three different Grand Slam tournaments.

- In women's doubles tennis the most frequent finishing shots were the F and B together, followed by the V, FRT, BRT, S and O.
- The most common ending zones were BMZ and NZ, while the least frequent is SZ.
- The most frequent shot by zone was the F_BMZ, followed by the FV_NZ, the B_BMZ and BV_NZ.
- Despite V not being used as often when compared to groundstrokes over the entire match, V are more likely to end points in women's double's tennis.

**Objective VII:** To analyse the differences across playing surfaces in relation to the finishing shot, ending zone and shot by ending zone of the women's doubles tennis matches.

- As for the type of finishing shot, statistically significant differences were found in the percentage of F. Specifically, RG shows higher values than W in the percentage of F. Moreover, significant differences among surfaces were found in the percentage of FRT, with AUS showing higher values than RG in the percentage of FRT.
- There were no significant differences among the different surfaces in the relative frequencies per match of the finishing zone with which the points end.
- As for the shot by ending zone, significant differences were observed in the percentage of F_BMZ. Specifically, RG exhibited higher values than W in the

percentage of F_BMZ. Additionally, significant differences among surfaces were found in percentage of O_BMZ, with W showing higher values than RG.

# 7. PRACTICAL APPLICATIONS

The potential practical applications of the project are outlined below:

- The results suggest that in women's doubles tennis, controlling the game in the net area, as well as being efficient with V and F shots, is very important and can be decisive in the outcome of the match. Consequently, this study may be useful for coaches from both a tactical and technical standpoint when designing practices for professional doubles women's players.
- From a tactical standpoint, this study highlights the importance of net play and the strategic selection of finishing shots in women's doubles tennis. Coaches and players should focus on developing skills that enable aggressive net play, such as effective volleying and O shots, to dominate the NZ.
- Emphasizing the practice of specific shots that were found to be more prevalent in successful point endings, like the FV and F from the BMZ, could be beneficial.
- The results can be used to design conditioning programs tailored to the specific demands of doubles play. Conditioning programs can target agility, reaction speed, and quick direction changes, which are essential for success in doubles.
- Tailoring training to simulate match conditions across different surfaces can also prepare players to adapt their game strategically to the unique demands of each Grand Slam surface, enhancing their competitiveness at the highest level of the sport.
- The study highlights that analysing game rhythm can improve overall strategy: Given the importance of rhythm and game structure in doubles, coaches can design training sessions that simulate various phases of a point—fast attacks, rhythm changes, and defense. This will help players maintain control throughout the match despite fluctuations in the game's pace.
- The results indicate that technology can be used to enhance real-time decision-making: Using data analysis technologies (such as video analysis software) allows for the evaluation of player performance based on point-ending zones and the most common shots (e.g., FV and F) during Grand Slam matches. This helps coaches adjust strategy in real time and focus on areas of weakness.
- The results can be used to develop technical-tactical, conditioning and mental training programmes for professional doubles players based on data regarding what actually occurs on court.

# 8. LIMITATIONS OF THE STUDY

There are several factors to take into account when interpreting the results of this doctoral thesis. In summary, the key limitations of the study are as follows:

- The study's methodology, while robust, is limited by its observational design, as it focuses exclusively on high-level women's doubles matches at Grand Slam tournaments. This constraint may not capture the full diversity of strategies and outcomes present at different competitive levels. Future studies should consider analysing matches from a broader range of tournaments and levels to provide a more comprehensive understanding of the dynamics in women's doubles tennis.
- Another significant limitation is the lack of consideration for player limb dominance, which could influence the effectiveness of certain shots and the set up of the players. Incorporating limb dominance and the relationship between shot speed and finishing shots into future research could offer deeper insights into match play dynamics.
- Although the reliability of data collection was very high, there was no access to automatic data collection systems that would allow for greater precision in the positions of the players or in the time.
- As this was an observational study of competitive matches, analyses of physiological variables that could have complemented the results shown in the study were not carried out as the use of electronic devices is not permitted during matches.

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# 10. ANNEXES

## 10.1. Annex 1: Publication I

## 10.2. Annex 2: Publication II

## 10.3. Annex 3: Publication III

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