

Article

Beyond Instinct: Data-Driven Decision Trees for Tactical Shot Selection in Professional Padel

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Abstract: The aim was to analyze the frequency of finalist technical-tactical actions in professional padel according to their effectiveness and sex of the players. Through a descriptive empirical design, 878 points corresponding to ten WPT matches of the 2023 season were analyzed. Through the creation of decisional trees, it was obtained that, in smashes, recovery smashes and out of the court, the percentage of winning shots are higher in men's padel than in women's. While, in volleys, bandejas, viboras, off-the-wall and forehands/backhands, the percentage of winning shots is higher in women's padel than in men's. On the other hand, in men's padel, smashes and recovery smashes are the shots with which more winnings are achieved, while in women's, only smashes are the shots with which more winners are achieved. Coaches must plan training sessions to work on strategies that lead players to force errors on the opponent or make shots that allow them to achieve success.

Keywords: racquet sports; performance; notational analysis; game analysis; male; female



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1. Introduction

Padel is one of the most widely played racquet sports worldwide, played in pairs on a 20 × 10 m court. The court is divided by a central net and enclosed by mesh walls, with a glass back wall measuring four meters in height and side walls reaching three meters. Players can utilize these walls during gameplay, allowing for dynamic shot variations and strategic play [1]. Due to its social nature, simple rules, and the adaptability of its physical and technical-tactical demands to different skill levels [2], padel has experienced significant growth in the sporting world, with scientific research playing a fundamental role in its evolution [3]. The application of biomechanical, physiological and psychological principles has enhanced players' understanding of the sport, enabling them to optimize tactical decisions and select the most effective techniques for various in-game situations [4]. Data collection and analysis during real matches and training have provided valuable insights for refining strategies, enhancing injury prevention and optimizing on-court movement efficiency [5]. The synergy between science and padel benefits not only elite players but also enhances coaches' ability to develop strategies and improve players' decision-making. Consequently, research interest in this sport has grown, with a primary focus on performance analysis across various domains [6].

The many studies that have measured external loading parameters in professional padel have represented various conditions faced by the athletes [7]. These studies can be categorized into those that address: (a) temporal structure, (b) players' movements on the court, (c) scoreboard results and (d) technical-tactical actions.

In terms of temporal structure, a professional padel set typically lasts around 30 min [8] and gender differences show longer durations for women. Out of the total match duration, only 30% corresponds to the active phase of play, with each point averaging between 12.5 and 13.5 s [8]. There are also differences in the duration of matches between winners and losers, with winners' matches lasting on average 5116 s, while losers' matches last a total of 4998 s on average [9]. These durations are de-similar across categories, as well as varying across tournaments [10].

Regarding players' movement, high-level players cover an average distance of 1000 m per set, with 50.8% of this covered during ball play. On a per-point basis, a player covers an average of 11 m [11], while in the whole of the party they cover approximately 3500 m [9]. The primary movements involve lateral or forward motion, with a significant number of jumps executed [12]. The maximum speed they reach during matches is close to 15 km/h, while the maximum acceleration is around 4.5 m/s^2 [9]. This implies an external load on the player of between 50 and 60 a.u. measured from the Player Load variable [9]. The influence of the external load values on the internal load results in average maximum heart rate values close to 180 bpm, with a relative heart rate percentage of 70 to 80% [10]. This implies a subjective assessment through the RPE of 5 on average (scale 1–10), with an objective assessment through lactate of 3 mmol on average [10].

Regarding scoring, only two sets are played in over 70% of men's matches, while in women's padel, the percentage of two set matches falls below 70% [13]. Additionally, the number of games per match tends to increase as rounds of a tournament progress, with this number higher in women's padel [14]. Male professionals typically execute around 9.6 shots per point, while females execute approximately 12 shots per point [15]. However, it was observed that the number of shots per second is significantly higher in men than in women, indicating a higher pace of play [8]. The first four seconds of each rally are the most difficult, where the greatest number of unforced errors occur [16]. Thereafter, winning rallies longer than 11 s without making unforced errors in the first four seconds is considered a predictor of performance [16].

Padel includes a wide variety of technical-tactical actions, with shots generally categorized based on the type of impact. These can be classified as: (1) shots with bounce without wall, executed after the ball bounces on the floor but before contacting a wall, glass or fence (e.g., forehand and backhand); (2) shots with bounce after wall, performed after the ball rebounds off one or multiple walls (e.g., back-wall shots, side-wall shots, double-wall shots or back-wall combinations); (3) shots without bounce, executed before the ball touches the ground (e.g., volleys and smashes); and (4) other shots, including serves, returns, behind-the-back shots and shots played from outside the court. While men and women share many fundamental aspects of padel, differences in physical attributes and match dynamics influence shot selection. Men tend to perform a greater number of topspin and flat smashes, either to finish the point or to bring the ball back to their own side of the court, whereas women execute a higher frequency of bandejas, prioritizing control and positioning [17]. On the other hand, females perform a significantly higher percentage of wall exit shots and employ more lob trajectories, while males perform significantly more wall descents and back-walls and employ more straight trajectories [15,18,19]. As for the effectiveness of the shots at the net, the couples that serve and finish at the net increase the probability of winning in even exchanges in both men and women [20]. These tactical aspects are essential for the optimization of performance in padel, a sport in which technique and tactics constantly coexist.

The last shot of the point has been widely analyzed in both men's and women's professional padel [13]. These investigators noted that the point can end with a winner or an error. Prior research suggests that men make more winners than women, while

women commit more unforced errors than men [21]. In addition, on the last shot type, male players perform more winners with the smash and make more errors with the backhand volley, when compared to female players [22]. For their part, female players make more winners and errors than male players with the bandeja. However, the latest published evidence indicates that men tend to make more winners than women, but also more forced errors. Women tend to make more unforced errors [21]. There is also a correlation between the last shot chosen as a function of gender, so that the shot selection preference is maintained throughout the point [21]. Romero, González-Silva, Conejero and Fernández-Echeverría [6] analyzed cause-effect relationships with performance, finding that the type of shot, the distance to the net, the direction of the shot and the type of trajectory can predict performance. Specifically, smashes that are performed close to the net, with a downward trajectory, down the line, have a direct and positive relationship with performance.

The effectiveness of shots in padel is intrinsically related to technique, decision-making and adaptation to changing circumstances on the court [23]. These conditions are what the coach must be aware of in order to be able to apply them in training. Science has contributed significantly to the evaluation of the effectiveness of different shots, using methods such as video analysis [24,25], motion sensors [26] and physical performance measurements [27]. These studies have revealed patterns of success in relation to placement, speed, angle of impact and anticipation of the opponent's movements. Understanding the effectiveness of hitting is essential to improve player training and to optimize tactical strategies in the game of padel, by relying on objective data such as statistics to facilitate coaches' decision-making, making it more objective and operational [28]. Therefore, the objective was to analyze the frequency of technical-tactical finishing actions in professional padel according to their effectiveness and the sex of the players.

2. Materials and Methods

2.1. Research Design

This study follows an empirical methodology, specifically a descriptive research design [29]. It is categorized as observational, employing a nomothetic, cross-sectional and multidimensional approach [30].

2.2. Sample

The sample comprised 878 points (504 in the men's category and 374 in the women's category) from 10 matches (5 men's and 5 women's) played during the semifinal and final rounds of the 2023 WPT season. Specifically, the analysis focused on the last shot executed by the pair that concluded each point. The study was conducted in accordance with the guidelines of the Declaration of Helsinki, the Ethical Standards in Sport and Exercise Science Research of Harriss et al., (2022) [31] and was approved by the University Ethics Committee (154/2020). The investigation respected the framework of Organic Law 3/2018 of 5 December on Personal Data Protection and Guarantee of Digital Rights (2018).

2.3. Study Variables

To carry out this study, the variables analyzed were as follows:

- Sex: male and female categories were established to observe possible differences between the two.
- Type of finishing shot: following the classifications established by various studies [32], it was distinguished a total of nine types of shots, (volley, bandeja/vibora, smash, off-the-wall, lob, forehand/backhand, back-wall, recovery smash and off-court).
- Effectiveness of the type of finishing shot: a distinction was made between winning shot (the player wins the point with a direct shot, i.e., after bouncing on the other

side of the net correctly, the ball bounces once again; or the ball is hit on the body of the opponent before being out) and error (the player misses the last shot), following Courel-Ibanez and Sánchez-Alcaraz [33].

2.4. Process

The matches analyzed were broadcast in real time and subsequently archived on the WPT TV digital platform. From this source, the videos of the matches were selected for download and later input into the specialized LINCE application [34] for later observation. Likewise, the LINCE application included an ad-hoc instrument with the study variables and their corresponding categories (sex (male and female), type of finishing shot (volley, bandeja/vibora, smash. . .) and effectiveness of the type of finishing shot (winning shot and error)). Once the videos and the instrument were prepared in the LINCE application, the systematic observation process was carried out by a researcher with specialized training in padel tennis, author of numerous studies on the topic of study and a doctor in sports sciences. The researcher, after a training period (observing and recording a set), went point by point noting the category corresponding to each variable as it happened in each point that he viewed, being able to stop the video or repeat its viewing whenever he deemed it appropriate. Once the sample was registered, the data were extracted to SPSS, where the appropriate analyses were carried out.

To corroborate the accuracy of the data collected, an intra-observer reliability assessment was performed at the end of the observation process, which was quantified through the Multirater free Kappa coefficient [35]. The observer again analyzed a random sample of 100 points (although homogeneous in terms of sex (50 points from women and 50 points from men)) to ensure a relevant amount of data, between 10% and 20% of the study sample, obtaining an average coefficient higher than 0.90 (Table 1). Following Altman's approach [36], this value was considered to indicate a very high degree of agreement.

Table 1. Inter-observer and intra-observer reliability.

Study Variables	Inter-Observer	Intra-Observer
	K	
Sex	1.00	1.00
Type of finishing shot	0.83	0.88
Effectiveness of the type of finishing shot	0.80	0.85

In addition, inter-observer consistency was assessed, as another sports science researcher analyzed a random sample of 100 points (although homogeneous in terms of sex (50 points from women and 50 points from men)). Inter-observer reliability was also quantified using the Multirater free Kappa coefficient, obtaining an average value greater than 0.87 (Table 1).

2.5. Statistical Analysis

Descriptive analyses of the types of shots in men and women segmented by winners and errors were carried out. A Chi-squared Automatic Interaction Detection (CHAID) decision tree analysis was conducted using SPSS v.27 for Windows. The CHAID algorithm iteratively segments the dataset using chi-square statistical tests, selecting the most significant predictors at each branching point. The model employed cross-validation with 10 folds to enhance generalizability and prevent overfitting. The segmentation criterion was based on adjusted *p*-values from chi-square tests, ensuring that the most relevant splits were selected. The tree structure was determined using node-based criteria, setting maximum and minimum case thresholds per node to balance model complexity and inter-

pretability. A pruning method was applied to limit tree depth to a maximum of three levels. The model summary included only variables that were deemed significant for prediction, with variable importance ranked based on their contribution to the splits. This structured approach ensured a data-driven, interpretable model capable of identifying key patterns while maintaining robustness and reproducibility. The CHAID decision tree operates using classification probabilities, making it a valid approach for analyzing trends regardless of differences in sample size between males and females. Descriptive analyses, frequencies (n) and percentages (%) of the variables under study and inferential analyses were included in the analysis. The significance level was set at $p < 0.05$.

3. Results

Figure 1 shows the descriptive results of hitting as a function of outcome for males and females.

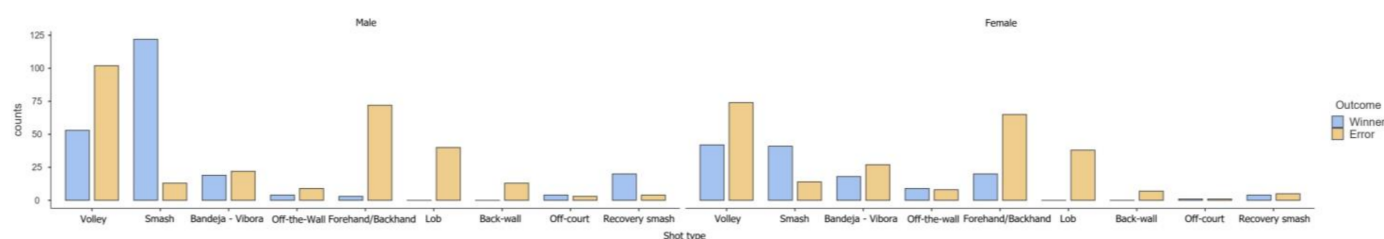


Figure 1. Descriptive data on shots according to sex.

Figure 2 shows the decision tree of the winning shots according to the type and sex of the players.

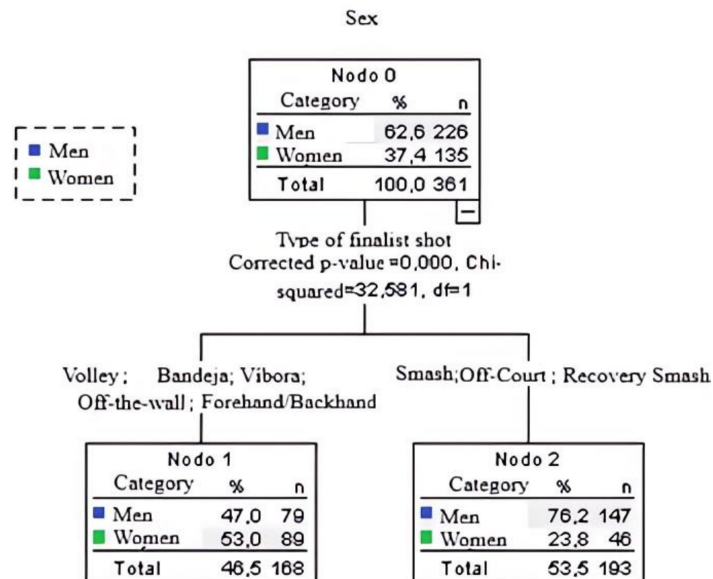


Figure 2. Decision tree for winning shots.

The overall classification accuracy of the general model was 76.2%, with a high correct classification rate for errors (93%) but a moderate rate for winners (52.1%). The model performed better for men (Figure 3), with an increased overall accuracy of 80.2%, correctly classifying 63.3% of winners and 93.9% of errors. However, the model was less effective in predicting winners for women (30.4%), despite maintaining a high accuracy for errors (94.1%) and an overall accuracy of 71.1% (Figure 4).

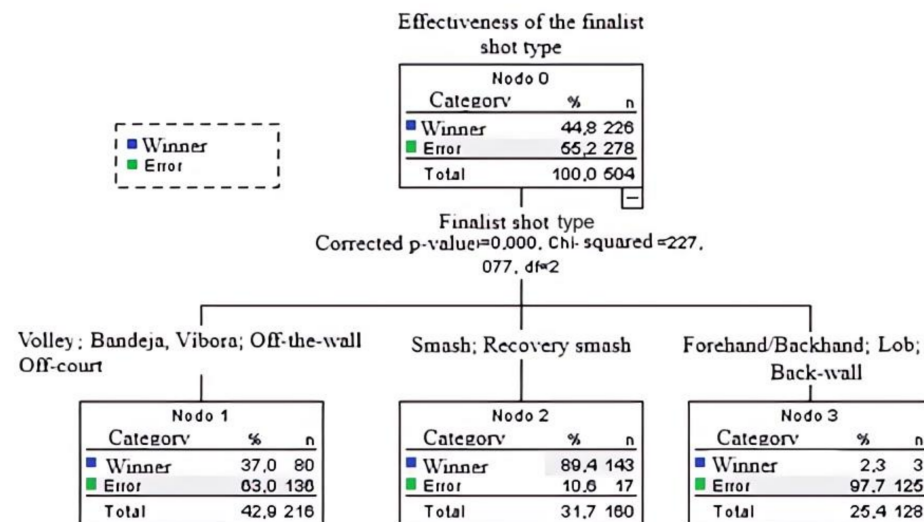


Figure 3. Decision tree male shots.

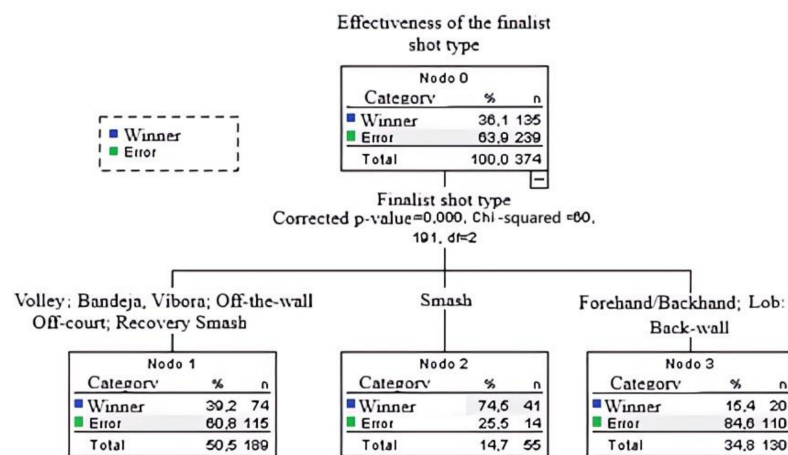


Figure 4. Decision tree female strikes.

In nodes 1 and 2, where the shots are distinguished, it can be indicated that, in smashes, recovery smashes and off-court shots, the percentage of winning shots is higher in men's padel (76.2%) than in women's padel (23.8%). Meanwhile, in volleys, bandejas, viboras, off-the-wall and forehand/backhand the percentage of winning shots is higher in women's padel (53.0%) than in men's padel (47.0%).

Figure 3 shows the decision tree of the shots in men's padel according to the type of final shot and its effectiveness.

As can be seen in node 0, the percentage of errors (55.2%) is higher than the percentage of winning shots (44.8%). However, in the following nodes, where the shots are distinguished, it can be indicated that in the smash and recovery smashes the percentage of winning shots (89.4%) is higher than the percentage of errors (10.6%).

Figure 4 shows the decision tree of the shots in women's padel according to the type of final shot and its effectiveness.

As can be seen in node 0, the percentage of errors (63.9%) is higher than the percentage of winning shots (36.1%). However, in the following nodes, where the shots are distinguished, it is possible to indicate that in the smashes the percentage of winning shots (74.5%) is higher than the percentage of errors (25.5%).

4. Discussion

The aim was to analyze the frequency of the final technical-tactical actions in professional padel according to their effectiveness and according to the sex of the players, clarifying the decision-making in real time based on the moment of the game and the individualized statistics.

Chacoma and Billoni [28] in their research showed that padel can be effectively approached from simple probabilistic rules for the choice of shots. Decision trees represent a valuable statistical tool in sports research [37,38], as they simplify the complexity of decision-making processes inherent to sports [39,40]. In the case of padel, their applicability is particularly relevant, as this sport combines technical, tactical and contextual aspects that influence players' choices during a match [41,42]. By identifying patterns and ranking the most influential variables, decision trees facilitate the analysis of game dynamics while providing practical insights for coaches and players to optimize strategies and enhance performance. In this context, their application in padel reinforces their value as an analytical tool and promotes a more evidence-based approach to the sport's development. In this study, the classification tree contributes to improving decision-making for both padel players and coaches. The results of this study corroborate that this mathematical technique is useful for improving strategic decision-making [43], taking the initiative in the game [44], coaches' decision-making [45] and player selection [46]. This technique should be applied to improve and optimize the performance of both players and coaches.

The results by sex indicate that smashes, off-court shots and recovery smashes are more frequently winning shots in men than in women. Conversely, volleys, bandejas, víboras, off-the-wall shots and forehand and backhand shots are more frequently winning shots in women than in men. These results are in line with previous studies that analyze the differences in performance between male and female professional padel according to the type of shots [15,47]. Furthermore, other research indicates that men generally hit more shots close to the net, while women hit more shots from the middle and back of the court [15,48,49]. Therefore, men develop a more aggressive game (performing smash, recovery smash...), while women develop a less aggressive game (performing volleys, bandejas...), perhaps due to the anthropometric and strength differences between male and female elite players [50,51]. In addition, previous studies reported that male players are taller, with higher muscle percentages and higher levels of vertical jump and grip strength [50–52], allowing them to finish the points with more powerful smashes than female padel players. Finally, a recent study also found that women make more winners than men from the baseline, with shots such as the forehand, backhand and bandeja [21]. Therefore, it is recommended to adjust the way of training according to the athletes' sex.

The results obtained show that both men and women make more errors than winning shots. Ramón-Llin et al. [53] also conclude that professional players make more errors than winning shots, although in their research they did not distinguish between men and women. Escudero-Tena, Muñoz, Sánchez-Alcaraz, García-Rubio and Ibáñez [32] also state that the number of errors in professional padel is higher than the number of winning shots. However, they also indicate that the difference between errors and winners increases as the importance of the point increases in men's padel. However, the opposite happens in women's padel, with the difference decreasing. Similarly, Sánchez-Alcaraz et al. [54] state in their study that the importance of the point on the match score makes players change their playing behavior. Therefore, players must focus on one of the primary objectives of padel: minimizing errors, particularly during crucial moments of the game, such as break points, set points and golden points. To achieve this, coaches can implement training routines that simulate these high-pressure situations, incorporating error penalties and scoreboard-based drills to enhance decision-making and mental resilience.

The men's shot tree reflects three nodes. One of the nodes includes balanced shots, 63% of which are in favor of the error (volley, bandeja, vibora, off-the-wall and off-court), winning shots in 89% of cases (smash and recovery smash) and shots that end as an error 98% of the time (forehand-backhand, lob and back-wall). On the other hand, although in the study by Sánchez-Alcaraz et al. [55], only smashes, volleys and bandejas are distinguished and each sample is different; it is shown that, like the results of the present study, the percentage of winners is higher in smashes and the percentage of errors is higher in volleys. However, in the case of bandejas, the percentage of errors and winners is similar, perhaps because in the present study both bandejas and viboras are included. Furthermore, in that study, it is indicated that a variable to take into account regarding the percentage of hits and errors is the distance to the net, since the effectiveness of volleys, smashes and bandejas will decrease as the player moves away from the net [55].

The women's shot classification tree reflects the same three nodes observed in men's padel. The first node, with a slightly higher success rate (61% error), favors volleys, bandejas, off-the-wall shots, off-court shots and recovery smashes. The second node, which includes smashes, shows a 75% success rate, while the final node, consisting of forehands, backhands, lobs and back-wall shots, exhibits an 85% error rate. These findings indicate that women's padel is more stable, as a greater variety of shots are concentrated in the first node compared to the other trees. In addition, the percentages found again coincide with those of Sánchez-Alcaraz, Jiménez, Muñoz and Ramón-Llin [55], being very similar in the volley and the bandeja. However, the authors reported a significantly higher smash effectiveness rate (89.8%) than the percentage observed in this study, suggesting that the effectiveness of the women's smash may be closer to that of men. Given that women's finishing shots are only highly effective in specific situations, it becomes essential to capitalize on the opponent's errors. This can be achieved by forcing them into executing multiple lobs—potentially leading to a finishing shot or an unforced error—as well as by directing play toward back-wall shots and forehand or backhand exchanges.

This study is based on observational data, which, while analyzed using standardized evaluation systems, inherently carries certain limitations. CHAID decision trees effectively identify patterns in sports performance, offering intuitive decision rules and handling complex data without strict assumptions. However, they can be sensitive to small data changes, affecting model stability, and may become less interpretable with intricate datasets. The model's high classification rates, particularly for error prediction, reinforce its reliability in capturing performance trends, although refinement is needed to improve winner classification. The decision tree model classifies shot effectiveness based on patterns in match play but does not account for individual physical attributes, biomechanics or musculoskeletal constraints, which can influence shot selection and execution. Factors such as strength, flexibility, joint mobility, fatigue levels and past injuries may impact a player's ability to execute specific shots successfully. Future research should integrate physiological profiling to provide a more comprehensive understanding of shot effectiveness, linking tactical decisions with an athlete's physical and technical capabilities.

5. Conclusions

The efficiency of the technical-tactical actions in men's professional padel differs from those of women's professional padel. Men hit more winning shots with smashes, recovery smashes and off-court shots than women, while women hit more winners with volleys, bandejas, viboras, off-the-wall and forehands/backhands than men. Therefore, coaches should work on the technical-tactical aspects of the game in padel specifically according to the sex of their players.

On the other hand, in men's padel the percentage of errors is higher than the percentage of winners. However, specifically, men are more likely to make a winner than an error with backhands and backhands, while the probability of error is higher with volleys, trays, slams, off-the-wall and off-court hits. The probability of a winner is practically nil with forehand/backhand, lobs and backhands. In women's padel, the percentage of errors is higher than the percentage of winners. According to the type of shots, women are more likely to make winners with smashes and more errors than winners with the rest of the shots analyzed.

Given that men more frequently execute smashes and recovery smashes, while women rely more on volleys, bandejas and viboras, training should be tailored accordingly. Male players should refine tactical shot selection, incorporating drills that limit smash use to encourage alternative strategies, such as controlled volleys or lobs. Female players should focus on transitioning from defensive volleys to offensive finishing shots, using progressive drills that start with bandejas and build into smashes to improve point construction. Additionally, anticipation and positioning exercises should be incorporated to help players recognize when to accelerate play rather than maintain a neutral stance.

Since smashes and recovery smashes result in the highest percentage of winning shots, training should emphasize precision and shot placement rather than just power. Target-based smash drills, where players aim for specific court zones, can enhance accuracy, while strength and conditioning programs should focus on lower-body explosiveness to maximize shot effectiveness. For off-the-wall shots, defensive scenario drills should replicate game situations, helping players develop consistency under match pressure. Forehand/backhand shots and lobs have the highest error rates, making technical refinement crucial. Controlled placement drills, where players must land shots in designated court zones, should be emphasized to improve accuracy under pressure.

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