Ramón-Llín, J.; Guzmán, J.F.; Muñoz, D.; Martínez-Gallego, R.; Sánchez-Pay, A.; Sánchez-Alcaraz, B.J. (2022). Analysis of Shots Patterns Finishing the Point in Padel through Decision-Tree Analysis. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 22 (88) pp. 933-947 Http://cdeporte.rediris.es/revista/revista88/artanalisis1409.htm
DOI: https://doi.org/10.15366/rimcafd2022.88.013

ORIGINAL

ANALYSIS OF SHOT PATTERNS FINISHING THE POINT IN PADEL THROUGH DECISION-TREE ANALYSIS

ANÁLISIS SECUENCIAL DE GOLPEOS FINALES DEL PUNTO EN PÁDEL MEDIANTE ÁRBOL DECISIONAL

Ramón-Llín, J.[1]; Guzmán, J.F.[2]; Muñoz, D.[3]; Martínez-Gallego, R.[4]; Sánchez-Pay, A.[5]; Sánchez-Alcaraz, B.J.[6]

[1] Profesor Ayudante Doctor de Universidad, Facultad de Magisterio. Universidad de Valencia (Spain) jesus.ramon@uv.es

[2] Catedrático de Universidad. Facultad de Ciencias de la Actividad Física y el Deporte. Universidad de Valencia (Spain) jose.f.guzman@uv.es

[3] Profesor Titular de Universidad, Facultad de Ciencias del Deporte. Universidad de Extremadura (Spain) diegomun@unex.es

[4] Profesor Ayudante Doctor de Universidad, Facultad de Ciencias de la Actividad Física y el Deporte. Universidad de Valencia (Spain) rafael.martinez-gallego@uv.es

[5] Profesor Ayudante Doctor de Universidad, Facultad de Ciencias del Deporte. Universidad de Murcia (Spain) aspay@um.es

[6] Profesor Contratado Doctor de Universidad, Facultad de Ciencias del Deporte. Universidad de Murcia (Spain) bjavier.sanchez@um.es

Spanish-English Translator: Diane Schofield, schofielddiane@gmail.com

Código UNESCO / UNESCO code: 5899 Educación Física y Deportiva / Physical Education and Sports.
Clasificación Consejo de Europa / Council of Europe classification: 17. Otras: Análisis del Rendimiento / Others: Performance Analysis.

Recibido 26 de junio de 2020 **Received** June 26, 2020
Aceptado 15 de enero de 2021 **Accepted** January 15, 2021

ABSTRACT

The main objective was to analyse the sequence of the last two shots of the point in padel and to make a classification through the multivariate decision tree approach. A total of 2,110 game actions were analysed. The variables studied were: shot, court zone, efficiency, direction, match outcome and court side. Matches were analysed through systematic observation. The results determined that maintaining net positions during the last two shots would increase the

probabilities of victory, observing that the most frequent sequence of the last two shots were groundstroke-volley and lob-smash. In addition, winners made the highest number of winning points at the net and the least number of errors on the baseline. On the other hand, the use of cross-court shots increased the chances of opponents' errors. These data have an important practical application in the perceptive and decisional training and feedback provided by the coach.

KEY WORDS: Racket sports, performance analysis, behaviour, tactics, decision making.

RESUMEN

El objetivo de este estudio fue analizar la secuencia de los dos últimos golpeos del punto en pádel, y clasificarlos a través de árbol decisional multivariante. Se analizaron un total de 2110 acciones de juego, siendo las variables analizadas: golpeo, zona de la pista, eficacia, dirección, resultado y lado de juego. Los partidos fueron analizados mediante observación sistemática. Los resultados mostraron que mantener posiciones cercanas a la red aumenta las probabilidades de victoria, observándose que las secuencias de finalización más frecuentes son las de fondo-volea y globo-remate. Las parejas ganadoras realizan mayor número de puntos ganadores en la red y menos errores en el fondo de la pista. Además, utilizar trayectorias cruzadas en el penúltimo golpe aumentará las posibilidades de un error posterior de los rivales. Estos datos tienen aplicación práctica en el entrenamiento perceptivo y decisional del jugador de pádel, y la aplicación de feedbacks por parte del entrenador.

PALABRAS CLAVE: Deportes de raqueta, análisis del rendimiento, comportamientos, táctica, toma de decisiones.

INTRODUCTION

Padel is a racket sport, practised in pairs, which takes place in a rectangular playing area divided into two halves by a central net. The padel court is characterised by having a completely closed perimeter, combining areas of metal mesh and areas of materials that allow a regular bounce of the ball (baseline and side walls), against which it can be played. (Pradas de la Fuente, González-Jurado, García-Giménez, Gallego Tobón, and Castellar Otín, 2019). The great development and expansion of this sport has been favoured by its social and playful nature, by its being practised by 4 players (Courel-Ibáñez et al., 2018; Sánchez-Alcaraz and Courel-Ibáñez, 2022); its ease of technical learning (Sánchez-Alcaraz, Courel-Ibáñez and Cañas, 2016); longer point duration, allowing longer playing time compared to other racket sports (Sánchez-Alcaraz, 2014; Courel-Ibáñez, Sánchez-Alcaraz and Cañas, 2017); and the large number of padel courts that facilitate access to practice (Muñoz et al., 2016).

This development has attracted interest from researchers, causing an increase in scientific publications, especially those related to the analysis of the game and performance due to its direct application to sports training (Sánchez-Alcaraz, Courel-Ibáñez and Cañas, 2018; Sánchez-Alcaraz, Jiménez, Muñoz and Ramón-Llin, 2022; Sánchez-Alcaraz, Siquier-Coll, Toro-Román, Sánchez-Pay and Muñoz, 2021), and others related to the development and validation of observation instruments (Díaz, Muñoz, Muñoz and Ibáñez, 2020; Fernández de Osso and León, 2017), anthropometric parameters (Muñoz et al., 2021; Sánchez-Muñoz et al., 2020) or teaching methodology (Sánchez-Pay, García-Castejón, Courel-Ibáñez and Sánchez-Alcaraz, 2020). The objective of such research is to ascertain the indicators that favour success in competition, attending to the demands and specific characteristics of the sport (Hughes and Bartlett, 2002).

In this regard, studies with professional padel players have determined that, at the tactical level, there are two basic play positions: the attack position, which is one in which the couple plays in situations close to the net, and the defence position, which is one in which the pair plays on the baseline of the court (Ramón-Llin, Guzmán, Llana, James and Vuckovic, 2017). Previous studies highlight the importance of occupying and maintaining an offensive position, close to the net, to increase the chances of success (Courel-Ibáñez, Sánchez-Alcaraz and Cañas, 2015; Ramón-Llin, Guzmán, Llana, Vuckovic and James, 2013). These studies show that more than 80% of winners are obtained from close to the net, using different technical actions, such as volleys (25%), the tray and the smash (12-18%) (Carrasco, Romero, Sañudo and De Hoyo, 2011; Escudero-Tena, Muñoz, Sánchez-Alcaraz, García-Rubio and Ibáñez, 2022; Ramón-Llín et al., 2020; Sánchez-Alcaraz et al., 2021). On the other hand, the players on the baseline of the court perform other types of shots, among which the lob predominates, with the aim of forcing the attacking pair to move to hit the ball in positions further away from the net, or swapping these tactical positions (Muñoz et al., 2017; Ramon-Llin et al., 2019). In this struggle for a positional advantage, players move during the point from the baseline (defensive zone) to the net (offensive zone) and vice versa, performing a variety of movements and specific behaviours (Courel-Ibáñez, Sánchez-Alcaraz and Muñoz, 2019; Torres-Luque, Ramirez, Cabello-Manrique, Nikolaidis and Alvero-Cruz, 2015).

Therefore, a better knowledge of technical and tactical actions is needed to provide accurate information of situations occurring during the real game, and to improve the training sessions. In addition, players' adaption to the game-dynamic during the match can also be observed (Courel-Ibáñez and Sánchez-Alcaraz, 2018). However, there is an important lack of studies to date focused on identifying effective play patterns (Courel-Ibáñez et al., 2019). Thus, current studies present a limited applicability because all of them are focused on the last stroke, without considering the previous actions (Courel-Ibáñez et al., 2019). So, it could be very important to identify game patterns related to the last two strokes of the point in padel. For this reason, it is desirable to develop automated classification methods like decision tree analysis (Kotsiantis, 2013), using dependent and independent nominal variables. These procedures identify the significant continuous or categorical variable interactions, merged in nodes.

In each analysis step, CHAID affects the one predictor that exerts the most influence on the dependent variable categories (Schnell, Mayer, Diehl., Zipfel and Thiel., 2014). This classification generates if-then rules, structuring sequential routes in nodes, which makes it a very effective multivariate analysis technique for the study of player behaviours (Ramaswami and Bhaskaran, 2010).

In addition, during the last few years, an increase has been observed in the use of this methodology in racket sports, like tennis and padel, in order to determine game patterns and to analyse the parameters affecting performance (i.e. which strokes make it possible to win the point, or which zone on the court is where most errors occur) (Courel-Ibáñez et al., 2019; Muñoz et al., 2017; Sánchez-Pay, Torres-Luque, Sanz-Rivas and Courel-Ibáñez, 2020).

Therefore, the aim of the present study was to analyse the last two strokes in the sequence to finish the point in high performance padel, and to develop a classification through a multivariate decision tree approach including technical, spatial and stroke effectiveness.

METHODS

Sample and variables:

The sample included 2,110 strokes corresponding to the penultimate and last shots of a total of 1,055 points from 9 padel matches from the first national category (Spain). A total of 36 men padel players aged between 19 and 39 years old (mean: 33.32; SD: 6.94) participated in the matches which were played following the official game regulations (FIP, 2017). The following variables were analysed, following the methodology of similar racket sport studies (Fernández de Ossó and León, 2017; Over & O'Donoghue, 2010):

- Court area: Two areas were distinguished, the net area (offensive area) and the baseline area (defensive area). The line that delimited both areas was located on the visual reference on the horizontal side fence of the court, four metres from the net (Figure 1), following a previous proposal by Courel-Ibáñez et al. (2015) and Ramón-Llin and Guzmán (2014). The position of the player was considered when hitting the ball.

- Shot number: The last two shots of every point were analysed, distinguishing between the penultimate and the last shot.

- Type of stroke: The technical actions of hitting were analysed following Courel-Ibáñez et al (2019), distinguishing between: ground stroke (forehand or backhand direct shot), back wall stroke (forehand or backhand after a rebound on the back wall), side wall stroke (forehand or backhand after a rebound on the sidewall), double wall stroke (forehand or backhand after a bounce on two walls of the court), depending on the bounce order (side and back wall or back and side wall), wall boast (forehand or backhand hitting the ball against the wall of the court itself),

lob (stroke made with a high trajectory with the aim of overcoming the opponents that are at the net), volleys (stroke without a bounce that is made by hitting the ball at head height, with either a forehand or backhand), powerful smash (shot without a bounce that is made by the dominant side of the player, hitting the ball with the arm outstretched, over the head, with a flat or topspin effect), and tray (stroke without a bounce that is made by the dominant side of the player, hitting the ball at an intermediate height between the volley and the smash and with a slice effect).

- Stroke effectiveness: the stroke effectiveness classification proposed by Courel-Ibáñez and Sánchez-Alcaraz (2017) was used, distinguishing between continuity (shot causing the point to continue), winner (the player wins the point with a direct stroke) and error (the player loses the point by missing the shot).

- Stroke direction: direction was divided between two possible options, down the line and crosscourt (Figure 1).

- Playing side: the player on the left and right sides of the game was distinguished in each pair (Figure 1).

- Match outcome: Winner and losing pair was used.

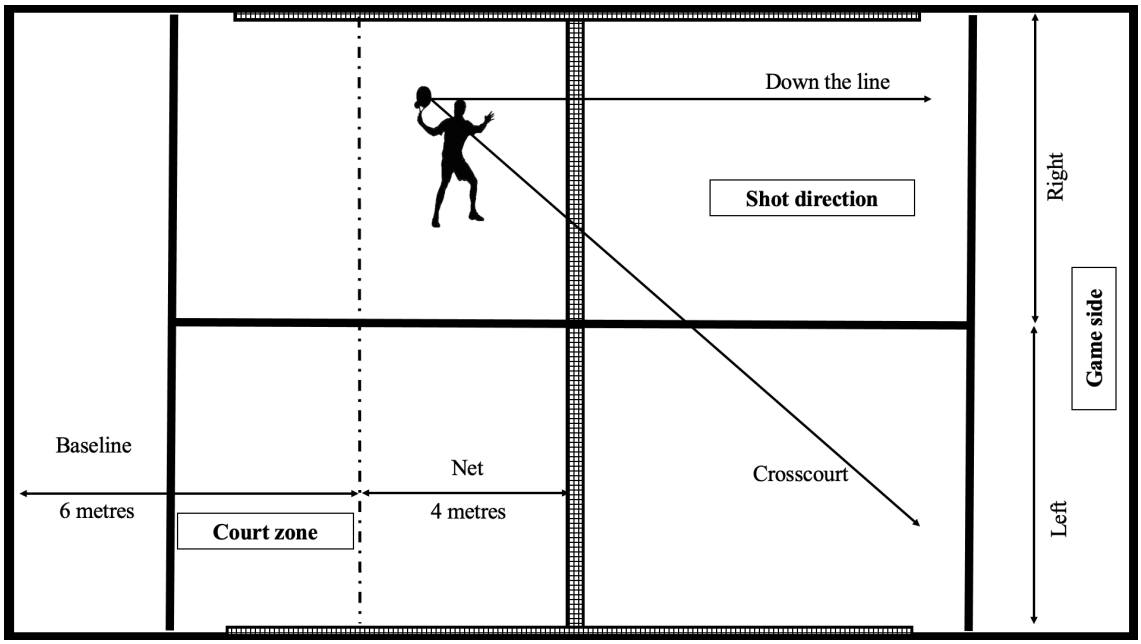

Figure 1. Court delimitation of zone (net or baseline), game side (right or left) and shot direction (down the line or crosscourt).

Procedure

Firstly, informed consent was requested from the tournament organisers and athletes for the recording of the matches. A digital video camera (SONY HDR-PJ620, Japan), placed 1.5 metres high and 3 metres from the back wall of the

court, was used to film the matches. The data were recorded through systematic observation, using specific software for video analysis: LINCE software (Gabín, Camerino, Anguera and Castañer, 2012). Two observers, graduates in Physical Activity and Sports Sciences, and padel coaches, with more than 10 years' experience in the sport, were specifically trained for this task. At the end of the training process, each observer analysed the same two sets in order to calculate the inter-observer reliability with the Multirater Kappa Free (Randolph, 2005) obtaining values above .80 in all variables analysed. To ensure the consistency of the data, intra-observer reliability was evaluated at the end of the observation process, obtaining minimum values of .80. Following Altman (1991) the kappa values showed the degree of agreement as very high (> .80)

Statistical analysis

Firstly, a descriptive exploration of the data obtained was carried out and frequency (n) and percentage (%) were calculated, identifying the most frequent hitting sequences. Subsequently, a comparison of the statistics of the type of shot action, court area, shot direction, playing side of the court and hitting sequence was carried out through Pearson's Chi-Square test. In addition, Z tests were performed to compare column proportions, adjusting the values of p <.05 with the Bonferroni correction. The effect size was calculated from Crammer's V (Cohen, 1988). Finally, a tree classification analysis was used to determine a predictive model of shots based on the court area (baseline and net). The CHAID (Chi Squared Automatic Interaction Detection) algorithm was used to identify relationships between categorical independent variables. The variables were considered independent, due to the unpredictability of the game actions and the influence of the competition on the interactions of the players (Duarte, Araujo, Correia and Davids, 2012). The following statistical specifications were considered in the CHAID analysis: (1) the level of significance was established at p <.05, (2) the maximum number of interactions was 100, (3) the minimum change in cell frequencies expected was of .001. The association strength of the variables and the effect size were studied by calculating the Corrected Typified Residuals (CTR) and the Phi coefficient (ö) for the Chi Square analyses (Fritz, Morris and Richler, 2012). The analyses were carried out with the IBM SPSS v. 25.0 for Macintosh (Armonk, NY: IBM Corp. USA).

RESULTS

Table 1 shows the differences in the distribution of frequencies and percentages of the variables of shot type, direction, court area and playing side, comparing between the penultimate and last shot of the point. As shown, the type of shot determined the way the padel players finished the point ($X^2(10)$ = 207.341; p = .000; V = .313). On the last shot the players made significantly more smashes (16.3%) and 7.8% more volleys. In addition, they made 10.4% fewer lobs, 6.3% fewer groundstrokes, and approximately 4% fewer wall shots than on the penultimate shot. Moreover, the shot number also determined the area of the court where the action was performed ($X^2(1)$ = 122.509; p = .000; V = .241). Thus, in the penultimate shot players performed significantly 24.1%

more actions at the back of the court than in the last shot, where net shots predominate (60%). On the other hand, no significant differences were found between the penultimate and last shot according to direction ($X^2(1) = .646$; $p = .421$; V = .018) and the playing side of the court ($X^2(4) = 8.342$; $p = .080$; V = .063). However, it was observed that players made approximately 20% more crosscourt shots than down the line shots in the last two shots of the point. In addition, approximately 10 and 15% more participation of the player on the left side of the court (backhand) was found in the penultimate and in the last shot of the point, respectively.

Table 1. Differences in the distribution of frequencies and percentages of the variables of shot type, direction, court area and playing side, comparing between the penultimate and last shot of the point.

	Shot number				
	Penultimate shot		Last shot		Sig.
	N	%	N	%	
Shot type					
Groundstroke	177**a**	16,8	111**b**	10,5	
Back wall	175**a**	16,6	139**b**	13,2	
Side wall	68**a**	6,4	28**b**	2,7	
Double wall	66	6,2	66	6,2	
Back wall boast	42	4,0	36	3,4	.000
Lob	148**a**	14,4	42**b**	4,0	
Volley	243**a**	23,0	325**b**	30,8	
Powerful smash	68**a**	6,4	240**b**	22,7	
Tray	68	6,4	68	6,4	
Court zone					
Baseline	676**a**	64,1	422**b**	40,0	.000
Net	379**a**	35,9	633**b**	60,0	
Shot direction					
Down the line	401	38,0	419	39,7	.421
Crosscourt	654	62,0	636	60,3	
Court side					
Right	467	44,2	451	42,8	.080
Left	588	55,8	603	57,2	

N = Number; % = percentage; **a,b** = indicate significant differences in the Z test for comparison of column proportions from p < .05 according to Bonferroni.

Table 2 shows the frequency and percentage of the most representative point outcome sequences, as well as the differences depending on the effectiveness of the last shot. The eight most representative termination sequences (> 50%) are listed in the table. The groundstroke vs. volley and lob vs. powerful smash sequence represented 20% of the actions. Similarly, it can be seen that the shots sequence determined the effectiveness of the last shot ($X^2(76) = 359.505$; $p = .000$; V = .584). Thus, the groundstroke vs. volley, volley vs. volley, and volley vs. groundstroke sequences ended significantly more in errors. In contrast, situations that ended in a powerful smash (after a lob or a back wall) obtained a significantly higher percentage of winners.

Table 2. Summary of shot sequences and differences depending on the effectiveness of the last shot.

	Total		Effectiveness				Sig.
			Winner		Error		
	N	%	N	%	N	%	
Shot sequence							
Groundstroke vs. Volley	127	12,0	36**a**	28,3	91**b**	71,7	.000
Lob vs. Powerful smash	91	8,6	78**a**	85,7	13**b**	14,3	
Volley vs. Volley	68	6,4	18**a**	26,5	50**b**	73,5	
Back wall vs. Volley	62	5,9	19a	30,6	43a	69,4	
Back wall vs. Powerful smash	51	4,8	41**a**	80,4	10**b**	19,6	
Volley vs.Groundstroke	48	4,5	10**a**	20,8	38**b**	79,2	
Powerful smash vs.Back wall	36	3,4	18a	50,0	18a	50,0	
Side wall vs.Volley	33	3,1	14a	42,4	19a	57,6	

N = Number; % = percentage; **a,b** = indicate significant differences in the Z test for comparison of column proportions from p < .05 according to Bonferroni.

Figure 2 shows the CHAID analysis model of tree classification of the shots in the different areas of the court. Firstly, a significant association was found with the type of shot ($X^2(1) = 122.509$; $p = .000$; RTCs = 11.1; $\varphi = .24$), obtaining 64.1% of cases in which the penultimate shot was made at the back of the court (Node 1) compared to 60.0% of cases in which the last shot was made at the net (Node 2). In addition, a significant association was observed in the penultimate shot with the match outcome ($X^2(1) = 21.723$; $p = .000$; RTCs = 4.7; $\varphi = -.14$), obtaining 43.1% in the cases where the winning team of the match made their penultimate shot at the net (Node 3) compared to 29.3% of the losing team (Node 4). Moreover, a significant relationship was observed in the last shot of the point and its effectiveness ($X^2(1) = 134.437$; $p = .000$; RTCs = 11.6; $\varphi = .35$), finding that 82.7% of winners were made at the net (Node 6) compared to 46.5% of missed shots (Node 5). Similarly, a positive association was found between the errors made in the last shot of the point and the match outcome ($X^2(1) = 7.070$; $p = .008$; RTCs = 4.7; $\varphi = .14$), observing that the winning team made 48.1% of the errors at the back of the court (Node 9) compared to 58.4% of errors of the losing team in the match (Node 10). Finally, a positive association was found between the penultimate shots made by the winning team of the match and their direction ($X^2(1) = 7.152$; $p = .007$; RTCs = 2.7; $\varphi = .11$), observing that the winners of the match perform 47.5% of the penultimate shots at the net with a crosscourt trajectory (Node 7) compared to 35.2% down the line (Node 8).

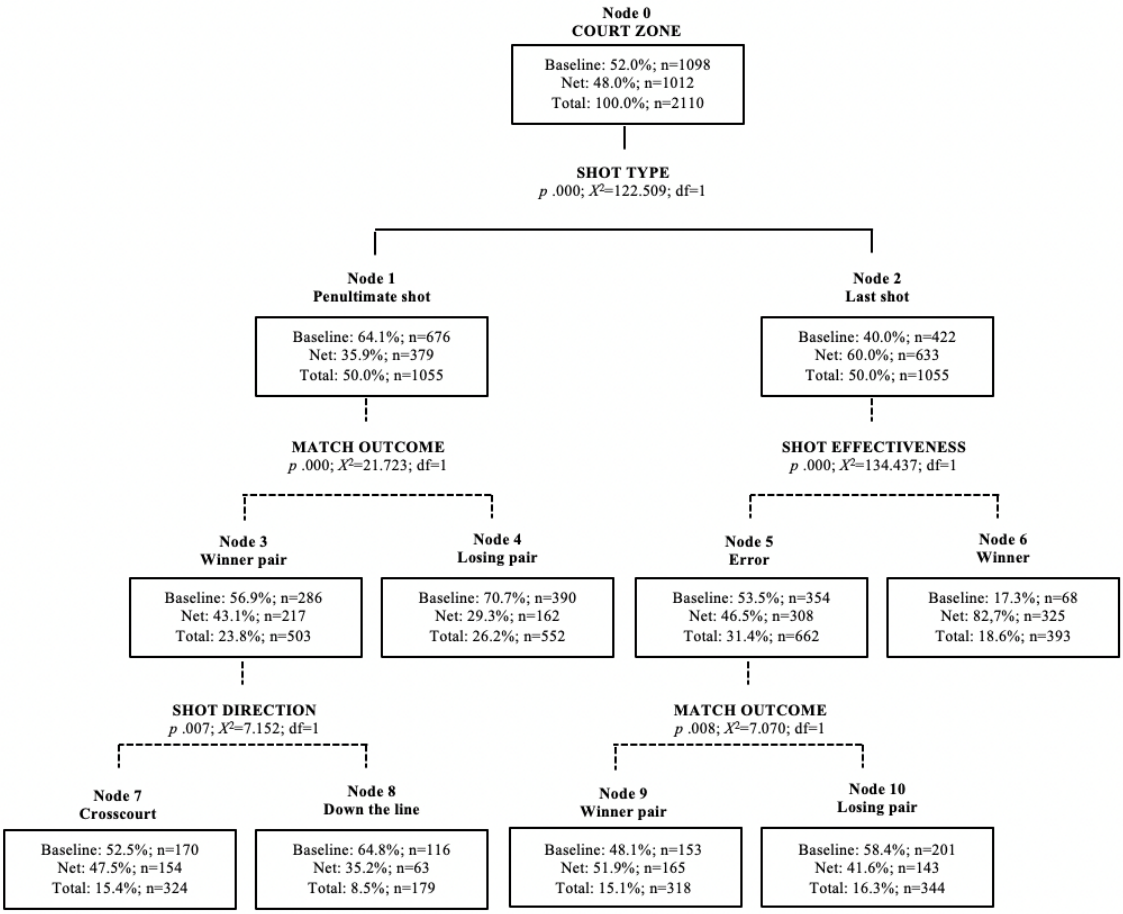

Figure 2. The CHAID analysis model of tree classification according to court zone where players hit the last two shots of the point.

DISCUSSION

The objective of this study was to analyse the last two shots of the rally in high-level padel, identify the most common finishing sequence, as well as perform a classification through a multivariate decision tree approach that includes technical, spatial and effectiveness of the shot performance indicators. The CHAID analysis was able to define and identify multiple patterns capable of explaining the performance of padel players in the last two shots of the rally. The results of this research showed two clearly different styles of play depending on the area of the court where the shot was made, and that are related to the number of shots in the rally, also defining their direction and effectiveness. In addition, the most common rally ending sequences, as well as their efficiency, were clearly identified. These data can serve as a reference for padel players and coaches in the design of training sessions adapted to the most effective game patterns to win a padel match (Camerino, Chaverri, Anguera & Jonsson, 2012). In general, the results of this study showed a prevalence of volleys, smashes, groundshots, backwalls and lobs in the last two shots of the rally, data similar to those provided in recent studies that analysed the distribution of shots in professional padel (Espino, Skiadopoulos, Gianikellis and Luis del Campo, 2016; Ramón-Llín et al., 2020; Sánchez-Alcaraz et al., 2021; Torres-Luque et al., 2015). However, this distribution varied significantly depending on the number of shots studied. Thus, a higher prevalence of shots

at the net (60%) was observed in the last action of the rally, while the penultimate shots were predominantly made at the back of the court (64%). These results differ significantly from those obtained in tennis, where the percentage of rallies that finished from the back of the court was higher than the percentage of rallies finished at the net (O'Donoghue and Ingram, 2001). Furthermore, the area of the court where the shot is made significantly determined the effectiveness of the last shot. Thus, 82% of the winners were produced at the net, data that confirm what has been contributed by other studies which have shown how shots close to the net (volleys and smashes) are the ones that present a higher percentage of effectiveness in padel. (Courel-Ibáñez et al., 2019; Sánchez-Alcaraz et al., 2020; 2021) as well as in tennis, although in the latter, with less efficacy (Over and O`Donoghue, 2010; Filipčič et al., 2008). Moreover, it was observed that the winning pair of the match made a significantly higher percentage of penultimate shots in the net area and a lower percentage of errors at the net in the last shot. These data suggest that maintaining offensive positions close to the net in the last padel shots will increase the chances of success in the game, as previous studies have affirmed, showing that more than 80% of the rallies are scored by the players that are in the net zone (Courel-Ibáñez et al., 2015) and, that spending more time in the offensive zone, determines the result of the padel game (Ramón-Llín, Guzmán, Martínez-Gallego, Vučković and James, 2014). Therefore, it could be argued that the winners of the match were the most effective pairs making a greater number of winning rallies at the net and fewer errors at the back of the court.

The sequence of the last two shots of the rally in padel (Table 2) reaffirms the results described in the previous paragraph. In this respect, the ground shot vs. the volley sequence was the most repeated game dynamic at the end of the rally (12%). It is striking that this dynamic ends in more than 71% of cases in an error. This could be due to a powerful ground shot trying to reduce the response time of the net player. This hypothesis could also explain the percentage of errors (73.5%) in the volley vs. volley sequence where both players are at the net and there is little response time (Courel-Ibáñez et al., 2019), which would make it difficult to correctly execute the last shot. On the contrary, the sequences that end in a powerful smash (either preceded by a lob or by a back wall) do so mainly with a winning shot (> 80%), reaffirming the idea of the effectiveness of the smash in the rally (Sánchez- Alcaraz et al., 2020). On the other hand, one of the most innovative results of this investigation was the finding that the winning pair of the match made more than twice the number of penultimate shots crosscourt (n = 154) than down the line (n = 63), when they were in the net zone. Similar studies have observed in crosscourt shots a direction of the ball towards the side of the court, causing a bounce on the metallic mesh, the side wall or the corner between the back wall and the side wall, increasing the possibility of winning the rally (Courel-Ibáñez et al., 2019). In addition, this crosscourt direction is more effective in positions close to the net, especially in the central area of the court, since the hitting angle is greater (Courel-Ibáñez et al., 2019). Therefore, an important practical application would be the design of training exercises with crosscourt volleys and smashes from the net (towards the metallic mesh and the side wall), seeking to unbalance the opponents by forcing them to make mistakes. The results related to the playing

side showed 15% more participation of the player on the left side of the court (advantage), in the last shot of the rally. These data suggest that their greater participation in the last shots would be related to a greater ability to finish rallies, which would define them as having a more offensive style of play. However, these results could be related to the laterality of the players (Ramón-Llín et al., 2021), since, in those pairs with two right-handed players, the player on the left is the one who would perform the most smash shots, as he can hit the ball with his dominant arm in the central area of the court (Courel-Ibáñez and Sánchez-Alcaraz, 2018; Ramón-Llín et al., 2021).

The main contribution of this work is the use of temporal pattern analysis or *t-patterns*, with the aim of contributing to the discovery of the behaviours that are most effective through the study of complex interactions (Borrie, Jonsson & Magnusson, 2002). In this way, and as the most important practical application, the results of this research will allow the training of perceptual and decision-making mechanisms during the game by the athlete, and the application of feedback about behaviours by the coach (Del Villar, González, Iglesias, Moreno and Cervelló, 2007; Nielsen and McPherson, 2001). However, this study has certain limitations that must be taken into account when interpreting the results. First of all, the score of the match has not been taken into account. Some studies have shown how the influence of the scoreboard status (winning, drawing or losing) depending on the moment of the match (rally, game and set), can influence decision-making in moments of pressure (choking), affecting performance (Mesagno, Geukes and Larking, 2015). Moreover, the laterality of the players or the speed of the shot has not been taken into account, a variable that could influence the distribution, direction or effectiveness of the shots (Courel-Ibáñez and Sánchez-Alcaraz, 2018; Sánchez-Alcaraz et al., 2016), so it is suggested that future research should analyse these variables and compare them with other categories such as women or young players.

CONCLUSIONS

This study presents new contributions on game analysis in padel. In conclusion, keeping a position close the net in the last two shots of the point, can increase the options of winning in professional padel. In this respect, the most frequent sequence to finish the point is groundstroke vs. volley and lob vs. smash.

In addition, the winning pairs in padel develop more winners at the net and fewer unforced errors at the back of the court. On the other hand, using crosscourt strokes (especially in the net zone) in the penultimate shot of the point could increase the probability of a further error from the rivals. Finally, these data suggest that the left-side players are greater specialists in the offensive and definitive strokes in padel.

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