Decoding the decade: Analyzing the evolution of technical and tactical performance in elite padel tennis (2011–2021)

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Abstract
Despite the recent popularity of padel tennis and extensive scientific research on technical and tactical performance, anthropometric, biomechanical, and physiological characteristics, there is still a lack of long-term retrospective investigation. Therefore, this study aimed to analyze key performance indicators (KPIs) to provide the changes in these indicators over a decade spanning from 2011 to 2021. The sample included 45 (i.e. 100 sets; 957 games; 5743 points; and 54,918 shots) professional men's matches (Padel Pro Tour and World Padel Tour finals and semifinals) from three different sports seasons (2011, 2016, and 2021). KPIs related to time motion and technical and tactical analysis (i.e. unforced errors and winner shots) were examined. A series of linear mixed models was performed to investigate difference among competition years (2011, 2016, and 2021). Comparing the evolution of the game across the observed decade, it emerged a more progressive intense game (more explosive and rapid playing actions), decreasing number of shots per point (8.8 vs 9.5), and an increasing number of shots per minute (44.2 vs 40.0). Further, an increase in the importance of efficiency in overhead shots (unforced errors from bandeja/vibora +116% from 2011 to 2016) and responding to serve shots (unforced errors from serve return +17% from 2011 to 2021) emerged. Therefore, the present findings are able to highlight the evolution playing of professional padel (i.e. fewer shots per point, shorter effective playing time, decreased average point durations, higher number of shots per minute), thus providing references to potential valuable training plans.

Keywords
Key performance indicators, racket sport, time-motion analysis, work-rest ratio

Introduction

Padel, also known as paddle tennis, is a racket sport born in 1969 in Mexico that has become very widespread across Europe in the present day.[1] According to its rules, it is a net sport similar to tennis in terms of score system, although some changes are present in terms of regulations, equipment, and play court. In particular, padel is played on a 20 m × 10 m (length × width) enclosed synthetic glass and metal court divided by a standard tennis net in the middle (0.88 m at the center strap and 0.92 m at the post). The back (3 m height × 10 m length) and the side walls (3 m × 2 m) end on another 2 m × 2 m wall, while the rest of the court consists of two metallic panels of equal dimensions (3 m × 2.59 m) and one gate (2 m × 0.82 m) for each half. This setting allows the ball to bounce on lateral and back walls (*International Padel Federation. Regulations of the*

Padel Game., 2021) and leads to longer rallies than other racket sports such as tennis or badminton.[2]

The progressive professionalization of padel over the years has been characterized by an evolution in terms of physical fitness,[3] scouting,[4] performance analysis,[5] and psychological support[6] to this sport, thus even improving the interest of several researchers in this sport. In fact, a recent bibliometric analysis on the state-of-art of padel highlighted that research was growing exponentially through the last 15 years (i.e. from 2007 to 2022).[7]

The increasing knowledge included technical and tactical performance, anthropometric, biomechanical, and physiological characteristics, as well as psychological features of the game.[8] Performance analysis emerged as the foremost area of interest, accounting for over 50% of the papers.[7] More specifically, papers focused on technical and tactical performance analysis are also the most cited ones, especially in professional and elite players, both males and females,[2,9] probably because the definition of the performance profile is primarily important and of reference for practical training applications. Subsequently, approximately 25% of the publications examined psychophysical and mental performance in the context of padel.[8] Finally, also investigations regarding anthropometric profiling, biomechanical analyses, and the injuries epidemiology in padel constituted notable research domains.[8]

From the perspective of selecting key performance indicators (KPIs), prior studies approached the analysis with both narrow and broader focuses. The narrow focus primarily examines technical indicators such as shot types (e.g. forehand, backhand), contact with opponents' board, shot height (e.g. overhead, underhand),[10] and shot trajectory (i.e. down the line or crosscourt).[11] On the other hand, the broader focus considers contingencies of the shots, including players' court location (baseline or net),[9] hitting side (left, right, or center), distance to the net when hitting,[11] and tactical perspectives focusing on the most effective type of hit to achieve an offensive position.[12]

From the notational analysis (NA) perspective, game performance analysis was carried out considering the technical and tactical KPIs, across different player categories, including elite, non-elite, and recreational players of both sexes and different age groups.[8–10,13–19] The primary focus was to examine the impact of these factors on the game's outcome. The evidence suggests that an effective game style is more likely to result in successful match outcomes. Specifically, it should be characterized by: (i) offensive skills such as a higher frequency of flat or topspin smashes and a reduced number of errors,[17,20] particularly in positions near the net,[21] (ii) defensive skills such as return-of-serve situations,[22] and (iii) effective decision-making in shot selection regarding type, direction, and height.[17,21] Furthermore, the time motion analysis (TMA) revealed that matches winners are able to engage in and win longer rallies (i.e. more than 11 seconds) compared to losers.[9]

Additionally, winners demonstrate the ability of avoiding unforced errors within the first 4 seconds of the rally.[9]

However, variations exist based on sexes and competitive levels. Female matches tend to have longer rally durations, more shots per rally, longer real play time, more resting time, greater resting time per rally, and more rallies per match than sex counterparts. Differently, national players exhibit a higher rate of play (shots per second), increased effective playing time, and a lower density (work-to-rest ratio) when compared to regional players.[8,10] In addition, in terms of technical and tactical aspects, female padel players use to perform higher number of first service faults, percentage of strokes from the midfield zone, winners and errors per game, breakpoints, and lobs per match,[23] and less percentages of the backhand lob, backhand volley, indirect forehand lob, and strokes close to the net and first service faults,[13] compare to male. Parallelly, in terms of age category, less strokes and lobs per rally emerged in U-16 than in U-18 male players, and more lobs per rally in U-16 than in U-18 female players.[24]

Previous investigations have predominantly examined technical and tactical KPIs in relation to match outcomes, often focusing on a relatively limited time span, typically ranging from 1 to 4 years.[18] Therefore, there is limited knowledge regarding the assessment of technical and tactical KPIs in padel over a substantially long period of time. The growing popularity of padel in recent years, coupled with the increasing level of competition, might have determined that the performance model has likely undergone changes. This may be particularly true at the elite level, where training and physical preparation focus on identifying evolving patterns in game style in order to achieve success. Consequently, the objective of this study was to comprehensively analyze the impact of technical and tactical KPIs, as well as temporal performance indicators, on match results. Therefore, we aimed to evidence the padel changes over a decade by means of the comparison of time motion and technical and tactical values reported for three different professional competitions (i.e. 2011, 2016, and 2021).

Materials and methods

Design and instruments

In this comparative study, a sample of 45 professional men's matches from three different sports seasons (i.e. 2011, 2016, and 2021) was analyzed. The matches were categorized based on the year and belonged to major world competitions, including the Padel Pro Tour 2010 circuit final and 14 finals of the Padel Pro Tour 2011 for the 2010–2011 season, eight finals and seven semifinals of the World Padel Tour 2016 circuit for the 2016 season, and 15 finals of the World Padel Tour 2021 circuit for the 2021 season. The sample included a total of 100 sets (i.e.

33, 32, and 35 from 2011, 2016, and 2021, respectively), with a total of 957 games, 5743 points, and 54,918 shots. In addition, the matches from 2011 were sourced from the Padel Magazine YouTube channel (https://www.youtube.com/c/PADELMagazineitalia),[25] while the matches from 2016 and 2021 were obtained from the official World Padel Tour website (https://worldpadeltour.com/en).[26] The matches were analyzed by a single expert analyst (more than 200 padel matches analyzed) using Longomatch Open Source software (version 1.3.2). However, to provide a reliable single analysis, either the intra- or inter-observer reliability was considered.[27] Three observers (i.e. the observer of the analysis reported for this study, and two additional padel experts with more than 200 padel matches analyzed) were involved to score twice the same KPI of the present study for two common sets of play randomly chosen (i.e. the two observations were separated by 7 days). Therefore, for each KPI, the ICC was calculated between the analyses of the same observer (intra-observer reliabilities: ICC range = 0.95–1.00) and of all three observers (inter-observer reliabilities: ICC range = 0.95–1.00).

Participants

The analysis included a total of 30 players across the three seasons. Out of these, eight players participated in both the 2011 Padel Pro Tour season and the 2016 World Padel Tour season, while six players participated both the 2016 and 2021 World Padel Tour season. Consequently, six players exclusively participated in the 2011 season, three in the 2016 season, and ten in the 2021 season. The average age and height of the players were 32 ± 6 years and 1.80 ± 0.06 m, respectively.

Procedures

Ten KPIs related to TMA were examined, as indicated by previous studies[8,10] (Supplementary 1). From the technical and tactical perspective, shots were analyzed according to their outcome (i.e. the unforced errors and winner shots) (see Supplementary 2). In particular, an unforced error was defined as an error without the opponent's influence, resulting in an immediate loss of the point (i.e. ball hit in the net or out) or in putting the opponents in a position to win the point because of an imprecise play. On the contrary, the winner shot was a shot that directly won the point or created an advantage by inducing the opponent to make a forced error. Moreover, shots were also described by the position of the hitters according to the following division of the court (Figure 1):

1. Net: the first 3.5 m from the net;
2. Middle: the second 3.5 m between the Net region and the service line;

3. Baseline: the 3 m area from the service line to the back wall;
4. Out-of-court: an area of at least 4 m in length and 2 m in width, located outside the playing rectangle and beyond the door, where players can retrieve balls the opponent hits from the side walls or the door.

Statistical analysis

Descriptive statistics were calculated for all investigated variables, and the data are presented as mean and 95% coefficient interval. Considering the time motion outcomes shoot per minute, shots per point, WRR, the differences between competition year (i.e. 2011, 2016, and 2021) and match results (i.e. winning or losing) were investigated using a series of linear mixed models. Differently, for total playing time, effective playing time, average rally duration and maximum rally duration only competition year fixed effects were detected using linear mixed model. The differences in unforced errors and winner shots between competition year (i.e. 2011, 2016, and 2021) and match results (i.e. winning or losing) were investigated using a series of linear mixed models. For all analysis, match results and years were considered fixed effects, while athletes' couples were included as random effects. Post hoc pairwise comparisons were performed using the Tukey's correction. The eta-squared value was calculated as effect size (ES). The absolute ES value was evaluated using the following thresholds: <0.01 = small, 0.01–0.06 = moderate, and >0.06 = large.[28] For the purpose of the study, only the main effect of the competition year was presented in the results section. All the statistical analysis was carried out using the statistical package R (version 4.2.3) with the packages lme4 (version 1.1.31) and emmeans (version 1.8.7).

Results

Time motion analysis

Figure 2 reports the significant outcomes for TMA according to the fixed effect competition years.

A difference in competition year was observed in WRR ($F = 12.417$; $p = 0.012$; ES = 0.004), Shots per minute ($F = 6.844$; $p = 0.002$; ES = 0.004), Shots per point ($F = 3.982$; $p = 0.044$; ES = 0.004), average rally duration ($F = 5.700$; $p = 0.006$; ES = 0.21). Specifically, the WRR for 2016 was significantly higher than the 2021 (0.52 vs 0.43), while shots per minute and shots per point in the 2011 were significantly lower than the 2021. No post hoc effects between competition years emerged for the average rally duration.

No significant differences in term of competition year were observed for total playing time ($F = 0.432$; $p = 0.514$; ES = 0.004), effective playing time ($F = 1.496$; $p = 0.262$; ES = 0.004), and maximum rally duration ($F = 2.790$; $p = 0.073$; ES = 0.12). See Supplementary 3.
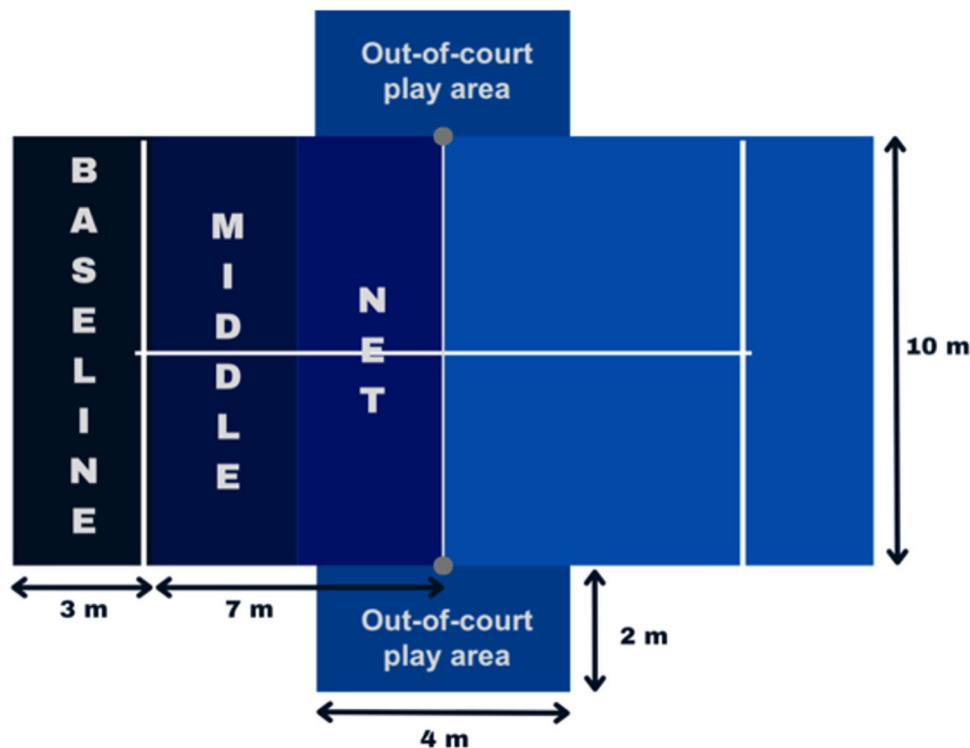
Figure 1. Division of the playing court.

Notational analysis

Figure 3 reports the significant outcomes for unforced error and shots resulting in a winner according to the fixed effect competition years.

Considering the indicators unforced errors, bandeja/vibora, smash x3, serve return, and out-of-court hitting zone, a significant main effect emerged across the competition years (bandeja/vibora: $F = 6.032$, $p = 0.004$, ES = 0.126; smash x3: $F = 6.717$, $p = 0.007$, EF = 0.156; serve return: $F = 6.770$, $p = 0.019$, ES = 0.139; out-of-court: $F = 3.892$, $p = 0.024$, ES = 0.085). In particular, post hoc analysis revealed a significant disparity between 2011 and 2016 for bandeja/vibora and smash x3 (see Figure 3(a) and (b)). Notably, while the bandeja/vibore unforced error shots increased in 2016, the smash x3 unforced error shots were entirely absent during that competition year. Differently, serve return (Figure 1(c)) and out-of-court (Figure 1(d)) were different between the years 2011 and 2021. Unforced error for serve return was higher for 2021, while out-of-courts was lower than 2011.

Considering winning shots, differences were reported for smash x3 ($F = 9.143$, $p = 0.005$, ES = 0.182; Figure 3-(e)). In particular, post hoc analysis reported a reduced performance of this type of winning shot over the years, with the mean decreasing from 2011 (13.3%) to 2021 (5.8%). Additionally, when considering the counter-attack type, an improvement of the occurrence of the opponent's out-of-bounds recovery has been reported from 2011 to 2016 ($F = 3.863$, $p = 0.025$, ES = 0.084) (Figure 3(f)). Furthermore, a distinct pattern emerged in the winning shot distribution within the hitting zone, with a specific reference to the middle zone ($F = 15.583$, $p < 0.001$, ES = 0.271), which results characterized by lower occurrence of play within this part of the field over years. While the winning shot percentage stood at approximately 33% in 2011, this figure dwindled to 24% and 19% in 2016 and 2021, respectively (Figure 3(g)). For more details about the outcome of unforced errors and shots resulting in the winner according to the match results and competition year, please see Supplementary 4 and Supplementary 5.

Discussion

This study analyzed the impact of technical and tactical KPIs and temporal performance indicators on match results in elite padel tennis, focusing on the relative changes over a decade-long period spanning from 2011 to 2021. Synthetically, the study pointed out that the current padel is characterized by a physically demanding style of play, featuring quick exchanges that are progressively shorter. The KPIs suggested an evolution towards a fast and explosive professional padel, with a decreasing number of shots per point, effective playing time, average
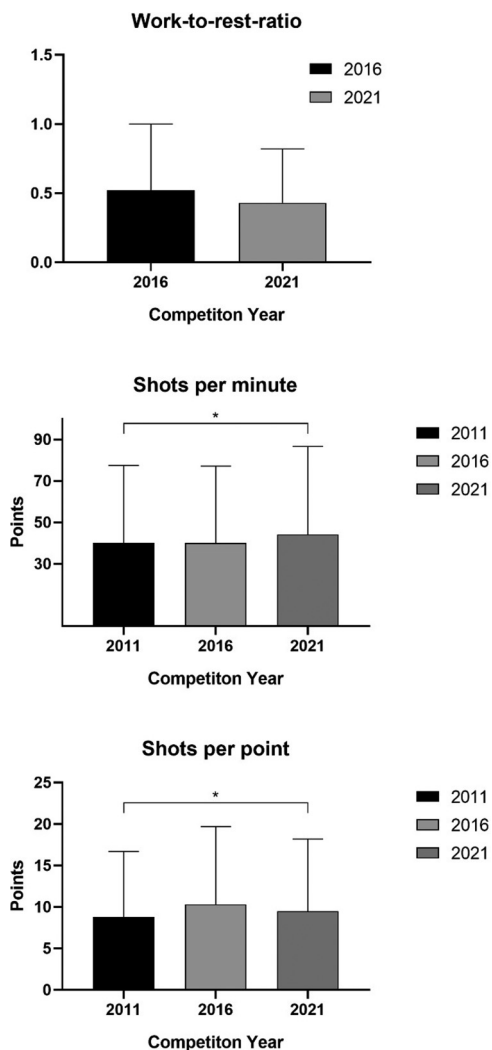
Work-to-rest-ratio

Shots per minute

Shots per point

Figure 2. Significant difference outcome for time motion analysis. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

point duration, and an increasing number of shots per minute.

From the TMA perspective, data reported in this study are consistent with existing literature.[10,19,29] In particular, it was shown that higher-level competitions are characterized by higher total (i.e. 93 minutes vs 53 minutes) and effective playing time (i.e. 29 minutes vs 17 minutes).[10] However, in case of similar technical and tactical levels (i.e. World Padel Tour vs Spanish top-level league), the effective playing times are alike (i.e. 29 minutes vs 25 minutes), while the total playing times differ (i.e. 93 minutes vs 54 minutes).[29] It is possible to speculate that this effect could be ascribed to media and entertainment constraints. Greater media coverage may lead to an increase in the average recovery time of a match, especially in the finals of World Padel Tour stages. In terms of evolution of the game style, the effective playing time increased by 17.5% between 2011 and 2016, followed by a decrease of

14.6% between 2016 and 2021. While the initial increase can be attributed to enhanced technical skills and increased tactical awareness developed during the period of significant padel growth in Spain,[7] the subsequent decline between 2016 and 2021 might be linked to a greater emphasis on physical preparation (e.g. overall enhancement of physical fitness, increased conditioning training, speed, explosiveness) and athletic conditioning (e.g. greater attention given to pre-season preparation) in recent years.[30] In addition, shots per minute registered a positive trend, increasing from 42 shots per minute in 2011 and 2016 to 44 shots per minute in 2021. These analyses highlight an increase in rally frequency, intensified gameplay, and suggest a greater emphasis on players' athletic conditioning, probably determined by a progressive evaluation of performance and training strategies of a novel sport such as padel.

The average point duration, across the three sports seasons, was 13.2 seconds, aligning with previous results in professional padel competitions who reported an average value of 12.6 seconds in 2016.[13] However, we also observed significant increases between 2011 and 2016 and significant decreases between 2016 and 2021. The initial increases, in line with the extended effective playing time, are likely attributed to a consolidation of technical skills and increased tactical awareness, while the decrease between 2016 and 2021 is likely due to the greater speed and explosiveness of the game.

Finally, the number of shots per point revealed significant changes between 2011 and 2016 (i.e. +23.3%). However, between 2016 and 2021, the trend decreased, albeit without significant differences (10.6 in 2016 vs 9.5 in 2021). This phenomenon reflects the prevailing trend in modern padel (especially considering the passage from 2011 to 2016), characterized by faster and quicker exchanges within briefer duration with respect to the past, and thus higher physically demanding to perform a highly intensive style of play.

From the NA perspective, this study focused on the tactical purpose of a particular shot. Thus, the characteristics of winning and unforced errors shots were recorded (see Supplementary 1 for more details) to analyze the changes over the decade. Specifically, the unforced errors derived from badeja/vibora increased in the last years, while the performance was moving to a faster and more explosive style. As a consequence, the bandeja/vibora seems to need to be executed with high confidence, consistency, and continuity, aiming to regain a net position as quickly as possible after a lob, ideally without making an error (Figure 2-(a)). In fact, according to previous studies,[17,20] bandeja/vibora are the most common rally-continuing overhead shots, but when a correct technical execution fails it results in an unforced error. Similarly, unforced errors derived from the serve return shots, also increased in the last years. Unlike in tennis, the serve is not considered shots of main importance in padel because the rules constraints to not serve with an
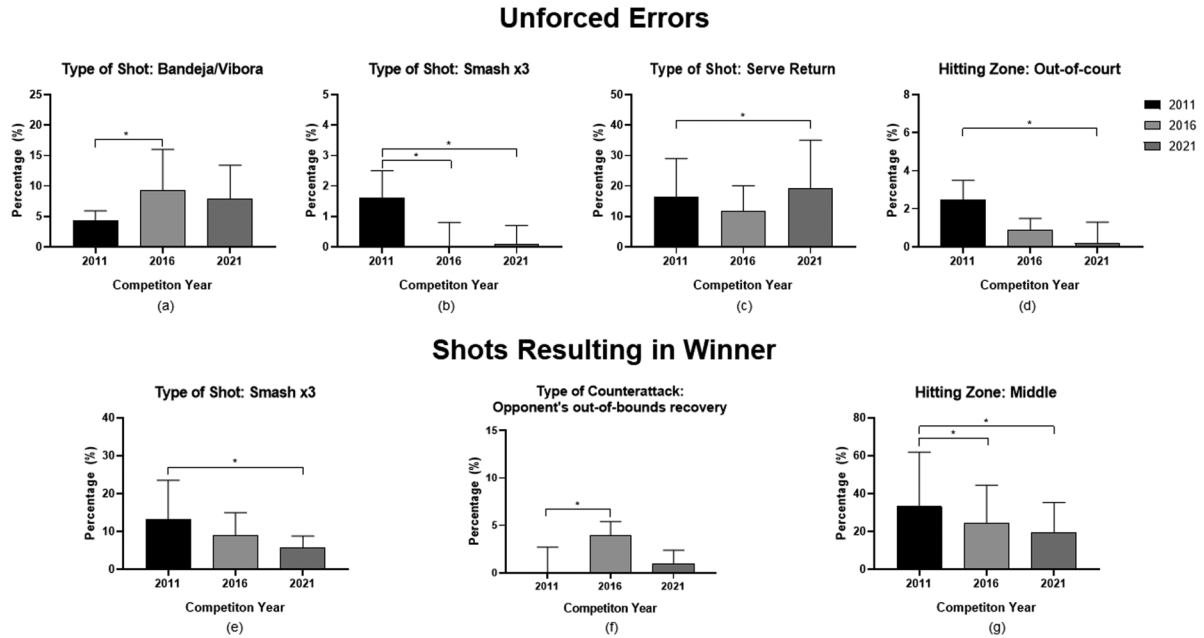
Unforced Errors

Shots Resulting in Winner

Figure 3. Significant difference outcome for notational analysis. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

over-head shot, although a well-executed serve is essential for maintaining the territorial advantage and the match momentum.[13,31] In this context, serve return shots aim to reduce the advantage gained from the serve by varying the direction and trajectory of the shot. However, if the ongoing demand for shot variation is not mastered, it might lead to an increase in unforced errors.

On the contrary, smash x3 decreased both resulting in unforced errors and winner shots (Figure 2(b) and (e)). Traditionally, smash x3 was categorized as a winning shot, but it is recently transitioning into a rally-continuing shot. This change can be linked to improvements in both the technical execution and defense of this shot, whether during out-of-court retrieval or when blocking from the baseline. Indeed, this pattern corresponds with the decrease in unforced errors observed in the out-of-court hitting zone between 2011 and 2021 (Figure 2(d)). In conjunction with the evolution of the playing style, characterized by quicker, briefer, and more explosive exchanges, the hitting zone of the winning shots also changed. Specifically, the middle zone (i.e. the second 3.5 meters between the net region and the service line) lost progressively relevance for winner shots (Figure 2(g)), although it exhibits characteristics similar to the net area (i.e. this area is the most advantageous for executing a winner due to the reduced distance from the net)[20,32] where players use to perform winner shots such as smash and tray.[13,21] A more aggressive style of play might have influenced players to remain either in the baseline (during the defensive phase) or at the net (during the offensive phase), at the expense of the middle (transition) area.

This study presents some limitations: the emphasis on physical preparation and athletic conditioning in recent years was only speculated, since no test was conducted to investigate variation in physical abilities of the professional athletes. Therefore, it would be desirable to directly investigate it through physical fitness[30] (e.g. anthropometry, leg reactive and maximal strength, handgrip strength, flexibility, agility) as well as psycho-physiological tests[33] (e.g. RPE), even in a longitudinal perspective. In addition, no data has been recorded according to the players' lateral dominance (i.e. presence of left-handed), which could affect the way and the style of play. Finally, the trend discussed in this study is the result of sampling data from 3 time points in the last 10 years, despite analyzing a substantial number of events (i.e. >54,000 shots). Hence, future research should aim to enhance the study of physical performance factors, technical and tactical data in relation to the lateral dominance, and sampling frequency, which might be facilitated by expanded event media coverage and improved video access for analysis.

Conclusion

The evolution of professional padel is marked on the one side by a faster and more dynamic form of competition, marked by fewer shots per point, shorter effective playing time, decreased average point durations, and an increased number of shots per minute. On the other side, unforced errors increased in bandeja/vibora and serve return shots, emphasizing the need for precision in executing these shots. Smash x3, once a winning shot, shifted towards a rally-continuing role due to improved execution and better defense. Winner shots were less common in the middle zone, indicating a shift towards an aggressive

style with players often staying at the baseline or net. As a consequence, these findings provide valuable insights for improving training strategies, both physical and technical and tactical aspects, as well as for forecasting the future evolution of the game. In addition, all the winning padel factors can lead to more aware training plans, with pertinent work-outs either according to the match evolution along a decade, and in relation to a successful playing behavior.

Declaration of conflicting interests

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Supplemental material

Supplemental material for this article is available online.

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