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ORIGINAL ARTICLE
EXERCISE PHYSIOLOGY AND BIOMECHANICS

The impact of altitude conditions on performance in men's and women's professional padel

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ABSTRACT

BACKGROUND: The aim of this study was to analyze whether there are differences in performance indicators between matches played at different altitudes in professional padel.
METHODS: Data were collected and analyzed based on players' sex, set number, and set score using video footage from the World Padel Tour (WPT), including open-access TV broadcasts and WPT's YouTube channel. Performance indicators – such as break points won, errors, winners, and winning smashes – were recorded across 1122 sets (485 matches) from three WPT seasons (2020-2022).
RESULTS: In men's padel, altitude-related differences were observed in break points (P=0.005), break points won (P=0.002), and winners (P=0.002). In women's padel, altitude-related differences were found in break points won (P=0.004), smashes (P<0.001), and winning smashes (P<0.001). Set number and set result were associated with variations in several performance indicators, depending on the tournament's altitude (below or above 500 meters).
CONCLUSIONS: These results represent reference data to help players and coaches train according to altitude conditions.

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KEY WORDS: Racket sports; Exercise; Athletic performance.

Padel is a racket sport where two pairs of players compete against each other in a match. It is played on a 20×10-meter court, divided by a central net, with an exterior enclosure made up of meshes and four-meter-high glass at the back of the court and three meters to the sides, against which players can hit the ball during the game.[1] There has been exponential growth in padel in recent decades,[2] and it is practiced by players of different ages and competitive levels, due to the simplicity of its rules and the fact that the physical and technical-tactical demands of the sport are adapted to the level of play.[1-6] This sport is currently practiced in more than 80 countries, with a recent significant increase in the number of padel facilities, commercial agreements (sponsorships, employment contracts, etc.), and sports licenses.[1, 7] Similarly, the number of scientific papers on padel has rapidly increased in recent years,[8-11] with performance analysis being the most studied topic. In professional padel, there are several tournament circuits, including A1 Padel, Premier Padel, and the now-defunct World Padel Tour (WPT). The WPT, which was the main professional circuit from 2013 to 2023, organized over 20 tournaments annually in cities around the world. Past research with professional padel players has determined differences between male and fe-

male players in various performance indicators. Regarding game parameters, point duration is higher in women's padel.[12, 13] Regarding game actions, men perform more shots in the net zone, such us backhand volleys, and flat and topspin smashes; women perform more shots in the middle and the back of the court, such us lobs and *bandejas*.[14-16] Regarding shot efficiency, women make a higher percentage of unforced errors, while men make a higher percentage of winners.[17] Finally, men are more effective when serving[18, 19] and women perform more breaks.[20] Performance differences between winning and losing teams have been also analyzed.[8, 21, 22] Match winners are more effective in long points (over 11 seconds) and make fewer errors in the first four seconds of the point. Also, winning teams perform more breaks, more attacking shots and smashes and spend more time in net zones than losing teams.[23] Since the 2020 season the WPT has incorporated the golden point rule in which teams play a point that will decide the game when the score is 40-40 (deuce).[24] Several research teams have analyzed the influence of the golden point on the game in professional men's and women's padel,[19, 25, 26] concluding that this point is a particular performance factor in the women's padel. Several researchers have examined the relationship between varying altitude conditions and player performance in tennis, another racket sport.[27, 28] These studies found that at higher altitudes, reduced atmospheric pressure results in less air resistance, leading to a higher ball bounce due to an increased coefficient of restitution.[27] As a result, the International Tennis Federation introduced the 'high-altitude' ball.[29] Sánchez-Pay *et al.*[28] found that higher altitude positively impacts serve performance in tennis, resulting in more aces and increased points won on both first and second serves. Similarly, physiological factors may influence performance in racquet sports. Other studies linking racquet sports and altitude suggest that training at high altitude improves physical fitness, including aerobic and anaerobic capacity.[30-32] High-intensity exercise at altitude has also been shown to enhance strength, speed, and reaction time in athletes. According to World Padel Tour (WPT) regulations, when padel tournaments are held at altitudes above 500 meters, players use specially designed padel balls that are heavier and have lower pressure. Despite these regulations, the relationship between altitude and performance indicators in professional padel has not yet been analyzed. Therefore, the aim of this research was to analyze player performance differences under varying altitude conditions, while also examining the influence of players' sex, game set number, and set score.

Materials and methods

Participants

A total of 1122 sets corresponding to 485 matches of the final draw (5 rounds) of 24 tournaments of three WPT seasons (2020-2022) of men's and women's padel were analyzed. Performance indicators were provided by WPT at the end of each set, through freely accessible videos on WPT TV[33] and on the official WPT YouTube channel.[34] In addition, contextual variables were collected through an *ad-hoc* instrument. All procedures were conducted according to ethical standards in sport and exercise science research[35] and our local Ethics Commission. Variables pertaining to performance indicators and contextual variables are detailed below.

Measures

The following performance indicators were considered for analyzing padel matches:

- break points – number of break points played and won;
- shot efficiency – number of winners (not including winning smashes) and errors;
- smash indicators – number of smashes played and won;
- golden point – number of golden points played and won.

The following parameters were considered as contextual variables:

- tournament altitude – <500 meters and >500 meters above the sea level. Altitude was determined by Google Earth, which gives the exact altitude of the place where each tournament was played;
- players' sex – male and female category;
- set number – first, second and third sets;
- set score – winning and losing team.

Design and procedures

Research methodology was quantitative, and descriptive, with data based on natural observations. Furthermore, this study is empirical, nomothetic, cross-sectional, and multidimensional.[36, 37] The performance indicators analyzed (which are provided by WPT), were collected from matches that are available on the WPT TV website and WPT YouTube channel. The analyst who recorded the performance indicators in WPT during the seasons indicated in the sample was a certified padel coach with more than 10 years of experience. However, an inter-observer reliability

analysis was performed to ensure the veracity of the data collected. One of the authors of the manuscript, doctor in sports sciences, author of numerous relevant scientific publications on padel and with more than 10 years of experience, using the LINCE video analysis software,[38] analyzed the performance indicators of a random sample of 180 sets to guarantee a relevant amount of data, between10 and 20% of the total study sample.[39] The reliability of the analysis test was 0.91, based on Cohen's Kappa coefficient (*K*),[40] considered almost perfect.[41] This doctor collected the contextual variables of the study, through an ad-hoc instrument. Furthermore, once the registration was completed, the doctor again collected a random sample of 180 sets in order to perform an intra-observer reliability analysis, with the average reliability of the analysis test being 1.00, considered perfect.[41] Table I details these findings.

Statistical analysis

It was verified that none of the recorded performance indicators met the normality criteria (Kolmogorov-Smirnov), so the hypothesis contrast model was non-parametric.[42] A descriptive analysis (means, standard deviations, median and interquartile range) of the performance indicators for each set, organized according to the contextual variables, was carried out. Subsequently, an inferential analysis was conducted, using the Mann-Whitney U Test to identify the differences between altitude conditions according to the players' sex, tournament round, set number and set score, adjusting the significance according to Bonferroni. Effect size was calculated from Cohen's *d*, considering a small 0.20, medium 0.50, and large 0.80 effect size.[43] Statistical analyses were performed using SPSS v.21 software (IBM Corp., Armonk, NY, USA).

TABLE I.—*Inter-observer and intra-observer reliability.*

Study variables	K
Winning break points	0.96
Break points	0.92
Errors	0.83
Winning smashes	0.93
Smashes	0.90
Winners	0.84
Golden points	1.00
Tournament altitude	1.00
Sex	1.00
Set number	1.00
Set score	1.00

Results

Table II shows the differences found between altitude conditions in WPT tournaments in performance indicators. There are more break points (Mann-Whitney U = 505676.500; *Z*=-3.401; P=0.001), break points won (Mann-Whitney U = 493889.500; *Z*=-4.338; P<0.001), winners (Mann-Whitney U = 500597.000; *Z*=-3.727; P<0.001) and golden points (Mann-Whitney U = 525936.000; *Z*=-2.054; P<0.040) in low altitude conditions (<500 meters), while they perform more smashes (Mann-Whitney U = 491414.500; *Z*=-4.365; P<0.001) and winning smashes (Mann-Whitney U = 469554.500; *Z*=-5.898; P<0.001) in high altitude conditions (>500 meters). In men's padel there are significant differences depending on the altitude conditions in break points (Mann-Whitney U = 161055.000; *Z*=-2.808; P=0.005), break points won (Mann-Whitney U = 160231.000; *Z*=-3.038; P=0.002) and winners (Mann-Whitney U = 159316.000; *Z*=-3.069; P=0.002), while in women's padel there are differences depending on the altitude conditions in break points won (Mann-Whitney U = 92272.500; *Z*=-2.902; P=0.004), smashes (Mann-Whitney U = 77763.500; *Z*=-6.351; P<0.001) and winning smashes (Mann-Whitney U = 74967.500; *Z*=-7.067; P<0.001) (Supplementary Digital Material 1: Supplementary Table I). For the influence of altitude conditions on performance indicators according

TABLE II.—*Altitude conditions and padel performance indicators.*

Performance indicators	<500 m		>500 m		P	*d*
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)		
Break points	3.3 (2.2)	3.0 (3.0)	3.0 (2.2)	3.0 (3.0)	0.001*	0.143
Break points won	1.4 (1.1)	1.0 (2.0)	1.2 (1.0)	1.0 (2.0)	<0.001*	0.177
Winners	13.6 (5.1)	14.0 (7.0)	12.8 (4.9)	13.0 (7.0)	<0.001*	0.158
Smashes	9.6 (5.4)	9.0 (7.0)	10.6 (5.3)	10.0 (7.0)	<0.001*	0.185
Winning smashes	5.5 (3.6)	5.0 (5.0)	6.5 (3.7)	6.0 (5.0)	<0.001*	0.250
Errors	6.6 (3.1)	6.0 (4.0)	6.7 (3.1)	6.0 (3.3)	0.485	0.029
Golden points	1.2 (1.0)	1.0 (2.0)	1.1 (1.1)	1.0 (2.0)	0.040*	0.083

SD: standard deviation; P: P value; *d*: effect size; IQR: interquartile range.
*P<0.05.

to the set number in men's and women's padel, significant differences were found in male category for winners (Mann-Whitney U = 26233.500; *Z*=-3.050; P=0.002) in the second set. In female category, differences were found in smashes in the first (Mann-Whitney U = 15100.500; *Z*=-4.186; P<0.001), second (Mann-Whitney U = 15608.000; *Z*=-3.670; P<0.001) and third set (Mann-Whitney U = 934.500; *Z*=-3.383; P=0.001), winning smashes in the first (Mann-Whitney U = 14452.000; *Z*=-4.755; P<0.001), second (Mann-Whitney U = 15352.000; *Z*=-3.903; P<0.001) and third set (Mann-Whitney U = 881.500; *Z*=-3.705; P<0.001) and in break point won (Mann-Whitney U = 16698.000; *Z*=-2.934; P=0.003) in the first set (Supplementary Digital Material 2: Supplementary Table II). For the impact of altitude conditions on performance indicators according to the set result in men's and women's padel, data reveals that altitude conditions have a more pronounced effect on performance indicators for players who win compared to those who lose in both men's and women's padel. In male winning players, altitude significantly influences several performance metrics: break points (Mann-Whitney U = 39,146.000; Z=-2.517; P=0.012), break points won (Mann-Whitney U = 36,916.000; Z=-3.785; P<0.001), and winners (Mann-Whitney U = 37,939.500; Z=-3.046; P=0.002). These metrics are notably higher at sea level. In male losing players, altitude affects only the number of break points (Mann-Whitney U = 39,992.500; Z=-2.121; P=0.034), with a higher number observed at sea level. In female winning players, altitude significantly influences several performance metrics: break points (Mann-Whitney U = 22,743.500; Z=-2.287; P=0.022), break points won (Mann-Whitney U = 20,641.000; Z=-4.012; P<0.001), and winners (Mann-Whitney U = 22,926.500; Z=-2.138; P=0.033), all of which are greater at sea level. Conversely, smashes (Mann-Whitney U = 18,104.000; Z=-5.452; P<0.001) and winning smashes (Mann-Whitney U = 17,525.500; Z=-5.875; P<0.001) are performed more effectively under altitude conditions. In female losing players, altitude affects only smashes (Mann-Whitney U = 20,592.000; Z=-3.653; P<0.001) and winning smashes (Mann-Whitney U = 19,414.000; Z=-4.504; P<0.001), with both metrics being more prevalent under high altitude conditions (Supplementary Digital Material 3: Supplementary Table III).

Discussion

This study presents novel insights into the technical and tactical performance indicators of elite-level padel players. The main findings indicate that tournaments held at altitudes greater than 500 meters above sea level see more smashes and winning smashes, whereas tournaments held at altitudes less than 500 meters exhibit more break points, golden points, and total winners. Additionally, significant differences were observed based on players' sex, set number, and set result. To the best of our knowledge, this is the first report to investigate altitude differences in performance indicators within professional padel. These findings advance our understanding of elite-level padel game dynamics and offer valuable information for coaches and players to enhance training and strategic decision-making. The current results show a strong relationship between break points and contextual variables in padel, such as match score or players' sex. Several studies suggest that winning pairs and female players perform more break points than losing pairs and male players.[44] Additionally, our results confirm a higher number of break points (played and won) in tournaments played <500 m above the sea level. Likewise, players should focus on serving strategies and tactics when playing in low-altitude tournaments. In tennis, previous studies show a higher duration in altitude conditions, more games per set and more matches to three sets played.[28] These authors report more aces and less breaks in altitude due to a more aggressive strategy when serving. In this sense, the serve in tennis is the most decisive technical-tactical action,[45] giving the opportunity of directly winning the point through an ace.[46] In this way, tennis players win almost 70% of the points with the first serve. A recent study in padel shows that padel players win a high percentage of points serving,[18, 26] especially at short-duration points, which could occur in altitude conditions, where the density of the air is lower and the ball has less resistance to its movement, achieving a higher speed.[27] This fact could provoke less break points at high altitude conditions. Regarding shot effectiveness, the current results indicate a significantly lower average of winners (excluding winning smashes) in tournaments played at altitudes above 500 meters for both men's and women's padel. It is important to note that in this study, the variable "winner" does not include winning smashes. This distinction is crucial, as a higher number of winners at high altitudes are likely to be attributed to smashes. However, altitude conditions do not appear to influence the number of errors in professional padel. Previous research has predominantly examined shot effectiveness,[14, 47, 48] consistently reporting that most winners result from overhead strokes, such as smashes and *bandejas*. Interestingly, altitude does not seem to affect this trend,

except in the female category, where significant differences in winning smashes were observed between tournaments played at altitudes above and below 500 meters. The increased smash effectiveness among female players could be linked to altitude conditions, which enhance ball bounce and speed. Notably, in the women's category, the type of ball remains consistent, regardless of altitude. In men's padel, previous studies have shown that players can win points with smashes from up to 7 meters away from the net, regardless of altitude.[14, 16, 22] The higher number of winners observed under altitude conditions in the men's category may instead be due to volleys – particularly forehand volleys – and off-the-wall shots, as noted in another research.[17, 49] A novel contribution of this study is the analysis of performance indicators in relation to score parameters in high- and low-altitude tournaments. Our findings show that more golden points are played in tournaments at altitudes below 500 meters above sea level. This supports the idea that contextual variables influence golden point outcomes.[19, 50] These authors found that serve efficiency and point duration increase during golden points, especially in the female category. Additionally, regarding set number, we observed a significantly higher number of break points in low-altitude tournaments, specifically in the second set for men and the first set for women. Other studies have confirmed that more games and golden points are played in the second sets of male padel matches.[25, 51] However, future research should explore this relationship in greater detail and consider other score parameters.

Practical applications

The findings of this study offer valuable insights for coaches and players to tailor their training strategies based on tournament altitude and player sex. For men, it is recommended to focus on practicing break points, particularly in scenarios such as games starting at 30/40, before low-altitude tournaments. Additionally, training should emphasize generating winners that exclude smashes, for instance, with the forehand and backhand volleys. For women, it is beneficial to prioritize smashes and winning smashes in preparation for high-altitude tournaments, as altitude conditions significantly enhance the effectiveness of these shots. Incorporating these targeted training approaches can help players optimize their performance under varying altitude conditions.

Limitations of the study

Finally, several limitations of this study should be acknowledged. First, meteorological factors (*e.g.*, wind speed, humidity, temperature), the season during which the tournaments took place (summer, autumn, winter, or spring), and whether the matches were played on indoor or outdoor courts were not considered. Second, the number of performance indicators analyzed was relatively low. Future research should examine the final shot of each point to better understand how padel players conclude points, both in terms of winners and errors. Additionally, point duration (*i.e.*, volume of play) could be a valuable variable to explore. Lastly, it would be insightful to investigate how players' performance evolves in high-altitude tournaments by employing a repeated measures design that compares a consistent sample of padel pairs over time. In this context, it would be valuable to explore whether training at high altitude prior to a tournament held under similar conditions offers performance benefits.

Conclusions

This study offers novel insights into the expanding field of notational analysis in padel by examining, for the first time, a large sample of tournaments across multiple seasons while comparing the effects of tournament altitude. These findings could help improve the quality and precision of training drills by tailoring them to the specific match activity and technical-tactical demands of playing in low or high-altitude conditions. Our results indicate that both men and women perform more smashes and winning smashes in high-altitude tournaments, where the ball bounces more. In contrast, in terms of serving efficiency, players win more breaks in low altitude tournaments. Additionally, contextual variables such as set number and match score influence player performance differently depending on tournament altitude. Therefore, in tournaments with high altitude players should be very offensive when they are in areas close to the net and make smashes as soon as they have the opportunity after an opponent's lob. While they are on the back court or defending, they should try to come out with *chiquitas* and low balls. On the contrary, in low altitude conditions, the serving players should take advantage of their advantage and close the points with few shots, as it is more likely that the opponents get to make breaks.

References

1. International Padel Federation. List of countries associated with the International Padel Federation; 2024 [Internet]. Available from: https://wwwpadelfipcom/es/ [cited 2024, Oct 30].

2. Courel-Ibáñez J, Sánchez-Alcaraz BJ, García-Benítez S, Echegaray M. Evolución del pádel en España en función del género y edad de los practicantes [Evolution of paddle tennis in Spain depending on the gender and age of the practitioners]. CCD 2017;12:39–46. [Spanish]

3. Courel-Ibáñez J, Sánchez-Alcaraz BJ, Muñoz D, Pérez FJ, Herrera RC, García JD. Gender reasons for practicing paddle tennis. Apunts Educ Fís Deporte 2018;133:116–25.

4. García-Benítez S, Courel-Ibáñez J, Pérez-Bilbao T, Felipe JL. Game responses during young padel match play: age and sex comparisons. J Strength Cond Res 2018;32:1144–9.

5. Pradas F, Sánchez-Pay A, Muñoz D, Sánchez-Alcaraz BJ. Gender differences in physical fitness characteristics in professional padel players. Int J Environ Res Public Health 2021;18:5967.

6. Pradas F, Toro-Román V, Ortega-Zayas MÁ, Montoya-Suárez DM, Sánchez-Alcaraz BJ, Muñoz D. Physical fitness and upper limb asymmetry in young padel players: differences between and categories. Int J Environ Res Public Health 2022;19:6461.

7. Muñoz D, Sánchez-Alcaraz BJ, Courel-Ibáñez J, Pastelero ER, Pérez FJ, Díaz J. Estudio sobre el perfil y distribución de las pistas de pádel en la comunidad autónoma de Extremadura [Study on the profile and distribution of paddle tennis courts in the autonomous community of Extremadura]. E-Balonmano 2016;12:223–30. [Spanish]

8. Conde-Ripoll R, Escudero-Tena A, Bustamante-Sánchez Á. Pre and post-competitive anxiety and self-confidence and their relationship with technical-tactical performance in high-level men's padel players. Front Sports Act Living 2024;6:1393980.

9. García-Giménez A, Pradas de la Fuente F, Castellar Otín C, Carrasco Páez L. Performance outcome measures in padel: a scoping review. Int J Environ Res Public Health 2022;19:4395.

10. Sánchez-Alcaraz BJ, Cánovas Martínez J, Sánchez Pay A, Muñoz D. Investigación en pádel Revisión sistemática [Padel research Systematic review]. Padel Sci J 2022;1:71–105. [Spanish]

11. Villar-León A, Muñoz D, Sánchez-Alcaraz BJ, Martín-Miguel I, Conde-Ripoll R, Escudero-Tena A. Playing high: strategic use of the lob in professional padel. Appl Sci (Basel) 2024;14:8261.

12. García-Benítez S, Pérez-Bilbao T, Echegaray M, Felipe JL. Influencia del género en la estructura temporal y las acciones de juego del pádel professional [Influence of gender on the temporal structure and playing actions of professional paddle tennis]. CCD 2016;11:241–7. [Spanish]

13. Martín-Miguel I, Muñoz D, Escudero-Tena A, Sánchez-Alcaraz BJ. Analysis of Off-the-wall smash shots in men's and women's professional padel. Percept Mot Skills 2024;131:843–60.

14. Lupo C, Condello G, Courel-Ibáñez J, Gallo C, Conte D, Tessitore A. Effect of gender and match outcome on professional padel competition. RICYDE 2018;14:29–41.

15. Torres-Luque G, Ramírez A, Cabello-Manrique D, Nikolaidis TP, Alvero-Cruz JR. Match analysis of elite players during paddle tennis competition. Int J Perform Anal Sport 2015;15:1135–44.

16. Sánchez-Alcaraz BJ, Pérez-Puche DT, Pradas F, Ramón-Llín J, Sánchez-Pay A, Muñoz D. Analysis of performance parameters of the smash in male and female professional padel. Int J Environ Res Public Health 2020;17:7027.

17. Escudero-Tena A, Almonacid B, Martínez J, Martínez-Gallego R, Sánchez-Alcaraz BJ, Muñoz D. Analysis of finishing actions in men's and women's professional padel. Int J Sports Sci Coaching 2022. [Epub ahead of print]

18. Conde-Ripoll R, Martín-Miguel M, Muñoz D, Escudero-Tena A. Performance dynamics in professional padel: winners, forced errors, and unforced errors among men and women players. Int J Perform Anal Sport 2024:1–17.

19. Sánchez-Alcaraz BJ, Muñoz FJ, Ramón-Llín J, Sánchez-Pay A, Muñoz D. Influencia del punto de oro en la estructura temporal y el marcador en pádel professional [Influence of the golden point on the temporal structure and the scoreboard in professional padel]. Kronos 2020;19:1–8. [Spanish]

20. Escudero-Tena A, Mancha-Triguero D, Pozo-Ayerbe C, Ibáñez SJ. Diferencias entre pádel profesional masculino y femenino en función del rendimiento según el set, la ronda y el tipo de torneo [Differences between male and female professional padel tennis based on performance according to the set, the round and the type of tournament]. Padel Sci J 2022;1:23–37. [Spanish]

21. Escudero-Tena A, Sánchez-Alcaraz BJ, García-Rubio J, Ibáñez SJ. Analysis of game performance indicators during 2015-2019 World Padel Tour seasons and their influence on match out-come. Int J Environ Res Public Health 2021;18:4904.

22. Sánchez-Alcaraz BJ, Courel-Ibáñez J, Muñoz D, Infantes-Córdoba P, de Zumarán FS, Sánchez-Pay A. Análisis de las acciones de ataque en el pádel masculino profesional [Analysis of attacking actions in professional men's padel]. Apunts Educ Fís Deport 2020;4:29–34. [Spanish]

23. Courel-Ibáñez J, Sánchez-Alcaraz BJ. Análisis predictivo del golpeo en pádel a través de modelos de árboles decisionales. RAMD 2017;10:158–62.

24. International Padel Federation. Rules of the game in padel; 2017 [Internet]. Available from: https://wwwpadelfipcom/es/ [cited 2024, Oct 30].

25. Muñoz D, Toro-Román V, Vergara I, Romero A, Fernández de Ossó A, Sánchez-Alcaraz BJ. Análisis del punto de oro y su relación con el rendimiento en jugadores profesionales de pádel masculino y femenino [Analysis of the golden point and its relationship with performance in professional male and female padel players]. Retos 2022;45:275–81. [Spanish]

26. Sánchez-Alcaraz BJ, Valcarcel M, Sánchez-Pay A, Ramón-Llin J, Martínez-Gallego R, Muñoz D. Análisis del saque en pádel professional [Analysis of the serve in professional padel]. Kronos 2022;21:2951. [Spanish]

27. Bermejo J. Análisis estructural del golpeo en tenis: una aproximación desde la biomecánica [Structural analysis of hitting in tennis: an approach from biomechanics]. Eur J Hum Mov 2013;31:111–33. [Spanish]

28. Sánchez-Pay A, Otálora-Murcia FJ, Sánchez-Alcaraz BJ. Influencia de la altitud en las demandas de competición del tenis profesional en pista dura y tierra batida [Influence of altitude on the competition demands of professional tennis on hard court and clay]. CCD 2019;14:243–9. [Spanish]

29. International Tennis Federation. Available from: Rules of tennis; 2016 [Internet]. Available from: https://ftpitftenniscom/login [cited 2024, Oct 30].

30. Brechbuhl C, Brocherie F, Millet GP, Schmitt L. Effects of repeated-sprint training in hypoxia on tennis-specific performance in well-trained players. Sports Med Int Open 2018;2:E123–32.

31. Brechbuhl C, Brocherie F, Willis SJ, Blokker T, Montalvan B, Girard O, *et al.* On the use of the repeated-sprint training in hypoxia in tennis. Front Physiol 2020;11:588821.

32. Quan Z, Zhao Y. Improvement of physical conditions in tennis players under high altitudes. Rev Bras Med Esporte 2023;29:e2022–655.

33. World Padel Tour TV. Homepage; 2024 [Internet]. Available from: https://www.worldpadeltourtv.com/ [cited 2024, Oct 30].

34. Youtube. World Padel Tour; 2024 [Internet]. Available from: https://www.youtube.com/@Worldpadeltour [cited 2024, Oct 30].

35. Harriss DJ, MacSween A, Atkinson G. Ethical standards in sport and exercise science research: 2020 update. Int J Sports Med 2019;40:813–7.

36. Anguera MT, Blanco-Villasenor A, Losada JL, Portell M. Pautas para elaborar trabajos que utilizan la metodología observacional [Guidelines for preparing works that use observational methodology]. Anu Psicol 2018;48:9–17. [Spanish]

37. Ato M, Lopez JJ, Benavente A. A classification system for research designs in psychology. Anal Psicol 2013;29:1038–59.

38. Gabin B, Camerino O, Anguera MT, Castañer M. Lince: multiplatform sport analysis software. Procedia Soc Behav Sci 2012;46:4692–4.

39. Igartua JJ. Métodos cuantitativos de investigación en comunicación [Quantitative communication research methods]. Barcelona: Editorial Bosh; 2006. [Spanish]

40. Cohen J. Weighted kappa: nominal scale agreement with provision for scaled disagreement or partial credit. Psychol Bull 1968;70:213–20.

41. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.

42. Field A. Discovering Statistics Using SPSS. Thousand Oaks, CA: Sage Publications; 2019.

43. Thalheimer W, Cook S. How to calculate effect sizes from published research: A simplified methodology. Work Learn Res 2002;1:1–9.

44. Escudero-Tena A, Courel-Ibáñez J, García-Rubio J, Ibáñez SJ. Sex differences in professional padel players: analysis across four seasons. Int J Perform Anal Sport 2021;21:651–62.

45. Fernández-García AI, Blanca-Torres JC, Hernández-García R, Torres-Luque G. Analysis of the statistical variables related to the service in high performance male tennis in junior and absolute category. CCD 2019;14:289–95.

46. Reid M, McMurtrie D, Crespo M. The relationship between match statistics and top 100 ranking in professional men's tennis. Int J Perform Anal Sport 2010;10:131–8.

47. Escudero-Tena A, Muñoz D, Sánchez-Alcaraz J, García-Rubio J, Ibáñez SJ. Analysis of errors and winners in men's and women's professional padel. Appl Sci (Basel) 2022;12:8125.

48. Martín-Miguel I, Almonacid B, Muñoz D, Sánchez-Alcaraz BJ, Courel-Ibáñez J. Game dynamics in professional padel: shots per point, point pace and technical actions. Sports (Basel) 2024;12:218.

49. Pozo-Ayerbe C, Escudero-Tena A, Ibáñez SJ. Análisis de los diferentes golpes ganadores en pádel profesional: masculino vs femenino [Analysis of the different winning shots in professional padel: male vs female]. E-Balonmano 2024;20:271–80. [Spanish]

50. Sánchez-Alcaraz BJ, Valcárcel M, Sánchez-Pay A, Ramón-Llin J, Martínez-Gallego R, Muñoz D. Serve analysis in professional padel. Kronos 2022;22:1–9.

51. Sánchez Alcaraz BJ, Siquier-Coll J, Toro-Román V, Sánchez-Pay A, Muñoz D. Análisis de los parámetros relacionados con el marcador en el circuito World Padel Tour 2019: diferencias por género, ronda y tipo de torneo [Analysis of the parameters related to the score in the World Padel Tour 2019 circuit: differences by gender, round and type of tournament]. Retos 2021;39:200–4. [Spanish]

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

Adrián Escudero-Tena has given substantial contributions to the study conception and design, and to the data collection; Iván Martín-Miguel, Bernardino J. Sánchez-Alcaraz, Rafael Conde-Ripoll and Diego Muñoz contributed to the formal analysis; all authors equally contributed to the manuscript draft, editing and critical revision for important intellectual content. All authors read and approved the final version of the manuscript.

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SUPPLEMENTARY DIGITAL MATERIAL 1

Supplementary Table I.—Spearman's (Rho and significance values) correlations between TMA and technical and tactical indicators for forwards.

Indicators	Correlations	TD	Z2	Z3	Z4	MPErec	Burst
Played balls (N.)	Rho	0.286	0.571	0.667	0.214	-0.214	0.132
	P	0.493	0.139	0.071	0.610	0.610	0.721
Successful passes (N.)	Rho	0.371	0.611	0.443	0.168	-0.072	-0.120
	P	0.365	0.108	0.272	0.691	0.866	0.778
Successful playing patterns (N.)	Rho	-0.095	0.143	0.119	0.190	0.214	-0.190
	P	0.823	0.736	0.779	0.651	0.610	0.651
Lost balls (N.)	Rho	-0.190	-0.024	0.214	-0.143	-0.357	0.333
	P	0.651	0.955	0.610	0.736	0.385	0.420
Fouls committed (N.)	Rho	0.108	-0.036	0.084	0.299	-0.168	0.018
	P	0.799	0.933	0.844	0.599	0.691	0.966
Fouls received (N.)	Rho	-0.048	0.143	0.524	0.476	-0.452	0.048
	P	0.911	0.736	0.183	0.233	0.260	0.911
Successful dribbling (N.)	Rho	0.072	-0.126	-0.378	0.306	0.613	0.072
	P	0.878	0.788	0.403	0.504	0.144	0.878
Total dribbling (N.)	Rho	-0.286	0.107	-0.036	-0.143	0.036	-0.500
	P	0.535	0.819	0.939	0.760	0.939	0.253
Successful/total dribbling (N.)	Rho	0.071	-0.119	-0.095	0.405	0.714*	-0.381
	P	0.867	0.779	0.823	0.320	0.047#	0.352
Successful crosses (N.)	Rho	0.253	0.217	-0.482	-0.566	0.349	-0.217
	P	0.545	0.606	0.227	0.143	0.396	0.606
Total crosses (N.)	Rho	0.071	0.286	0.167	0.143	-0.048	-0.238
	P	0.867	0.493	0.693	0.736	0.911	0.570
Successful/total crosses (N.)	Rho	0.317	0.268	-0.439	-0.708*	0.366	-0.512
	P	0.444	0.520	0.276	0.050#	0.373	0.194
Successful assists (N.)	Rho	0.027	-0.109	-0.027	-0.218	-0.682	0.873**
	P	0.949	0.797	0.949	0.604	0.062	0.005#
Total assists (N.)	Rho	-0.714*	-0.476	-0.19	-0.333	-0.571	0.071
	P	0.047#	0.233	0.651	0.420	0.139	0.867
Successful/total assists (N.)	Rho	0.027	-0.109	-0.027	-0.218	-0.682	0.873**
	P	0.949	0.797	0.949	0.604	0.062	0.005#
Shots towards goal (N.)	Rho	0.204	0.036	0.132	0.024	-0.096	-0.024
	P	0.629	0.933	0.756	0.955	0.821	0.955
Total shots (N.)	Rho	0.167	0.048	-0.381	-0.357	0.333	-0.500
	P	0.693	0.911	0.352	0.385	0.420	0.207
Shots towards goal/total shots (N.)	Rho	0.204	0.012	0.180	0.11	0.335	0.22
	P	0.629	0.978	0.670	0.82	0.417	0.52
Ball possession (sec)	Rho	0.190	0.452	0.452	0.357	0.024	-0.190
	P	0.651	0.260	0.260	0.385	0.955	0.651

TMA: target motion analysis.

*P≤0.05, significant correlations; **P≤0.01, significant correlations; #statistically significant.

SUPPLEMENTARY DIGITAL MATERIAL 2

Supplementary Table II.—Spearman's (Rho and significance values) correlations between TMA and technical and tactical indicators for midfielders.

Indicators	Correlations	TD	Z2	Z3	Z4	MPErec	Burst
Played balls (N.)	Rho	0.055	0.027	-0.391	-0.809**	0.273	-0.591
	P	0.873	0.937	0.235	0.003#	0.417	0.056
Successful passes (N.)	Rho	0.409	0.400	-0.173	-0.864**	-0.100	-0.309
	P	0.212	0.223	0.612	<0.001#	0.770	0.355
Successful playing patterns (N.)	Rho	-0.464	-0.418	-0.536	-0.309	0.491	-0.345
	P	0.151	0.201	0.089	0.355	0.125	0.298
Lost balls (N.)	Rho	-0.301	-0.346	-0.383	-0.182	0.697*	-0.610*
	P	0.369	0.297	0.245	0.592	0.017#	0.046#
Fouls committed (N.)	Rho	0.182	0.418	0.445	0.055	-0.300	0.227
	P	0.593	0.201	0.170	0.873	0.370	0.502
Fouls received (N.)	Rho	-0.055	0.041	-0.014	0.128	0.178	-0.351
	P	0.873	0.905	0.968	0.709	0.601	0.290
Successful dribbling (N.)	Rho	-0.524	-0.715*	-0.620*	0.159	0.579	-0.451
	P	0.098	0.013#	0.042#	0.640	0.062	0.164
Total dribbling (N.)	Rho	-0.273	-0.418	-0.082	0.418	0.155	0.182
	P	0.417	0.201	0.811	0.201	0.650	0.593
Successful/total dribbling (N.)	Rho	-0.497	-0.642	-0.556	-0.105	0.588	-0.269
	P	0.120	0.033	0.076	0.759	0.057	0.424
Successful crosses (N.)	Rho	0.055	0.138	0.138	0.202	0.055	-0.257
	P	0.872	0.687	0.687	0.552	0.872	0.446
Total crosses (N.)	Rho	-0.456	-0.342	0.050	0.460	0.465	0.128
	P	0.159	0.304	0.884	0.154	0.150	0.709
Successful/total crosses (N.)	Rho	0.405	0.405	0.115	-0.041	-0.207	-0.308
	P	0.217	0.217	0.736	0.904	0.542	0.357
Successful assists (N.)	Rho	-0.358	-0.075	-0.133	-0.243	0.058	-0.168
	P	0.279	0.826	0.697	0.472	0.866	0.622
Total assists (N.)	Rho	-0.182	-0.300	-0.364	-0.245	0.618*	-0.445
	P	0.593	0.370	0.272	0.467	0.043#	0.170
Successful/total assists (N.)	Rho	-0.358	-0.017	-0.006	-0.092	-0.012	-0.006
	P	0.279	0.960	0.987	0.787	0.973	0.987
Shots towards goal (N.)	Rho	-0.573	-0.682*	-0.545	0.200	0.700*	-0.418
	P	0.066	0.021#	0.083	0.555	0.016#	0.201
Total shots (N.)	Rho	-0.237	-0.346	-0.296	0.228	0.346	-0.424
	P	0.483	0.297	0.377	0.501	0.297	0.194
Shots towards goal/total shots (N.)	Rho	0.155	0.136	0.000	-0.091	-0.027	0.218
	P	0.650	0.689	1.000	0.790	0.937	0.519
Ball possession (sec)	Rho	-0.300	-0.373	-0.573	-0.582	0.655*	-0.627*
	P	0.370	0.259	0.066	0.060	0.029#	0.039#

TMA: target motion analysis.

*P≤0.05, significant correlations; **P≤0.01, significant correlations; #statistically significant.

SUPPLEMENTARY DIGITAL MATERIAL 3

Supplementary Table III.—Spearman's (Rho and significance values) correlations between TMA and technical and tactical indicators for defenders.

Indicators	Correlations	TD	Z2	Z3	Z4	MPErec	Burst
Played balls (N.)	Rho	0.350	0.150	0.183	0.133	0.317	-0.733*
	P	0.356	0.700	0.637	0.732	0.406	0.025#
Successful passes (N.)	Rho	-0.150	-0.267	-0.367	-0.350	0.367	-0.817**
	P	0.700	0.488	0.332	0.356	0.332	0.007#
Successful playing patterns (N.)	Rho	0.517	0.267	0.233	0.233	0.150	-0.500
	P	0.154	0.488	0.546	0.546	0.700	0.170
Lost balls (N.)	Rho	0.733*	0.500	0.600	0.600	0.033	-0.200
	P	0.025#	0.170	0.088	0.088	0.932	0.606
Fouls committed (N.)	Rho	-0.133	-0.183	-0.317	-0.100	0.350	-0.233
	P	0.732	0.637	0.406	0.798	0.356	0.546
Fouls received (N.)	Rho	0.217	0.000	0.000	-0.017	-0.133	-0.233
	P	0.576	1.000	1.000	0.966	0.732	0.546
Successful dribbling (N.)	Rho	0.831**	0.627	0.661	0.610	-0.034	-0.220
	P	0.006#	0.071	0.053	0.081	0.931	0.569
Total dribbling (N.)	Rho	0.862**	0.678*	0.686*	0.661	-0.033	-0.151
	P	0.003#	0.045#	0.041#	0.053	0.932	0.699
Successful/total dribbling (N.)	Rho	0.630	0.341	0.289	0.077	-0.060	-0.281
	P	0.069	0.370	0.450	0.845	0.879	0.464
Successful crosses (N.)	Rho	0.836**	0.679*	0.714*	0.531	0.165	-0.435
	P	0.005#	0.044#	0.031#	0.141	0.671	0.242
Total crosses (N.)	Rho	0.485	0.527	0.343	0.159	0.033	-0.243
	P	0.185	0.145	0.366	0.683	0.932	0.529
Successful/total crosses (N.)	Rho	0.621	0.456	0.511	0.201	-0.183	-0.128
	P	0.074	0.217	0.160	0.604	0.638	0.743
Successful assists (N.)	Rho	0.548	0.456	0.548	0.342	-0.068	0.068
	P	0.127	0.217	0.127	0.367	0.861	0.861
Total assists (N.)	Rho	0.683*	0.650	0.583	0.533	-0.183	-0.283
	P	0.042#	0.058	0.099	0.139	0.637	0.460
Successful/total assists (N.)	Rho	0.548	0.456	0.548	0.342	-0.068	0.068
	P	0.127	0.217	0.127	0.367	0.861	0.861
Shots towards goal (N.)	Rho	0.837**	0.611	0.644	0.469	0.092	-0.293
	P	0.005#	0.081	0.061	0.203	0.814	0.444
Total shots (N.)	Rho	0.837**	0.611	0.678*	0.552	0.209	-0.360
	P	0.005#	0.081	0.045#	0.123	0.589	0.342
Shots towards goal/total shots (N.)	Rho	0.378	0.042	0.101	-0.143	0.244	-0.395
	P	0.316	0.915	0.796	0.714	0.527	0.293
Ball possession (sec)	Rho	-0.300	-0.533	-0.617	-0.367	0.567	-0.650
	P	0.433	0.139	0.077	0.332	0.112	0.058

TMA: target motion analysis.

*P≤0.05, significant correlations; **P≤0.01, significant correlations; #statistically significant.