TESIS DE LA UNIVERSIDAD DE ZARAGOZA
2023
35

Alejandro García Giménez

# Análisis de las características antropométricas y del efecto agudo inducido por la práctica del pádel sobre marcadores hematológicos, urinarios y neuromusculares

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ISSN 2254-7606

Prensas de la Universidad
Universidad Zaragoza

ISSN 2254-7606

Universidad Zaragoza
1542

Tesis Doctoral

# ANÁLISIS DE LAS CARACTERÍSTICAS ANTROPOMÉTRICAS Y DEL EFECTO AGUDO INDUCIDO POR LA PRÁCTICA DEL PÁDEL SOBRE MARCADORES HEMATOLÓGICOS, URINARIOS Y NEUROMUSCULARES


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**UNIVERSIDAD DE ZARAGOZA**
**Escuela de Doctorado**


Programa de Doctorado en Ciencias de la Salud y del Deporte

2023

# Tesis Doctoral en modalidad por compendio de publicaciones

La Tesis Doctoral que se presenta titulada "ANÁLISIS DE LAS CARACTERÍSTICAS ANTROPOMÉTRICAS Y DEL EFECTO AGUDO INDUCIDO POR LA PRÁCTICA DEL PÁDEL SOBRE MARCADORES HEMATOLÓGICOS, URINARIOS Y NEUROMUSCULARES: DIFERENCIAS ENTRE GÉNEROS" se ajusta a la normativa vigente en la actualidad en la Universidad de Zaragoza, según Extracto del Acuerdo de 25/06/2020 del Consejo de Gobierno de la Universidad de Zaragoza por el que se aprueba el Reglamento sobre Tesis Doctorales (Título IV, Capítulo III), en cuanto a la modalidad denominada como compendio de publicaciones. La Tesis Doctoral cumple con los requisitos solicitados para las publicaciones en cuanto al lugar del doctorando en los artículos, el factor de impacto de la revista, y el tipo de indexación en el Journal Citation Report (JCR) de la Web of Science. Los estudios se han publicado en revistas relacionadas con las ciencias de la actividad física y la salud, centrándose en los perfiles temáticos de la antropometría y la alteración de marcadores hematológicos, urinarios y neuromusculares tras la práctica de un partido simulado de pádel. A continuación, se relacionan los cuatro artículos publicados que componen la presente Tesis Doctoral:

1. Pradas, F., González-Jurado, J. A., García-Giménez, A., Gallego Tobón, F., & Castellar, C. (2019). Anthropometric characteristics of elite paddle players. Pilot study. *Revista Internacional de Medicina y Ciencias de La Actividad Fisica y Del Deporte*, *19*(74), 181–195. https://doi.org/10.15366/rimcafd2019.74.001

2. Pradas, F., García-Giménez, A., Toro-Román, V., Sánchez-Alcaraz, B. J., Ochiana, N., & Castellar, C. (2020). Effect of a padel match on biochemical and haematological parameters in professional players with regard to gender-related differences. *Sustainability*, *12*(20), 8633. https://doi.org/10.3390/su12208633

3. Pradas, F., García-Giménez, A., Toro-Román, V., Ochiana, N., & Castellar, C. (2021). Gender differences in neuromuscular, haematological, and urinary responses during padel matches. *International Journal of Environmental Research and Public Health*, *18*(11), 5864. https://doi.org/10.3390/ijerph18115864

4. García-Giménez, A., Pradas, F., Castellar, C., & Carrasco, L. (2022). Performance Outcome Measures in Padel : A Scoping Review. *International Journal of Environmental Research and Public Health*, *19*, 4395. https://doi.org/10.3390/ijerph19074395

# Tesis Doctoral

# Análisis de las características antropométricas y del efecto agudo inducido por la práctica del pádel sobre marcadores hematológicos, urinarios y neuromusculares: diferencias entre géneros


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# Análisis de las características antropométricas y del efecto agudo inducido por la práctica del pádel sobre marcadores hematológicos, urinarios y neuromusculares: diferencias entre géneros

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Fdo. Francisco Pradas de la Fuente

En Huesca, a 19 de Julio de 2022

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Fdo. Germán Vicente Rodríguez

En Zaragoza, a 19 de Julio de 2022

# AGRADECIMIENTOS

En primer lugar, agradecer a mis directores, Fran, Carlos y Germán por todo el apoyo, seguimiento, paciencia y consejos, que sin duda me han ayudado en el desarrollo y elaboración de esta Tesis Doctoral durante estos años.

En segundo lugar, agradecer a mi familia; mi pareja Claudia, mis padres Felipe y Katy, y mi hermano Andrés por estar siempre echándome una mano cuando más me hace falta.

Por último, dedicar esta Tesis Doctoral a mi compañero de universidad Alejandro Larroya Pérez, que en paz descanse, con quien soñábamos llegar juntos a este momento. “Larry, va por ti.”

# CONTENIDO

# ÍNDICE DE FIGURAS

# ÍNDICE DE TABLAS

# ÍNDICE DE ABREVIATURAS

**ABK:** salto Abalakov

**CK:** creatinquinasa

**DOMS:** Delayed Onset Muscle Soreness

**FC:** frecuencia cardíaca

**$FC_{máx}$:** frecuencia cardíaca máxima

**$FC_{med}$:** frecuencia cardíaca media

**FEP:** Federación Española de Pádel

**FIL:** fuerza isométrica lumbar

**FIP:** Federación Internacional de Pádel

**FMIM:** fuerza máxima isométrica de la mano

**FRIM:** fuerza resistencia isométrica de la mano

**GOT:** transaminasa glutámico oxalacética

**GPT:** transaminasa glutámico pirúvica

**GREC:** Grupo Español de Cineantropometría

**IMC:** índice de masa corporal

**ISAK:** Sociedad Internacional para el Avance en Cineantropometría

**LA:** lactato

**LDH:** lactato deshidrogenasa

**LPM:** lanzamiento de pelota medicinal

**LPM-L:** lanzamiento de pelota medicinal lateral

**ppm:** pulsaciones por minuto

**PPT:** Pádel Pro Tour

**ROS:** especies reactivas de oxígeno

**SC:** salto con contramovimiento

**SV:** salto vertical

**$VO_{2máx}$:** consumo máximo de oxígeno

**VT:** umbral ventilatorio

**$VT_1$**: umbral ventilatorio 1

**$VT_2$:** umbral ventilatorio 2

**YOYO IR1:** test YOYO de recuperación intermitente 1

# 1. INTRODUCCIÓN

## 1.1. Historia del pádel

El pádel es un deporte de raqueta moderno que se juega por parejas y tiene su origen en Acapulco (Méjico) en el año 1962. Fue entonces cuando Enrique Corcuera incorporó al frontón de su casa una pared opuesta al mismo de unos tres metros de altura, colocando una red en el centro y cerrando los costados de la pista con cuatro medias paredes bajas. De esta manera, cuando la pelota de frontón pasaba la línea defensiva y rebotaba en el muro posterior, los jugadores esperaban el rebote para seguir jugando, originando así la nueva forma de juego (Federación Internacional de Pádel, 2022a).

En España, este deporte llegó de la mano del Príncipe Alfonso de Hohenlohe, quien construye en el año 1970, en el Hotel Marbella Club de su propiedad, dos pistas de pádel tras haber jugado varios veranos en Acapulco en casa de su amigo Enrique Corcuera (Federación Internacional de Pádel, 2022a).

Durante los años 80 y 90, estas pistas fueron la sede de los torneos "Pro-Am", donde las parejas estaban formadas por un jugador experto y una persona famosa, lo que provocó un gran interés mediático que contribuyó a la difusión de este nuevo deporte. Posteriormente, el Club Puerta de Hierro de Madrid construyó sus primeras cinco pistas, seguido de la urbanización de la Moraleja y su Golf Club, convirtiéndose estos últimos en un centro de juego de muy buen nivel (Federación Internacional de Pádel, 2022a).

Simultáneamente, el pádel llegó a Argentina en 1969 de la mano de turistas argentinos que conocieron y practicaron esta disciplina en Marbella. Las primeras pistas se construyeron en el Club Tortugas y en el Ocean Club de Mar del Plata. En el año 1983, el deporte también desembarcó en Uruguay en el Balneario Zorba de Punta del Este, siendo una atracción deportiva para los veraneantes (Federación Internacional de Pádel, 2022a).

Con el paso de los años, el deporte del pádel atrajo en Argentina cada vez más adeptos, importantes empresarios y deportistas que lo promovieron, realizándose los primeros eventos en los que se contaba con grandes patrocinadores y cobertura en los medios de comunicación. Posteriormente, en los años 80 se inauguraron pistas de pádel en las principales ciudades de la provincia de Buenos Aires y en todo el litoral atlántico. En 1991, el pádel llegó a ser considerado el segundo deporte más practicado en Argentina después del fútbol (Federación Internacional de Pádel, 2022a).

Fue en el año 1988 cuando se fundó la Asociación Paddle Argentino (APA) con el fin de regularizar el "paddle" argentino a nivel nacional y como referencia internacional. Cinco

años más tarde, el 12 de julio de 1991, se fundó en Madrid la Federación Internacional de Pádel (FIP), de la mano de las Federaciones Nacionales de Argentina, España y Uruguay (Federación Internacional de Pádel, 2022b). A día de hoy, la FIP cuenta con 51 federaciones nacionales, más de 300.000 jugadores federados y 18 millones de jugadores activos distribuidos en 90 países (Federación Internacional de Pádel, 2022b).

Cabe resaltar en España la organización del primer Campeonato Mundial de pádel en 1992, cuya edición tuvo lugar en las ciudades de Madrid y Sevilla. Desde entonces, este evento se ha mantenido celebrándose cada dos años en: Mendoza (Argentina, 1994), Madrid (España, 1996), Mar del Plata (Argentina, 1998), Ciudad de México (México, 2002), Gran Buenos Aires (Argentina, 2004), Murcia (España, 2006), Calgary (Canadá, 2008), Riviera Maya mexicana (México, 2010), Cancún (México, 2012), Mallorca (España, 2014), Cascais (Portugal, 2016), Asunción (Paraguay, 2018) y Doha (Qatar, 2021) (Federación Internacional de Pádel, 2022a).

Actualmente, existen jugadores y jugadoras profesionales de pádel que compiten en una red completa de torneos internacionales a nivel mundial, bajo la denominación "FIP Tour" y celebrados en España, Portugal, Méjico, Argentina, Qatar, Italia, Emiratos Árabes Unidos, Estados Unidos, Suecia, Alemania, Ecuador, Uruguay, Holanda, Paraguay, Lituania, Chile, Irlanda, Japón, Dinamarca y Francia (Federación Internacional de Pádel, 2022c). Dentro de esta red de torneos, se incluyó en 2013 el circuito profesional World Pádel Tour (WPT), hasta entonces denominado Pádel Pro Tour (PPT), dentro del calendario oficial de la FIP (Federación Internacional de Pádel, 2022a).

En España, el pádel se ha convertido en una modalidad deportiva muy popular con más de 4 millones de practicantes regulares, ubicándose este deporte entre los 10 más practicados del país (Courel-Ibañez et al., 2017). A nivel federativo, el número de licencias nacionales en el año 2021 fue de 92.872, un 66,07 % mayor que hace cinco años, según datos de la Federación Española de Pádel (FEP) (Figura 1). La distribución de licencias entre géneros en el año 2021 fue favorable para las licencias masculinas, siendo un 64,6 % frente a un 35,4 % de licencias femeninas (Federación Española de Pádel, n.d.).

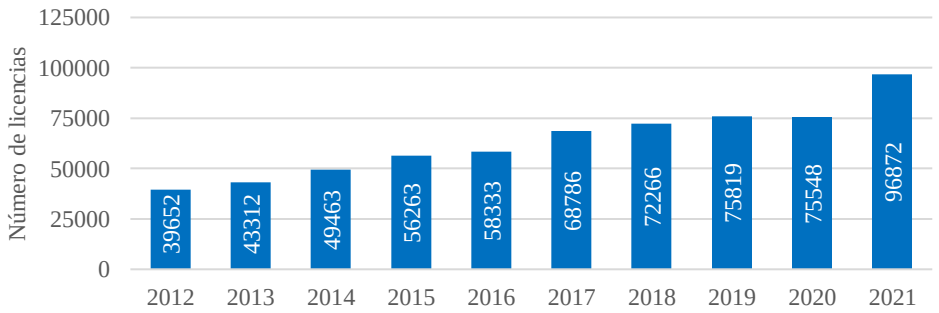


Figura 1. Evolución de licencias nacionales. Datos extraídos la FEP (Federación Española de Pádel, n.d.)

## 1.2. Reglamento del juego del pádel

En el pádel, dos parejas se enfrentan entre ellas siguiendo las reglas y sistema de puntuación del tenis, con la diferencia de que se juega en una pista cerrada por paredes de cristal sintético y metal, donde la pelota puede rebotar en los laterales y el fondo durante los puntos. Las medidas de la pista son de 20 m de largo por 10 m de ancho (medidas interiores), con una tolerancia de 0,5 % (Figura 2). La pista de pádel se encuentra dividida por la mitad con una red de tenis (0,88 m en el centro y 0,92 m en los laterales) (Figura 3). Cada mitad de la pista está formada por dos áreas de servicio, definidas por la línea de servicio, la cual es paralela y dista 6,95 m con respecto a la red, y por una línea perpendicular que divide en dos las líneas de servicio y de la red llamada línea central de saque (Federación Internacional de Pádel, 2021).

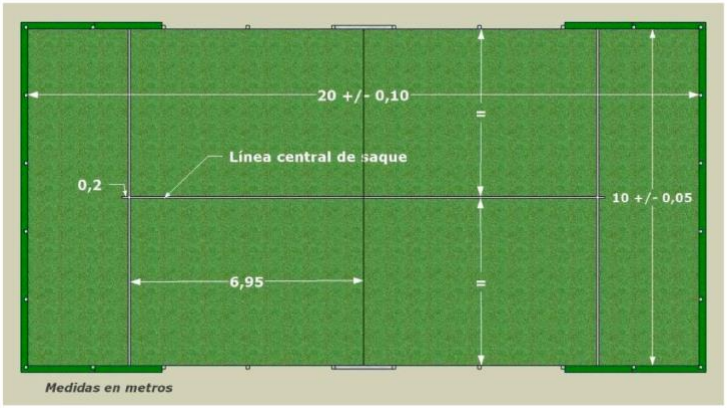


Figura 2. Dimensiones de la pista de pádel (Federación Internacional de Pádel, 2021)


Figura 3. Dimensiones de la red de pádel (Federación Internacional de Pádel, 2021)

La altura mínima libre debe ser de 6 m en toda la superficie de la pista, sin que exista ningún elemento que invada dicho espacio. Por su parte, la altura total del cerramiento es de 4 m, compuesto los tres primeros metros por la pared de fondo y un último metro de malla metálica. Las paredes laterales miden 3x2 m (alto por ancho) acabando en otra pared de 2x2 m (alto por ancho) (Figura 4). El resto de la pista consiste en dos paneles metálicos de igual medida (3x2,59 m) y una puerta de 2x0,82 m (Federación Internacional de Pádel, 2021).

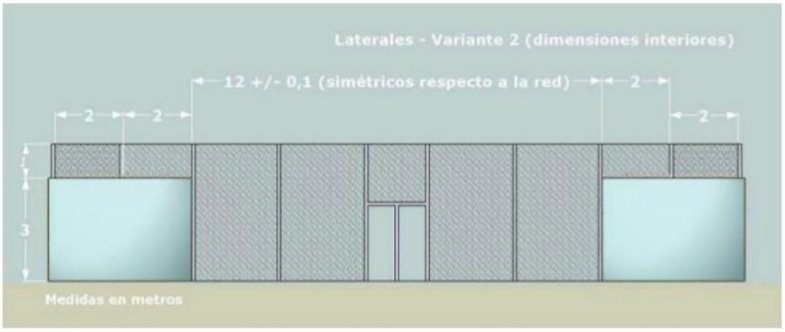


Figura 4. Dimensiones de los cerramientos laterales de la pista de pádel (Federación Internacional de Pádel, 2021)

Estas características de la pista y la posibilidad de jugar con los cerramientos de la misma, ya sea con la pared de fondo, lateral o ambas a la vez, permite que durante el transcurso de un partido la pelota se pueda devolver de tres formas diferentes (Pradas et al., 2014):

1. De forma directa: golpeando la pelota directamente hacia el campo contrario sin dejarla botar o tras un bote sobre la pista.
2. De forma directa: golpeando la pelota tras rebotar sobre alguna de las paredes. Una vez que la pelota bota sobre la pista, el jugador permite que rebote sobre la pared de fondo, la pared lateral o ambas, y posteriormente realiza el golpeo directo hacia el campo contrario sin utilizar el rebote en ninguna de las paredes para ello.
3. De forma indirecta: golpeando la pelota contra la pared de fondo, pared lateral o ambas paredes para enviarla directamente al campo contrario. En esta ocasión, la pelota debe haber rebotado previamente bien sobre el suelo, o bien sobre el suelo junto al posterior rebote en la pared de fondo, lateral o ambas.

Esta dinámica tan particular del juego del pádel, permite que los puntos sean más largos y que el número de acciones y de golpeos realizados por cada jugador sean mayores en comparación con otros deportes de raqueta como el bádminton, tenis o squash (Courel-Ibáñez et al., 2017).

# 2. REVISIÓN BIBLIOGRÁFICA

## 2.1. Producción científica en el deporte del pádel

Al realizar un análisis pormenorizado de la producción científica existente relacionada con el deporte del pádel, se puede apreciar cómo desde la primera publicación que se tiene constancia en 1995 y hasta el año 2021 se ha incrementado de manera considerable el número de publicaciones relacionadas con este deporte (Figura 5). Consultando las bases de datos PubMed, SPORTDiscus y Scopus, con fecha límite hasta el 31 de diciembre de 2021, se pone de manifiesto que las publicaciones que contenían en su título o resumen las palabras clave "padel" o "paddle tennis" (Figura 5), han aumentado gradualmente en la última década, alcanzando unos valores porcentuales próximos al 99 % del total de artículos publicados en este deporte, ya sea en lengua inglesa o castellana. Este dato muestra el importante interés demostrado por los investigadores, en especial en los últimos diez años, por estudiar y publicar datos científicos relacionados con el deporte del pádel.

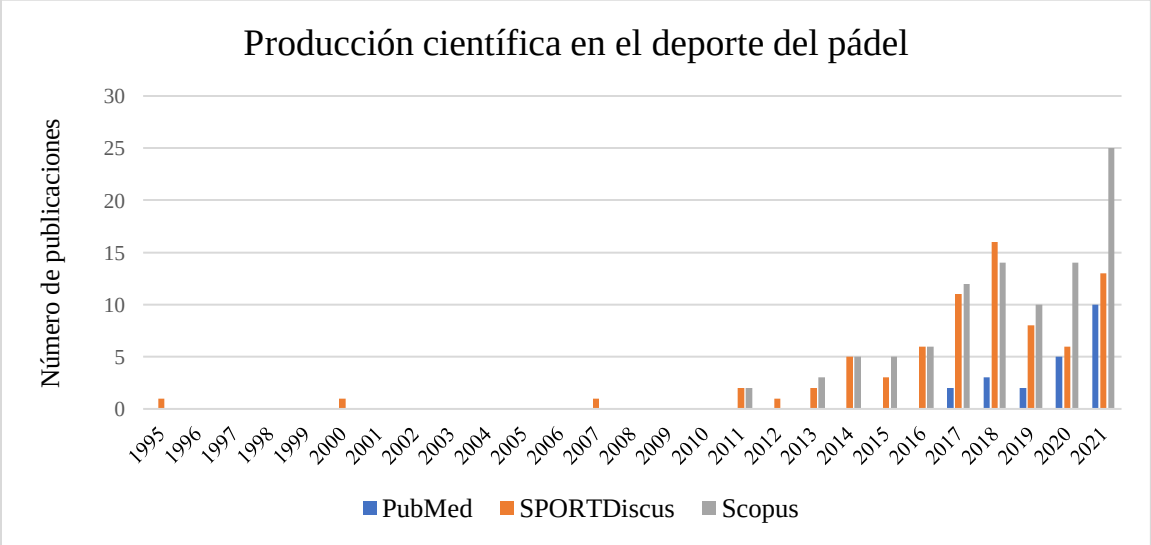


Figura 5. Publicaciones científicas en PubMed, SPORTDiscus y Scopus.

Las dos primeras referencias encontradas en la literatura científica que hacen mención al deporte del pádel datan de los años 1995 (Goldfine, 1995) y 2000 (Hynes-Dusel, 2000). Sin embargo, estas publicaciones realmente no tratan sobre el pádel que conocemos hoy en día, sino que presentan una versión reducida del tenis a modo de juego, para que los alumnos pueden aprender las destrezas básicas del tenis en menos tiempo, utilizando palas de madera y pelotas de tenis (Figura 6). No es hasta el año 2007 cuando Carrasco et al. (2007), realizaron la primera publicación relativa al pádel actual, analizando sus exigencias fisiológicas y estructurales. Desde entonces y hasta la actualidad, se puede observar un aumento exponencial de la producción científica, en donde se analiza e investiga desde diferentes ámbitos a este deporte (Figura 5).


Figura 6. Representación gráfica de la pala de pádel presentada en la publicación de Bernie Goldfine de 1995 (Goldfine, 1995)

Observando el objeto de estudio de las publicaciones sobre pádel hasta el momento, se aprecia que predominan aquellas cuya intención es la de analizar la estructura y dinámica de juego de los partidos con un 52 % del total (Figura 7). Estas publicaciones comprenden el análisis de los patrones de juego, variables temporales, variables situacionales, indicadores de rendimiento, acciones de juego, formaciones tácticas, efectividad y mano dominante de los jugadores. En segundo lugar, el estudio de la fisiología y del rendimiento físico de los jugadores supone un 26 % del total de las publicaciones. En estos artículos, el objeto de estudio es el impacto fisiológico que supone el pádel para los jugadores, analizándose la frecuencia cardíaca (FC), el consumo máximo de oxígeno ($VO_{2máx}$), parámetros condicionales asociados al rendimiento físico como la fuerza neuromuscular, velocidad y agilidad, así como la fatiga mental. En tercer lugar, la epidemiología de lesiones asociada al pádel comprende un 11 % de los estudios publicados. Los artículos acerca del perfil antropométrico de los jugadores suponen el 5 % del total. Por último, aspectos relacionados con la biomecánica del jugador de pádel, es el objeto de estudio que menor interés ha causado entre los autores con un 3 % de las publicaciones centradas sobre este tema. Cabe mencionar también que un 3 % de los artículos publicados tratan tanto el perfil antropométrico de los jugadores como la fisiología y el rendimiento físico.

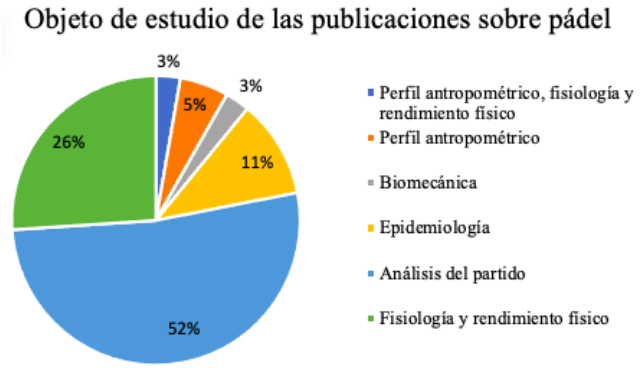


Figura 7. Objeto de estudio de las publicaciones sobre pádel en PubMed, SPORTDiscus y Scopus (García-Giménez et al., 2022)

## 2.2. Antropometría y somatotipo

Los jugadores de pádel de alto nivel, tanto hombres como mujeres, presentan un perfil antropométrico de tipo meso-endomorfo (Castillo-Rodríguez, Hernández-Mendo, et al., 2014; Martínez-Rodríguez et al., 2015; Pradas et al., 2014, 2019; Sánchez-Muñoz et al., 2020), mientras que a nivel aficionado en ambos sexos es predominantemente endomorfo (Muñoz et al., 2020). Estas diferencias antropométricas entre diferentes niveles de juego pueden ser debidas a la mayor cantidad de horas de entrenamiento y competición de los jugadores nacionales e internacionales (Tabla 1 y 2).

Al comparar el biotipo existente en deportistas de alto nivel de hombres y mujeres, se aprecia que los jugadores presentan mayores valores de masa, altura e índice de masa corporal (IMC), y menor porcentaje de grasa que las jugadoras (Castillo-Rodríguez, Hernández-Mendo, et al., 2014). Sin embargo, en un estudio realizado por Martínez-Rodríguez et al. (2015), se informó de mayores porcentajes grasos en hombres de nivel universitarios que en mujeres de élite (Pradas et al., 2014).

## 2.3. Fisiología: consumo máximo de oxígeno, umbrales ventilatorios, frecuencia cardíaca y lactato

Los tests de laboratorio muestran un $VO_{2máx}$ que oscila entre 38,4±0,7 $ml \cdot kg^{-1} \cdot min^{-1}$ y 55,64±8,84 $ml \cdot kg^{-1} \cdot min^{-1}$ dependiendo del sexo y nivel de los deportistas (Tabla 3). Además, los umbrales ventilatorios 1 ($VT_1$) y 2 ($VT_2$), se sitúan respectivamente entre el 72 % y el 84-85 % del $VO_{2máx}$ (Carrasco et al., 2011; De Hoyo et al., 2007; Díaz-García et al., 2017). Durante los partidos, Carrasco et al. (2011) y De Hoyo et al. (2007) encontraron valores de consumo de oxígeno por debajo del 50 % del $VO_{2máx}$.

La frecuencia cardíaca máxima ($FC_{máx}$) y frecuencia cardíaca media ($FC_{med}$), siguen un patrón similar tanto en jugadores de alto nivel como en jugadores aficionados, donde varios autores han reportado valores entre 154-179 pulsaciones por minuto (ppm) para los primeros y de entre 130-151 ppm para los segundos (Tabla 4). Al comparar estos valores con la FC absoluta, los máximos se corresponden con un 80-85 % de la $FC_{máx}$ y la $FC_{med}$ con un 68-74 % de la $FC_{máx}$. Díaz-García et al. (2017), observaron que los jugadores aficionados permanecían el 97,75 % del tiempo por debajo del umbral aeróbico y el 2,25 % entre el $VT_1$ y el $VT_2$, lo que confirma, a nivel cardiovascular, que el pádel a nivel aficionado se basa principalmente en esfuerzos aeróbicos.

Tabla 1. Valores de edad, masa, altura, IMC, porcentaje de grasa corporal y somatotipo de jugadores de pádel en función de su nivel

| Estudio | n | Nivel | Volumen de entrenamiento (h·semana$^{-1}$) | Masa (kg) | Altura (cm) | IMC (kg·m$^{-2}$) | Masa grasa (%) | Endomorfía | Mesomorfía | Ectomorfía |
|---|---|---|---|---|---|---|---|---|---|---|
| Castillo-Rodríguez et al. (2014) | 36 | Nacional | # | 78,52±8,65 | 177,4±6,44 | 24,94±2,48 | # | 3,55±1,1 | 6,93±1,3 | 1,89±1,0 |
| Martínez-Rodríguez et al. (2015) | 21 | Universitario | # | 74,3±8,6 | 180±10 | 23,6±2,1 | 18,3±6,2 | 3,7±1,2 | 4,1±0,9 | 2,4±0,8 |
| Muñoz et al. (2020) | 20 | Regional (1ª División) | >10 | 78,35±6,82 | 181,69±0,05 | 23,78±2,44 | 11,98±2,27 | 3,92±1,12 | 4,41±1,29 | 2,58±1,20 |
| | 20 | Regional (3ª División) | *ns* | 82,37±9,42 | 178,83±0,05 | 25,72±2,25 | 14,86±3,20 | 5,03±1,42 | 4,98±1,49 | 1,65±0,78 |
| Sánchez-Muñoz et al. (2020) | 25 | WPT (élite) | 11,4±7,8 | 77,2±9,9 | 177,7±7,3 | 24,4±2,5 | 11,9±4,1 | 3,7±1,3 | 5,7±1,2 | 2,0±1,1 |
| | 35 | WPT (sub-élite) | 5,8±5,2 | 77,6±10,2 | 178,3±7,7 | 24,4±2,3 | 14,6±5,4 | 4,3±1,5 | 5,3±0,9 | 2,1±1,1 |

# Datos no disponibles; *ns*: entrenamiento no sistemático

Tabla 2. Valores de edad, masa, altura, IMC, porcentaje de grasa corporal y somatotipo de jugadoras de pádel en función de su nivel

| Estudio | n | Nivel | Volumen de entrenamiento (h·semana$^{-1}$) | Masa (kg) | Altura (cm) | IMC (kg·m$^{-2}$) | Masa grasa (%) | Endomorfía | Mesomorfía | Ectomorfía |
|---|---|---|---|---|---|---|---|---|---|---|
| Castillo-Rodríguez et al. (2014) | 12 | Nacional | # | 59,02±6,72 | 167,6±6,52 | 21,03±2,13 | # | 4,11±0,8 | 5,36±1,2 | 2,99±1,2 |
| Pradas et al. (2014) | 6 | WPT | 15,5±3,6 | 62,9±2,02 | 169,3±3,6 | 21,98±1,1 | 17,3±1,4 | 3,7±0,5 | 4,2±0,6 | 2,5±0,7 |

# Datos no disponibles

Tabla 3. $VO_{2máx}$ y umbrales ventilatorios analizados mediante test de laboratorio en jugadores de pádel

| Autores | Muestra | Nivel | $VO_{2máx}$ ($ml \cdot kg^{-1} \cdot min^{-1}$) | Umbral anaeróbico (%$VO_{2máx}$) | Umbral aeróbico (%$VO_{2max}$) |
|---|---|---|---|---|---|
| Carrasco et al. (2011) | 12 Hombres | Élite | 55,64±8,84 | 84 | # |
| Hoyo et al. (2007) | 12 Hombres | Élite | 55,64±8,84 | 84 | # |
| Díaz-García et al. (2017) | 8 Hombres | Aficionado | 51,15±5,73 | 85,41±4,38 | 72,51±5,57 |
| Borges & Boscolo (2018) | 21 Hombres | Alto, medio y bajo | 40,0±1,3 | # | # |
| | 14 Mujeres | Alto y medio | 38,4±0,7 | # | # |
| Pradas et al. (2014) | 6 Mujeres | Élite | 47,33±4,57 | # | # |

# Datos no disponibles

Tabla 4. Frecuencia cardíaca máxima y media durante partidos de pádel

| Autores | Muestra | Nivel | $FC_{máx}$ (ppm) | $FC_{med}$ (ppm) |
|---|---|---|---|---|
| Amieba & Salinero (2013) | 8 Hombres | Aficionado | 176±9,20 | 136±9,04 |
| Carbonell et al. (2017) | 9 Hombres | Aficionado | 179±9,4 | 150±8,6 |
| Carrasco et al. (2011) | 12 Hombres | Élite | 169,72±18,41 | 148,30±13,63 |
| Hoyo et al. (2007) | 12 Hombres | Élite | 169,72±18,41 | 148,30±13,63 |
| Díaz-García et al. (2017) | 8 Hombres | Aficionado | 154,75±7,25 | 130,8±10,4 |
| Pradas et al. (2014) | 6 Mujeres | Élite | 177±9,2 | 151±8,1 |
| Sánchez-Alcaraz (2014) | 16 Hombres | Medio | 175,24±16,54 | 141,23±10,89 |

# Datos no disponibles

La concentración de LA parece seguir un patrón similar durante los partidos, comenzando con valores por debajo del $VT_1$ (1,83-1,90 $mmol \cdot l^{-1}$) y alcanzando valores entre el $VT_1$ y $VT_2$ (2,40-3,38 $mmol \cdot l^{-1}$) (Amieba & Salinero, 2013; Castillo-Rodríguez, Hernández-Mendo, et al., 2014; Pradas, Cachón et al., 2014). Por el contrario, la percepción subjetiva del esfuerzo es similar ($p < 0,05$) tanto después del primer set como al finalizar el partido (Amieba & Salinero, 2013).

Al comparar diferentes niveles de juego, Castillo-Rodríguez, Hernández-Mendo, et al. (2014), encontraron una respuesta cardiovascular significativamente menor ($p < 0,05$) en jugadores de alto nivel frente a jugadores de medio y bajo nivel. Los datos mostraron un mayor tiempo entre el 50-70 % de la $FC_{máx}$ (43,7 % vs. 15,2 %), menor tiempo entre el 80-90 % de la $FC_{máx}$ (12,9 % vs. 32,8-30,4 %), y una menor percepción subjetiva del esfuerzo, sugiriendo una mejor forma cardiovascular en los mejores niveles de juego. Del mismo modo, aunque sin ser estadísticamente significativo, los valores máximos de LA fueron menores en jugadores de alto nivel (2,87 $mmol \cdot l^{-1}$) frente a los de nivel medio (2,74 $mmol \cdot l^{-1}$) y bajo (3,38 $mmol \cdot l^{-1}$).

## 2.4. Rendimiento físico

Varias investigaciones han analizado el rendimiento físico en el pádel mediante diversas pruebas (Tabla 5). Se han encontrado diferencias significativas ($p < 0,05$) entre géneros en cuanto a distancia recorrida durante el test YOYO de recuperación intermitente 1 (YOYO IR1), salto vertical (SV), lanzamiento de pelota medicinal (LPM), fuerza máxima isométrica de la mano (FMIM), fuerza resistencia isométrica de la mano (FRIM) y sprint de 10 m y de 20 m (Borges & Boscolo, 2018; Sánchez-Alcaraz et al., 2018).

Tabla 5. Datos de diferentes tests físicos en jugadores de pádel

| Test | Autores | Muestra | Nivel | Valor |
|---|---|---|---|---|
| LPM | Borges & Boscolo (2018) | 7 Hombres | Alto | 4,1±0,8 m |
| | | 7 Hombres | Medio | 4,6±0,4 m |
| | | 7 Hombres | Bajo | 4,8±1,1 m |
| | | 6 Mujeres | Alto | 3,0±0,3 m |
| | | 8 Mujeres | Medio | 2,7±0,2 m |
| | Sánchez-Alcaraz et al. (2018) | 8 Hombres | Alto | 6,25±9,7 m |
| | | 9 Mujeres | Alto | 4,23±6,7 m |
| S-MBT de derecha | Courel-Ibáñez & Herrera-Gálvez (2020) | 9 Hombres | Alto | 9,5±2,1 m |
| | | 9 Hombres | Bajo | 9,6±2,1 m |
| S-MBT de revés | | 9 Hombres | Alto | 9,1±2,0 m |
| | | 9 Hombres | Bajo | 9,7±2,0 m |
| FMIM | Borges & Boscolo (2018) | 7 Hombres | Alto | 46,3±11,7 kg |
| | | 7 Hombres | Medio | 51,6±5,4 kg |
| | | 7 Hombres | Bajo | 49,0±6,0 kg |
| | | 6 Mujeres | Alto | 30,3±2,7 kg |
| | | 8 Mujeres | Medio | 29,6±4,3 kg |
| | Courel-Ibáñez & Herrera-Gálvez (2020) | 9 Hombres | Alto | 47,5±10,0 kg |
| | | 9 Hombres | Bajo | 47,3±10,0 kg |
| | Sánchez-Muñoz et al. (2020) | 25 Hombres | Élite | 51,3±12,5 kg |
| | | 35 Hombres | Sub-élite | 48,1±7,1 kg |
| FRIM | Borges & Boscolo (2018) | 7 Hombres | Alto | 31,7±13,1 kg |
| | | 7 Hombres | Medio | 36,1±11,7 kg |
| | | 7 Hombres | Bajo | 38,5±7,9 kg |
| | | 6 Mujeres | Alto | 24,3±4,6 kg |
| | | 8 Mujeres | Medio | 33,1±5,7 kg |
| FIL | Sánchez-Muñoz et al. (2020) | 25 Hombres | Élite | 147,0±43,5 kg |
| | | 35 Hombres | Sub-élite | 126,9±30,4 kg |
| SV | Borges & Boscolo (2018) | 7 Hombres | Alto | 33,6±4,8 cm |
| | | 7 Hombres | Medio | 36,2±3,2 cm |
| | | 7 Hombres | Bajo | 34,0±5,9 cm |
| | | 6 Mujeres | Alto | 28,4±5,3 cm |
| | | 8 Mujeres | Medio | 20,5±4,6 cm |
| SC | Sánchez-Muñoz et al. (2020) | 25 Hombres | Élite | 44,6±5,3 cm |
| | | 35 Hombres | Sub-élite | 42,3±6,2 cm |
| YOYO IR1 | Borges & Boscolo (2018) | 7 Hombres | Alto | 308,0±82,0 m |
| | | 7 Hombres | Medio | 480,0±128,0 m |
| | | 7 Hombres | Bajo | 485,0±178,0 m |
| | | 6 Mujeres | Alto | 293,0±54,0 m |
| | | 8 Mujeres | Medio | 190,0±66,0 m |
| | Courel-Ibáñez & Herrera-Gálvez (2020) | 9 Hombres | Alto | 890,0±299,9 m |
| | | 9 Hombres | Bajo | 960,0±299,9 m |
| 10m Sprint | Sánchez-Alcaraz et al. (2018) | 8 Hombres | Alto | 2,56±0,26 s |
| | | 9 Mujeres | Alto | 2,84±0,17 s |
| 20m Sprint | | 8 Hombres | Alto | 3,87±0,30 s |
| | | 9 Mujeres | Alto | 4,29±0,37 s |

LPM: lanzamiento de pelota medicinal; LPM-L: lanzamiento de pelota medicinal lateral; FMIM: fuerza máxima isométrica de la mano; FRIM: fuerza resistencia isométrica de la mano; FIL: fuerza isométrica lumbar; SV: salto vertical; SC: salto con contramovimiento; YOYO IR1: test YOYO de resistencia intermitente 1

Comparando diferentes niveles de juego, Borges & Boscolo (2018), observaron en jugadores aficionados una menor FC después del test YOYO IR1 con respecto a jugadores de mayor nivel, tanto en hombres como en mujeres ($p < 0,05$), pudiendo reflejar un mejor estado de forma cardiovascular de aquellos de menor nivel. En el mismo estudio, los valores hallados en hombres de mayor nivel fueron también menores en los tests LPM y FMIM que en jugadores de niveles medio y bajo. Los autores argumentaron que tales diferencias podían deberse a las mejores facultades técnico-tácticas de los jugadores de mayor nivel para compensar sus limitaciones físicas. Al contrario sucede en el género femenino, ya que las mujeres de mejor nivel cubrieron más distancia durante el test YOYO IR1 y saltaron más alto en el SV que las de nivel medio ($p < 0,05$) mostrando, de esta forma, una mejor condición cardiovascular y fuerza del tren inferior (Borges & Boscolo, 2018). Por otro lado, Courel-Ibáñez & Herrera-Gálvez (2020) observaron en jugadores de alto nivel una mejor precisión de golpeo ($p < 0,05$) y recuperación tras 60 s ($p < 0,05$) que en aquellos de nivel bajo. En cambio, los de alto nivel reportaron peores valores de equilibrio anterior y posteromedial ($p < 0,05$), sugiriendo un mayor riesgo potencial de lesiones. Continuando con la comparación entre niveles de juego, Sánchez-Muñoz et al. (2020) encontraron en su estudio mejores valores de FIL ($p < 0,05$) en jugadores élite frente a jugadores sub-élite.

Finalmente, en relación con la práctica del pádel y su influencia sobre la salud, Courel-Ibáñez et al. (2018), reportaron un mayor estado de forma en mujeres adultas que lo practicaban (35-55 años), con respecto a un grupo de control sedentario. Aquellas que jugaban a pádel de forma regular obtuvieron mejores valores de resistencia abdominal, SV, equilibrio monopodal y estado de forma cardiovascular ($p < 0,001$).

### 2.5. Bioquímica

Los antecedentes del estudio de la bioquímica en pádel se reducen a la publicación de Bartolomé et al. (2016), quienes valoraron, en jugadores de alto nivel, la respuesta de siete oligoelementos en un partido de competición. Los resultados obtenidos indicaron un incremento significativo ($p < 0,05$) en los valores urinarios de Cu, Ni y Zn. Los autores argumentaron que estos cambios podrían haber sido provocados por el aumento de las exigencias energéticas y de antioxidantes, consecuencia del catabolismo producido tras un esfuerzo agudo que involucra impactos mecánicos frecuentes, como saltos, giros y acciones explosivas. Por el contrario, encontraron una disminución ($p < 0,05$) en el valor de Li en la orina, lo que podría indicar un proceso biológico del organismo para evitar su pérdida durante el esfuerzo físico, y así asegurar el óptimo desarrollo de los procesos hormonales, metabólicos, neurológicos e inmunológicos en los que se ve involucrado.

### 2.6. Biomecánica

Granda-Vera et al. (2019) analizaron la existencia, o no, de señales visuales (también llamadas pre-señales), en golpeos de derecha desde el fondo de la pista después de que la pelota rebote en la pared. Para ello hicieron un análisis cinemático en una muestra de jugadores de pádel de nivel nacional e internacional. Tras realizar el análisis observaron, en los jugadores diestros, que la altura de la mano ($r = 0,896$; $p < 0,001$) y la

posición del talón izquierdo ($r = 0,777$; $p < 0,001$), al comienzo y al final de sus respectivos movimientos, estaban fuertemente relacionados con la dirección de la pelota hacia el campo contrario. Es decir, cuanto mayor era la altura de la mano que ejecutaba el golpeo (derecha), y más abierta la posición del talón contrario (izquierdo), los golpeos se dirigían hacia el lado izquierdo de la pista y viceversa. Estos resultados podrían ser de gran utilidad para mejorar la anticipación perceptiva de los jugadores, tanto a nivel aficionado como en la élite.

El rol del complejo pie-tobillo fue valorada en el estudio de Priego-Quesada et al. (2014), con el fin de prevenir lesiones causadas por los gestos específicos del pádel. Los autores observaron que la zona del antepié es la que sufre mayor estrés durante los desplazamientos laterales, los movimientos hacia delante, el *split-step* y en los giros de pivote, lo que podría derivar en una sobrecarga plantar y provocar lesiones relacionadas con el pie, como sesamoiditis, fascitis plantar o fracturas por estrés. Considerando los resultados obtenidos en esta investigación, se resalta la importancia de llevar un calzado específico adecuado de pádel, la necesidad de realizar entrenamientos del denominado *foot core*, y un adecuado trabajo de movilidad de la articulación del tobillo y propiocepción del conjunto pie-tobillo.

### 2.7. Epidemiología de lesiones

En la investigación epidemiológica de García–Fernández et al. (2019), se observó en el pádel una ratio de 2,75 lesiones por cada 1.000 horas de juego, ocurriendo el cuadro lesional con más frecuencia hacia el final del partido (42 %) o del entrenamiento. Priego-Quesada et al. (2018), hallaron en jugadores aficionados que el 40 % se lesionaban al menos una vez al año. Por otro lado, Sánchez Alcaraz et al. (2019), informaron de una incidencia de lesiones mayor en jugadores no profesionales, de los cuales el 71,26 % se lesionaban al menos una vez al año.

Respecto a la tipología de las lesiones, las tendinosas suelen ser las más frecuentes, seguidas de las musculares y ligamentosas o articulares (García–Fernández et al., 2019; Priego-Quesada et al., 2018). Respecto a su severidad, las leves están más relacionadas con lesiones músculo-tendinosas en el tren superior ($p < 0,05$), mientras que las moderadas se relacionan con las de tipo ligamentoso en el tren inferior ($p < 0,05$) (García–Fernández et al., 2019). Además, la mayoría de las lesiones se producen sin contacto (68 %), siendo la sobrecarga muscular el motivo más habitual (García–Fernández et al., 2019).

En cuanto a la ubicación de las lesiones, el tren inferior parece ser el área más comúnmente afectado entre los jugadores de pádel (Priego-Quesada et al., 2018; Sánchez-Alcaraz et al., 2019), habiéndose encontrado una estrecha relación entre sobrecargas musculares ($p < 0,001$) y lesiones recurrentes ($p < 0,05$) (García–Fernández et al., 2019). Otras áreas de lesión frecuentes en este deporte son las de la zona lumbar, rodilla, hombro, isquiosurales, gastrocnemios, sóleos y fascia plantar (Tabla 6) (Castillo-Lozano, 2017; Castillo-Lozano & Casuso-Holgado, 2015, 2017; García–Fernández et al., 2019; Priego-Quesada et al., 2018).

Tabla 6. Incidencia y ubicación lesional en jugadores de pádel

| Ubicación de la lesión | Indicencia (%) | | | | |
|---|---|---|---|---|---|
| | Castillo-Lozano & Casuso-Holgado (2015) | | Castillo-Lozano (2017) | Castillo-Lozano & Casuso-Holgado (2017) | García–Fernández et al. (2019) |
| | Seniors | Juniors | | | |
| Hombro | 86,7 | 60,0 | 20,6 | 13,1 | 8,4 |
| Codo | 10,0 | 6,7 | 29,8 | 74,4 | 20,5 |
| Muñeca | 36,7 | 10,0 | 2,7 | 5,2 | 4,8 |
| Cuello | # | 6,7 | 7,6 | 5,3 | 8,4 |
| Zona lumbar | 13,3 | 23,3 | 27,5 | 20,2 | 9 |
| Tobillo | 6,7 | 6,7 | 9,8 | 7,9 | 7,8 |
| Gastrocnemios / Sóleo | 10,0 | # | # | 13,8 | 8,4 |
| Isquiosurales | 13,3 | # | 7,4 | 12,5 | 1,8 |
| Rodilla | 20,0 | 10,0 | 22,9 | 15,1 | 10,8 |
| Fascia plantar | 3,3 | 10,0 | 3,8 | 7,1 | 11,4 |

# Datos no disponibles

Diversos autores han observado que la edad, IMC y lateralidad ($p < 0,05$), son aspectos determinantes en la incidencia de lesión y que podrían explicar entre el 7,5 % y el 68,5 % de las lesiones producidas en este deporte (Castillo-Lozano, 2017; Castillo-Lozano & Casuso-Holgado, 2015, 2017). Estos resultados son similares a los expuestos por García–Fernández et al. (2019), quienes demostraron una mayor ratio de lesión en relación a la edad ($p < 0,05$) y al aumento de IMC ($p < 0,01$). De hecho, los mismos autores indicaron que la edad también parece estar relacionada con la tipología e incidencia de las lesiones (García–Fernández et al., 2019). Por su parte, Sánchez Alcaraz et al. (2019), encontraron una mayor ratio de lesiones musculares en jugadores mayores de 35 años (23,2 %) y de lesiones tendinosas en aquellos menores de 35 años (17,2 %) ($p < 0,01$).

El nivel de juego y el sexo también parece tener influencia sobre las lesiones. Se ha encontrado un mayor número de lesiones en jugadores de menor nivel, especialmente en tendones y hombros ($p < 0,05$) (Sánchez Alcaraz et al., 2019). En la investigación de García–Fernández et al. (2019), se encontraron diferencias significativas ($p < 0,05$) entre el nivel de los jugadores y el tipo de lesión. Los jugadores aficionados sufrieron más frecuentemente tendinopatías y fascitis plantar, mientras que en los profesionales se mostraron más lesiones por sobrecarga. Al evaluar la posible influencia del género respecto a las lesiones, Castillo-Lozano & Casuso-Holgado (2017) observaron una mayor incidencia de lesiones en las mujeres ($p < 0,01$), y en especial en aquellas ubicadas en gastrocnemios y sóleo ($p < 0,05$). Por otro lado, Sánchez Alcaraz et al. (2019), reportaron una mayor incidencia lesional en los miembros superiores e inferiores en las mujeres ($p < 0,05$) y en el tronco en los hombres ($p < 0,05$).

## 2.8. Análisis de los partidos

### Análisis espacio-temporal

Los valores correspondientes a la duración del partido, set, juego, punto y descanso se presentan en la Tabla 7. Los datos muestran en categoría masculina una duración de los partidos de entre 3.041,83 s y 5.389,2 s, con tiempos de juego y descanso de 4,84-15,50 s y 9,11-30,4 s respectivamente.

Tabla 7. Variables temporales en partidos de pádel

| Autores | Muestra | Nivel | Duración del partido (s) | Duración del set (s) | Duración del juego (s) | Duración del punto (s) | Descanso por punto (s) |
|---|---|---|---|---|---|---|---|
| Pradas et al. (2014) | 6 Mujeres | Profesional | 3.371±38 | 1.768±39 | 197±25 | # | # |
| Amieba & Salinero (2013) | 8 Hombres | Aficionado | # | # | 159±38 | # | # |
| Carbonell et al. (2017) | 9 Mujeres | Aficionado | 3.601±36 | # | # | # | # |
| Carrasco et al. (2011) | 12 Hombres | Alto nivel | # | # | 163,06±3,04 | 7,24 | 9,11 |
| Muñoz et al. (2016) | Hombres | Regional | 3.231,7 | 1.491,5 | 151,48 | 12,7±10,05 | 14,95±6,32 |
| Torres-Luque et al. (2015) | 8 Hombres | Profesional | 3.041,83±263,29 | # | # | 9,30±4,00 | 19,25±10,22 |
| | 8 Mujeres | | 3.721,33±774,77 | # | # | 9,67±4,76 | 21,82±12,32 |
| Sánchez-Alcaraz et al. (2020) | Hombres | Profesional | 2.881,8±866,4 | # | # | # | # |
| | Mujeres | | 3.042,0±910,2 | # | # | # | # |
| Lupo et al. (2018) | 12 Hombres | Profesional | # | # | # | 12,6±2,1 | 30,4±5,7 |
| | 10 Mujeres | | # | # | # | 16,8±2,8 | 28,8±6,9 |
| García-Benítez et al. (2016) | 18 Hombres | Profesional | 5.389,2±1.848,6 | 2.114,4±600,6 | 159,6±104,4 | 10,8±7,7 | 17,2±7,7 |
| | 10 Mujeres | | 5.355,6±1.569,6 | 2.296,8±708,6 | 216,6±26,6 | 15,8±12,7 | 20,3±7,2 |
| García-Benítez et al. (2017) | Sub-16 Hombres | Nacional | 4.866±954 | 2.017±455 | 142±89 | 14,3±7,9 | # |
| | Sub-18 Hombres | | 5.214±2.145 | 2.166±600 | 163±84 | 15,5±6,4 | # |
| | Sub-16 Mujeres | | 4.926±1.380 | 2.035±599 | 167±86 | 15,6±6,1 | # |
| | Sub-18 Mujeres | | 3.168±1.002 | 1.535±650 | 168±107 | 14,1±5,2 | # |
| Ramón-Llin et al. (2017) | 20 | Profesional | # | # | # | 6,44 | # |
| | 20 | Aficionado | # | # | # | 6,20 | # |
| | 20 | Recreacional | # | # | # | 4,84 | # |

# Datos no disponibles

En categoría femenina se ha reportado una duración de los partidos de entre 3.042,0 s y 5.355,6 s, con tiempos de juego y descanso de 9,67-16,80 s y 20,3-28,8 s respectivamente. Torres-Luque et al. (2015), observaron que la duración de los puntos se distribuye habitualmente entre 3 a 6 s (23,2 %), 6 a 9 s (29,3 %) y 9 a 12 s (19,6 %) en ambos sexos. El tiempo de descanso y el número de descansos parece estar influenciado por la duración del set ($p < 0,05$) (Muñoz et al., 2016), la importancia del punto ($p < 0,05$) y el uso del punto de oro ($p = 0,007$) (Sánchez-Alcaraz et al., 2020). En cuanto a la duración de los partidos durante un torneo, Sánchez-Alcaraz et al. (2020), reportaron mayores duraciones desde la ronda de semifinales ($p = 0,004$), tanto en categoría masculina como femenina.

El análisis de los partidos de pádel muestra diferencias entre género en cuanto a las acciones de juego y las variables temporales. Los partidos femeninos presentan una mayor duración de los puntos, golpeos por punto, tiempo de juego real, tiempo de descanso, tiempo de descanso por punto y puntos por partido frente a los partidos masculinos (García-Benítez et al., 2016, 2017; Lupo et al., 2018; Torres-Luque et al., 2015). Por el contrario, García-Benítez et al. (2017), encontraron mayores tiempos de juego efectivo por juego (%), juegos por set y duración de los juegos en categoría sub-18 masculina frente a la femenina ($p < 0,05$). Respecto a la ratio trabajo:descanso, se encontraron similares valores entre ambos sexos (García-Benítez et al., 2017).

Atendiendo a la variable edad, se han encontrado menores valores de tiempo de descanso entre puntos en jugadoras sub-18 frente a jugadoras sub-16 ($p < 0,01$). En hombres, se han observado menores duraciones de partido ($p < 0,05$), de puntos ($p < 0,01$) y de tiempo de descanso entre puntos ($p < 0,01$) en jugadores sub-16 frente a sub-18 (García-Benítez et al., 2017).

Comparando diferentes niveles de juego, Ramón-Llin et al. (2017), registraron una mayor ratio de juego (golpeos por segundo), en jugadores de nivel nacional frente a aquellos de nivel regional ($p < 0,05$). En el mismo estudio, los partidos de jugadores aficionados difirieron de los de nivel nacional y regional en duración de los puntos, número de puntos por partido, distancia recorrida, ratio de juego y velocidad de desplazamiento durante el juego.

Respecto a la distancia recorrida, los jugadores de pádel recorren entre 1.813 m y 2.052 m por partido (Amieba & Salinero, 2013; Castillo-Rodríguez, Hernández-Mendo, et al., 2014), con una velocidad media de 2,59±0,40 $km \cdot h^{-1}$, donde solamente el 0,7 % de los desplazamientos se producen a velocidades superiores a 12 $km \cdot h^{-1}$, hasta una velocidad máxima de 15,4±1,58 $km \cdot h^{-1}$ (Amieba & Salinero, 2013).

**Análisis de los golpeos**

La volea, el remate y el revés son los tipos de golpeo más comunes durante los partidos de pádel de acuerdo a diversos autores (Courel-Ibañez et al., 2019; Mellado-Arbelo et al., 2019; Priego-Quesada et al., 2013; Torres-Luque et al., 2015). Los tipos de golpeo también dependen de la zona de la pista desde la que se efectúan: en la red, en la zona central o en la línea de fondo. En la red (juego ofensivo), predomina el uso de voleas y golpeos por encima de la cabeza en la línea central, tanto para mantener una ventaja posicional como para resolver los puntos. Por el contrario, en la línea de fondo (juego defensivo), es relevante el uso de globos y de golpeos tras rebotar la pelota en la pared. El juego en la zona central (transición), se caracteriza por el mayor uso de la volea de revés en el centro, volea y bandeja en los laterales y el remate para resolver los puntos (Courel-Ibañez et al., 2019).

Comparando diferentes niveles de juego, Ramón-Llin et al. (2017), observaron que los jugadores de nivel nacional utilizaban más la volea (28,3 % vs. 16,7 %), la bandeja (8,9 % vs. 7,4 %) y el remate (5 % vs. 2,9 %) en el juego ofensivo, y los golpeos contra la pared (fondo, lateral y doble) en el juego defensivo, frente a los jugadores aficionados. En cambio, los jugadores aficionados tienden a utilizar los globos con más frecuencia (12 % vs. 10,7 %).

En cuanto a los puntos ganadores, el remate es el golpeo más frecuente en jugadores profesionales (Mellado-Arbelo et al., 2019; Ramón-Llin et al., 2020). Dentro de los diferentes tipos de remate, la bandeja es el más utilizado por los jugadores de pádel, tanto en hombres como en mujeres, presentando un porcentaje de continuidad del punto de casi el 90 %. El mayor porcentaje de puntos ganadores (cerca del 60 %), lo tienen el remate plano y el liftado, aunque su eficacia desciende significativamente cuando el jugador los ejecuta lejos de la red ($p < 0,05$), especialmente para el remate plano. El análisis de esta variable, atendiendo al género, muestra un mayor porcentaje de remates ganadores en hombres frente a mujeres, principalmente del remate plano ($p = 0,02$). Por otro lado, las mujeres realizan significativamente más remates liftados cruzados que los hombres ($p = 0,005$) (Sánchez-Alcaraz et al., 2020).

Courel-Ibañez et al. (2019), hallaron que dos de cada diez golpeos durante los partidos de pádel fueron realizados mediante la acción técnica del globo. Se ha observado una predominancia de los globos frente a otros tipos de golpeo (60,6 % vs. 39,4 %), con el objetivo de subir a la red, tanto en jugadores profesionales del WPT, como en aquellos pertenecientes a primera división regional (Muñoz, 2017). De hecho, el uso de los globos aumenta la probabilidad de dar continuidad a los puntos, según varios autores (Muñoz, 2017; Ramón-Llin et al., 2019). Comparando partidos femeninos y masculinos, García-Benítez et al. (2016), cuantificaron más del doble de globos por partido en el pádel femenino profesional (347,83±132) que en el masculino (149±47,93) ($p < 0,001$). Estos resultados también fueron similares en jugadores sub-16 ($p = 0,01$) (García-Benítez et al., 2017).

En el estudio de Lupo et al. (2018), se observaron diferencias entre géneros en jugadores profesionales con un mayor número de golpeos por punto (12,2±2,0 vs. 9,6±1,5; $p < 0,001$), faltas en el primer servicio (0,9±0,3 vs. 0,5±0,3; $p < 0,001$), remates que provocaron que la pelota saliera de la pista (0,2±0,2 vs. 0,4±0,2; $p < 0,001$), y porcentaje de golpeos desde la zona media de la pista (51,6 ± 12,5 vs. 42,9 ± 9,4; $p = 0,012$), en partidos femeninos frente a los masculinos. Al contrario, observaron mayores valores de porcentaje de golpeos de revés (7,8±3,6 vs. 6,1±4,1; $p = 0,02$), voleas de revés (12,5±6,7 vs. 16,4±4,5; $p = 0,027$), golpeos cerca de la red (20,9±8,9 vs. 34,2±11,9; $p = 0,001$) y faltas en el primer servicio ($p < 0,001$) en los partidos masculinos frente a los femeninos.

**Servicio y resto**

Se ha observado que la pareja que sirve cuenta con una ventaja táctica en aquellos puntos que duran menos de siete intercambios, variando en función del nivel de los jugadores (Ramón-Llin et al., 2019; Sánchez-Alcaraz et al., 2020). Con el objetivo de dar continuidad al juego y disminuir la ventaja del servicio, el 70,6 % de los restos se ejecutan mediante golpes planos, siendo hacia al jugador que sirve el 71,9 % de las veces, o bien mediante globos (29,4 %), dirigidos ya sea al rival que sirve (48,8 %), o a su pareja (51,2 %) (Ramón-Llin et al., 2019).

En este aspecto del juego se han encontrado diferencias entre sexos. Sánchez-Alcaraz et al. (2020), indicaron que los jugadores masculinos obtienen un mayor porcentaje de primeros servicios exitosos ($p < 0,05$), y de puntos en una situación de servicio ($p < 0,01$), en cambio, las mujeres juegan una mayor proporción de restos de revés o diagonales ($p < 0,05$) y utilizan el globo con más frecuencia para restar ($p < 0,05$).

Con respecto a las áreas de juego, en el lado izquierdo de la pista los servicios se dirigen más frecuentemente (12 %) hacia la pared lateral, mientras que desde el lado derecho se suelen realizar en dirección a la "T" (14 %). Al restar, los jugadores de la izquierda ejecutan casi un 15 % más de restos dirigidos hacia la línea que los de la derecha. En cuanto a los golpeos, los jugadores de la izquierda realizan más del 75 % de sus restos de revés, mientras que los de la derecha suelen restar con golpes de derecha (Sánchez-Alcaraz et al., 2020).

**Lado de la pista y mano dominante**

Ramón-Llin et al. (2020), hallaron que los jugadores ubicados en la zona izquierda de la pista realizan un mayor porcentaje de golpeos en diagonal y golpeos ganadores, que aquellos situados en el lado derecho ($p < 0,001$). Por otro lado, en la zona derecha de la pista se ejecutan con más frecuencia bandejas, remates, golpeos paralelos a la pared o de espaldas ($p < 0,001$).

En cuanto a la mano dominante, Courel-Ibáñez & Sánchez-Alcaraz (2018), observaron un patrón técnico de juego similar entre jugadores con diferencias en los golpeos ejecutados desde la línea de servicio ($p < 0,001$), realizando los jugadores diestros más globos (33,3 % vs. 22,5 %) y los zurdos más golpeos directos (38,4 % vs. 30,9 %). Comparando ratios de efectividad, los zurdos anotan más puntos a través de los remates (63,3 % vs. 40,7 %), cometen más errores en el juego contra la pared (37,7 % vs. 19,5 %) y utilizan más golpeos directos para dar continuidad a los puntos (24,8 % vs. 19,4 %) ($p < 0,05$). Sin embargo, los jugadores diestros anotan más puntos utilizando golpeos contra la pared (17,4 % vs. 5,6 %), cometen más errores en los golpeos de volea (29,3 % vs. 18,4 %) y utilizan con más frecuencia el globo para dar continuidad a los puntos (18,7 % vs. 14,9 %). Además, los jugadores diestros aseguran más los puntos con un número menor de errores no forzados (11,2 % vs. 8,2 %) y mayor porcentaje de acciones para darle continuidad al juego (84,9 % vs. 79,9 %).

# 3. HIPÓTESIS

Las hipótesis de la presente Tesis Doctoral son:

1. Las características antropométricas de los jugadores de pádel de alto nivel son semejantes a las de otros deportes de raqueta con un predominio endomorfo en mujeres y mesomorfo en hombres.

2. La práctica competitiva del deporte del pádel tiene un impacto agudo generalizado sobre marcadores hematológicos y urinarios en jugadores masculinos y femeninos de alto nivel.

3. La dinámica de juego del pádel de alto nivel provoca una fatiga neuromuscular similar en ambos sexos caracterizada por un descenso de los niveles de fuerza máxima del brazo dominante y de la fuerza reactiva del tren inferior.

# 4. OBJETIVOS

## Objetivo general

El objetivo general de la Tesis Doctoral ha sido analizar las características antropométricas y evaluar el impacto fisiológico, metabólico y neuromuscular de carácter agudo que produce la competición de pádel de alto nivel.

## Objetivos específicos

Para conseguir el objetivo general de la Tesis Doctoral, se definen los siguientes objetivos específicos:

1. Describir y comparar el perfil antropométrico, composición corporal y somatotipo de jugadores de pádel de alto nivel de ambos sexos.

2. Examinar el impacto que produce una competición de pádel de alto nivel sobre parámetros hematológicos y bioquímicos en jugadores profesionales masculinos y femeninos.

3. Analizar la fatiga neuromuscular que provoca un partido de competición de pádel considerando las posibles diferencias entre sexos.

4. Proveer de una contextualización actualizada del pádel con respecto a la antropometría, demandas fisiológicas y físicas, biomecánica, epidemiología de lesiones y análisis del partido, proponer futuras líneas de investigación para un mejor conocimiento del deporte y hacer llegar el conocimiento científico tanto a entrenadores como deportistas con el fin de mejorar el rendimiento.

# 5. PRESENTACIÓN DE LOS TRABAJOS PUBLICADOS

**Anthropometric Characteristics of Elite Paddle Players. Pilot Study.**

El análisis del biotipo de los deportistas en deportes de raqueta es un aspecto muy estudiado en disciplinas tales como el squash (Mellor et al., 1995), el bádminton (Abián et al., 2012), el tenis (Sánchez-Muñoz et al., 2007) y el tenis de mesa (Pradas et al., 2013; Sepúlveda et al., 2015), considerando su relación directa con el rendimiento en el deporte. En cambio, aunque actualmente hay estudios interesantes que describen el perfil antropométrico de los jugadores de pádel, es difícil estandarizar los datos presentados dada su heterogeneidad. En algunos casos los estudios se han llevado a cabo con deportistas universitarios (Martínez-Rodríguez et al., 2015), con muestras muy pequeñas de jugadores de élite (Pradas, Cachón et al., 2014), o incluso comparando jugadores de diferentes niveles de juego (Castillo-Rodríguez, Hernández-Mendo, et al., 2014).

Por otro lado, teniendo en cuenta el importante crecimiento y profesionalización que ha sufrido el pádel durante estos últimos años, cada vez son más los jugadores de alto nivel que provienen de una formación exclusiva en este deporte, y no proceden de otros deportes de raqueta, especialmente del tenis. Este hecho, permite a los investigadores valorar de forma más específica el biotipo de referencia, de acuerdo con la realidad actual del pádel de alto nivel.

Teniendo en consideración estos antecedentes, el objetivo de esta primera publicación fue describir las características antropométricas, composición corporal y somatotipo de una muestra internacional de jugadores de pádel de alto nivel de ambos sexos.

En el estudio participaron 29 jugadores (14 mujeres y 15 hombres), de categoría absoluta, que participaban en competiciones de máximo nivel nacional, torneos PPT y eventos WPT durante los últimos diez años.

Para la valoración antropométrica se siguieron los protocolos propuestos por la Sociedad Internacional para el Avance en Cineantropometría (ISAK) y el Grupo Español de Cineantropometría (GREC). Todas las mediciones fueron realizadas por un experto acreditado por la ISAK, ayudado por un asistente para registrar los valores obtenidos.

Una vez analizados todos los valores de las diferentes variables registradas, las novedades más importantes halladas en esta investigación fueron las siguientes:

- Se encontraron diferencias entre sexos en las variables masa, talla e IMC ($p < 0,001$); en los pliegues tricipital, muslo y pierna ($p < 0,001$); en el sumatorio de 6 pliegues;

en los perímetros brazo, muslo ($p < 0,001$) y pierna ($p < 0,03$); y en todos los diámetros analizados ($p < 0,001$).

- Se encontraron diferencias entre sexos en los componentes del somatotipo endomórfico ($p < 0,01$), mesomórfico ($p < 0,001$) y ectomórfico ($p < 0,05$).
- Las jugadoras de pádel presentan un somatotipo endo-mesomórfico y los jugadores mesomórfico-endomórfico.

**Effect of a Padel Match on Biochemical and Haematological Parameters in Professional Players with Regard to Gender-Related Differences.**

Hasta el momento, la respuesta fisiológica durante la práctica del pádel se ha descrito como predominantemente aeróbica, con pequeños periodos de alta y muy alta intensidad (Pradas, Cachón et al., 2014). Esta relevancia del sistema aeróbico, también se ha confirmado a través de la baja intensidad hallada durante el juego, junto a periodos de descanso del 60,3 % del tiempo total de juego (Bartolomé et al., 2016). Los jugadores de pádel deben ejecutar movimientos rápidos, con continuos cambios de dirección en periodos de tiempo corto, utilizado principalmente el sistema de los fosfágenos para obtener la energía. De hecho, la glucólisis anaeróbica parece ser menos importante, habiéndose reportado concentraciones máximas de 2,4 $mmol \cdot l^{-1}$ (Pradas, Cachón et al., 2014).

Este carácter aeróbico del pádel, se ve además fundamentado en estudios donde se han alcanzado valores medios de consumo de oxígeno durante el juego de 40-50 % del $VO_{2máx}$ medido previamente en condiciones de laboratorio (Carrasco et al., 2011; De Hoyo et al., 2007). Asimismo, la $FC_{med}$ durante los partidos se sitúa entre el 76,3 % y 84,9 % de la $FC_{máx}$ (Carrasco et al., 2011; Pradas, Cachón et al., 2014).

Respecto a la respuesta hematológica y bioquímica, estudios previos la han analizado en otros deportes de raqueta tales como el tenis (Bergeron et al., 1991; Ojala & Häkkinen, 2013) o el bádminton (Abián et al., 2015; Majumdar, 1997). En cambio, no se han encontrado estudios que la evalúen en jugadores de pádel alto nivel. Atendiendo a la importancia que puede tener el conocimiento de estos valores para el control de la carga y planificación de los entrenamientos, el objetivo de esta segunda investigación fue el de observar el efecto de una competición sobre parámetros hematológicos y bioquímicos en jugadores profesionales de pádel, evaluando las posibles diferencias entre ambos sexos.

En el estudio participaron 30 jugadores profesionales (16 mujeres y 14 hombres), de categoría absoluta que competían en el circuito profesional WPT durante los siete años anteriores.

Previo a los partidos simulados, se determinó el $VO_{2máx}$ y $FC_{máx}$ de los jugadores mediante una prueba incremental en tapiz rodante hasta el agotamiento. Para el análisis hematológico y bioquímico, dos muestras de sangre de 5 mL fueron extraídas 90 minutos antes del partido e inmediatamente después, con el objetivo de ser analizadas posteriormente. Los parámetros hematológicos fueron determinados mediante un analizador hematológico (Coulter modelo AcT diff.). La bioquímica completa fue procesada en el laboratorio del Hospital Universitario San Jorge (Huesca, España), mediante técnicas de espectrofotometría utilizando un analizador de química analítica modelo Advia 1650 (Bayer, Alemania).

Una vez se analizaron todos los parámetros objeto de estudio en esta investigación y comparados sus resultados entre sexos, los hallazgos más relevantes fueron:

- La muestra masculina mostró mayores valores basales de glóbulos rojos, hematocrito, hemoglobina, urea, creatinina, ácido úrico, albúmina, transaminasa glutámico oxalacética (GOT), transaminasa glutámico pirúvica (GPT), lactato deshidrogenasa (LDH) y creatinquinasa (CK) que la femenina ($p < 0,01$).
- Atendiendo al efecto del partido, se observaron diferencias significativas en los valores de urea, creatinina, CK y glucosa ($p < 0,05$).
- Respecto a la interacción grupo-partido, se obtuvieron diferencias significativas en la concentración sérica de sodio y cloruro ($p < 0,05$).

**Gender Differences in Neuromuscular, Haematological and Urinary Responses during Padel Matches.**

Estudios previos han puesto de manifiesto diferencias entre géneros con respecto a la estructura temporal y acciones de juego durante los partidos de pádel (García-Benítez et al., 2017; Sánchez-Alcaraz et al., 2020; Sánchez-Alcaraz et al., 2021). La cantidad de acciones tácticas, tales como el número de globos o de remates por punto, es mayor en categoría femenina frente a la masculina (García-Benítez et al., 2016). Las jugadoras utilizan con más frecuencia los servicios de derecha y de revés que los jugadores masculinos, así como ejecutan menos voleas de revés que los hombres (Torres-Luque et al., 2015). Los hombres realizan un mayor porcentaje de remates ganadores que las mujeres (Sánchez-Alcaraz et al., 2020). Respecto a la estructura temporal, el tiempo total de partido, tiempo de juego y cantidad de acciones por partido son mayores en categoría femenina. Por el contrario, en categoría masculina predominan acciones de juego cortas y más intensas (Sánchez-Alcaraz et al., 2018; Torres-Luque et al., 2015). Considerando estas diferencias en las características tácticas y temporales entre géneros, cabe esperar que tanto la carga física como la respuesta fisiológica pudiera diferir entre ambos sexos.

Como se ha observado en diversas investigaciones, la práctica de deportes de raqueta produce respuestas agudas relevantes en el organismo (Abián et al., 2015; Ojala & Häkkinen,

2013). Algunos autores han reportado mayor cantidad de dolor muscular de inicio retardado o DOMS (*Delayed Onset Muscle Soreness*) y reducción de la contracción muscular máxima voluntaria tras varios partidos de tenis (Ojala & Häkkinen, 2013). En partidos de bádminton simulados se han encontrado cambios en los valores de hemoglobina y hematocrito (Abián et al., 2015). En otros deportes de raqueta también se han observado reducciones en la función neuromuscular después de los partidos (Girard & Millet, 2009; Girard et al., 2008).

En cambio, a pesar del aumento de producción científica sobre el pádel, la literatura respecto a la respuesta fisiológica aguda posterior a un partido es todavía limitada y desconocida (Pradas et al., 2020). De hecho, no se han encontrado trabajos que hayan estudiado la respuesta neuromuscular de ambos sexos tras un partido de pádel. Parece ser que, tal y como ocurre en otros deportes de raqueta, la fatiga que produce un partido de pádel podría modificar la respuesta neuromuscular posterior de los jugadores. De hecho, el conocimiento de su respuesta neuromuscular y fisiológica podría facilitar la programación y control de las cargas de entrenamiento con el fin de alcanzar un mejor rendimiento.

Teniendo en consideración estos precedentes, el objetivo de la tercera investigación de esta Tesis Doctoral fue el de analizar la respuesta neuromuscular, urinaria y hematológica de los jugadores tras un partido de competición simulado y las posibles diferencias entre géneros.

En el estudio participaron 28 jugadores (15 mujeres y 13 hombres), que competían de manera regular en el circuito profesional WPT en los siete años previos.

Previo a los partidos simulados, se evaluaron las características antropométricas de los participantes de acuerdo con los protocolos propuestos por la ISAK. Durante los partidos simulados los jugadores fueron monitorizados mediante pulsómetros (Vantage M, Polar, Finlandia), controlándose además la cantidad de líquido ingerida. La bebida consistió en agua mineral que los jugadores podían beber *ad libidum* durante los partidos. Una hora antes y 2-5 minutos después de los partidos se evaluó su función neuromuscular a través de: (1) la fuerza isométrica máxima de prensión de la mano dominante y no dominante, mediante un dinamómetro (Takei Instruments Ltd., Tokio, Japón) y (2) la altura, potencia y tiempos de los saltos SJ, CMJ y Abalakov (ABK) mediante una plataforma de saltos (Chronojump Boscosystems, Barcelona, España). Del mismo modo, 120 minutos antes y 7-10 minutos después de los partidos, se extrajeron dos muestras de sangre de 5 mL con el objetivo de ser analizadas posteriormente. Los parámetros hematológicos (glóbulos rojos, hematocrito y hemoglobina), fueron determinados mediante un analizador de hematología (Coulter modelo AcT diff.) en el laboratorio del Hospital Universitario San Jorge (Huesca, España). Respecto al análisis urinario, se tomaron muestras de la primera orina de la mañana y la primera posterior a la competición simulada. Tras la recopilación de muestras, se utilizaron 10 mL de orina para analizar la gravedad específica mediante un refractómetro (URC-Ne, Atago,

Japón), y las variables bioquímicas (pH, microalbuminuria y eritrocitos) utilizando tiras reactivas (Combur Test, Roche, España) y un analizador de orina (Urysis 1100, Roche, España).

Una vez analizados todos los valores de los parámetros evaluados, los resultados que se obtuvieron en esta tercera investigación fueron:

- La muestra masculina inició los partidos simulados en un estado de deshidratación mayor que la muestra femenina ($p < 0,05$).
- Se observaron diferencias significativas ($p < 0,05$) en la respuesta neuromuscular y hematológica pre-partido entre ambos sexos, obteniendo la muestra masculina mayores valores en ambos tipos de variables. Tales resultados indican mejores de niveles de fuerza y condición cardiovascular inicial, vinculada esta última a niveles de hematocrito, glóbulos rojos y hemoglobina más altos, en los varones respecto a las mujeres.
- Los partidos simulados afectaron negativamente a la altura de salto ABK ($p < 0,05$) e incrementaron la concentración de microalbuminuria ($p < 0,01$), asociada al ejercicio de alta intensidad, en ambos sexos.
- Los porcentajes de cambio en la fuerza isométrica máxima de prensión manual, y saltos SJ (altura y potencia), CMJ (altura) y ABK (altura) fueron mayores en hombres que en mujeres ($p < 0,05$).

**Performance Outcome Measures in Padel: A Scoping Review.**

Durante los últimos años ha habido un aumento de la literatura científica en la que se aborda el pádel. Este aumento del interés científico por este deporte ha permitido alcanzar un mejor entendimiento de las características y requerimientos del pádel, tanto para jugadores profesionales como para jugadores aficionados. Los estudios publicados han abordado diferentes aspectos relacionados con el deporte, como son las características antropométricas de los jugadores (Muñoz et al., 2021; Sánchez-Muñoz et al., 2020), aspectos biomecánicos (Priego-Quesada et al., 2014), epidemiología de lesiones (García–Fernández et al., 2019; Sánchez Alcaraz et al., 2019), requerimientos fisiológicos y físicos (Castillo-Rodríguez, Alvero-Cruz, et al., 2014), la estructura temporal, táctica y tipos de golpeos (Escudero-Tena et al., 2020; Ramón-Llin et al., 2020; Sánchez-Alcaraz et al., 2020; Sánchez-Alcaraz et al., 2020). En cambio, las investigaciones que hayan abordado una revisión profunda acerca del conocimiento científico sobre el pádel son escasas (Sánchez-Alcaraz et al., 2018; Sánchez-Alcaraz & Gómez-Mármol, 2015; Villena-Serrano et al., 2016), al contrario de lo que sucede en otros deportes de raqueta como el tenis (Killit et al., 2018; Kolman et al., 2019), tenis de mesa (Ferrandez et al., 2021), bádminton (Phomsoupha & Laffaye, 2020) o squash (Jones et al., 2018).

En este sentido, el cuarto y último artículo de la Tesis Doctoral tiene como objetivos proveer una contextualización actualizada sobre el pádel, realizando una *scoping review* o revisión sistemática exploratoria respecto a las características antropométricas y biomecánicas de los jugadores, las demandas fisiológicas y físicas del juego, la epidemiología de lesiones y el análisis de los partidos. De esta forma, también se pretende analizar los vacíos existentes en el conocimiento científico sobre estos temas de interés, y así poder proponer futuras líneas de investigación que permitan profundizar en un mejor conocimiento del pádel. Para realizar esta revisión se siguió el método PRISMA ScR propuesto por Tricco et al. (2018), seleccionando publicaciones con fecha previa al 31 de enero de 2022. Las bases de datos utilizadas fueron PubMed, Scopus y SPORTDiscus. La revisión finalmente incluyó 72 artículos.

Los campos sobre los que más producción científica se encontró fueron el análisis de los partidos, las demandas físicas y fisiológicas de los jugadores, y sus características antropométricas, probablemente dada su estrecha relación con el rendimiento deportivo. Por otro lado, los campos menos estudiados fueron las características biomecánicas y la epidemiología de lesiones.

Atendiendo a la falta de literatura en referencia a algunos aspectos relacionados con el pádel, se identificaron en esta publicación las siguientes posibles futuras líneas de investigación:

- Rendimiento y fatiga mental.
- Efectividad de planes de prevención de lesiones durante cierto periodo de tiempo.
- Indicadores visuales (pre-índices) y anticipación perceptiva.

# 6. JUSTIFICACIÓN DE LA UNIDAD TEMÁTICA

Los cuatro trabajos científicos presentados en el apartado anterior tienen como foco de atención el deporte del pádel. Todos ellos tratan de dar respuesta a aspectos poco investigados o todavía por investigar en este deporte.

En primer lugar, el primer artículo consiste en el análisis antropométrico de jugadores internacionales de alto nivel de categoría masculina y femenina. Siendo esta una publicación pionera a nivel mundial, en donde se recogen datos de una muestra equitativa de jugadores, de ambos sexos con experiencia en torneos WPT, PPT y de máxima categoría nacional durante los diez años previos al estudio.

El segundo artículo se centra en el impacto fisiológico que supone un partido de pádel en jugadores profesionales, atendiendo a las diferencias que pudiera haber entre sexos. Este impacto fisiológico se evalúa a través del análisis de parámetros hematológicos y bioquímicos, comparando los valores previos y posteriores a una competición simulada, aspectos evaluados previamente en otros deportes como el tenis y el bádminton, pero no existiendo investigaciones de índole similar en el pádel.

El tercer artículo incluye la valoración de la respuesta neuromuscular que produce la práctica del pádel, evaluando variables condicionales (fuerza de los miembros superiores e inferiores) y el impacto fisiológico que implica para el organismo el deporte del pádel, a través del análisis de diferentes marcadores hematológicos y urinarios. Para llevar a cabo este estudio, se tomaron las muestras durante una competitiva simulada considerando a jugadores y jugadoras profesionales con el fin de observar, además, las posibles diferencias entre sexos.

Por último, el cuarto artículo consiste en una *scoping review* o revisión sistemática exploratoria que clasifica los trabajos publicados sobre el pádel. En esta publicación se exponen los aspectos más relevantes acerca de las características antropométricas y biomecánicas de los jugadores, las demandas fisiológicas y físicas del deporte, la epidemiología de lesiones y el análisis de los partidos, y en donde se proponen futuras líneas de investigación.

En conclusión, a lo largo de estos trabajos de investigación se han estudiado y evaluado en profundidad las características antropométricas, el impacto fisiológico y la respuesta neuromuscular de jugadores de pádel de alto nivel atendiendo a las diferencias entre sexos, así como se han revisado todos los estudios previos publicados acerca del pádel hasta el día de hoy.

Por consiguiente, la unidad temática está completamente justificada, cumpliéndose con el requisito necesario para la presentación de una Tesis Doctoral por compendio de artículos.

# 7. RESULTADOS

Los resultados obtenidos en la Tesis Doctoral se presentan a continuación en forma de cuatro publicaciones, manteniendo el formato en el que se han publicado en las diferentes revistas internacionales.

Pradas de la Fuente, F.; González-Jurado, J.A.; García-Giménez, A.; Gallego Tobón, F. y Castellar Otín, C. (2019) Características antropométricas, de jugadores de pádel de élite. Estudio piloto / Anthropometric Characteristics of Elite Paddle Players. Pilot Study. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 19 (74) pp. 181-195 Http://cdeporte.rediris.es/revista/revista74/artcaracteristicas1012.htm
DOI: http://doi.org/10.15366/rimcafd2019.74.001

# ORIGINAL

# ANTHROPOMETRIC CHARACTERISTICS OF ELITE PADDLE PLAYERS. PILOT STUDY

# CARACTERÍSTICAS ANTROPOMÉTRICAS DE JUGADORES DE PÁDEL DE ÉLITE. ESTUDIO PILOTO

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**Acknowledgments**

This study was developed within the framework of the research project 'Análisis de las demandas fisiológicas del pádel de competición: estudio de marcadores asociados al rendimiento físico-deportivo' funded by the Instituto de Estudios Altoaragoneses.

**Código UNESCO / UNESCO code**: 2402 Antropología (Física) / Anthropology (Physical)
**Clasificación Consejo de Europa / Council of Europe classification**: 9. Cinantropometría / Kineanthropometry

## ABSTRACT

Paddle is one of the racket sports that has grown the most in recent years. However, there are few or very limited studies that address the biotype of this discipline, especially in the elite paddle. The aim was to describe the anthropometric characteristics, body composition and somatotype of an international sample of high level paddle players. 29 subjects national top level (15 male and 14 female) participated in this study. 16 anthropometric variables were evaluated. Differences were found between sexes in the variables weight, height and BMI ($p < 0.001$); in triceps, thigh and leg folds ($p < 0.001$); in the arm, thigh ($p < 0.001$) and leg ($p < 0.03$) perimeters; and in all diameters analysed ($p < 0.001$). Differences were also found between men and women in the endomorphic ($p < 0.01$), mesomorphic ($p < 0.001$) and ectomorphic ($p < 0.05$) components of the somatotype. Male players present a mesomorphic-endomorphic somatotype while female players are preferably endo-mesomorphic. This research provides up-to-date reference data for somatotype in elite paddle players.

**KEY WORDS:** paddle; body composition; anthropometry; somatotype.

## RESUMEN

El objetivo de este estudio fue describir las características antropométricas, la composición corporal y el somatotipo de una muestra internacional de jugadores de pádel de alto nivel de ambos sexos. En el estudio participaron 29 jugadores (15 varones y 14 mujeres) de categoría absoluta. Un total de 16 variables antropométricas fueron evaluadas. Se encontraron diferencias entre sexos en las variables masa, talla e IMC ($p<0,001$); en los pliegues tricipital, muslo, pierna ($p<0,001$) y en el sumatorio de 6 pliegues; en los perímetros brazo, muslo ($p<0,001$) y pierna ($p<0,03$); y en todos los diámetros analizados ($p<0,001$). Asimismo se encontraron diferencias en los componentes endomórfico ($p<0,01$), mesomórfico ($p<0,001$) y ectomórfico ($p<0,05$) del somatotipo. Los jugadores presentan un somatotipo mesomórfico-endomórfico y las jugadoras endo-mesomórfico. Esta investigación aporta datos biotipológicos actualizados de referencia para el pádel de élite.

**PALABRAS CLAVE:** pádel; antropometría; composición corporal; somatotipo.

## INTRODUCTION

The effort character occurred during paddle tennis practice is acyclic, where intermittent periods of work and rest continuously take place in a similar manner to other racket modalities (Cabello-Manrique & Gonzalez-Badillo, 2003; Chin, Steininger, So, Clark, & Wong, 1995; Fernández, Mendez-Villanueva, & Pluim, 2006; Pradas, González-Jurado, Molina Sotomayor, & Castellar Otín, 2013). This sport is practiced in pairs and it is developed in a rectangular play area divided into two fields by a central net. The paddle tennis court is characterized by its completely closed girth, combining metallic mesh areas and areas made of materials which allow a regular rebound of the ball (bottom and side walls) against which the game can be played.

Paddle tennis' practice singularity in regard to other racket sports lies in its unique game dynamics, being the only discipline in which it is allowed to return the ball sent by the rival pair in three different ways: a) directly hitting the ball towards the opposing field without letting it drop or after a bounce on the court; b) performing the hit after bouncing the ball on the court and then some wall (lateral, background or both); and c) indirectly, hitting the ball against the side or bottom walls of the playing area where the players are located (Pradas et al., 2014)

From a physiological point of view, paddle tennis has the particularity of bringing together the participation of the different metabolic pathways. Considering the temporal structure of the different gaming actions that occur in this sport, there is visibly an lactic anaerobic metabolic system predominance, although a alactic anaerobic activity also exists to a lesser extent. However, as a consequence of the total duration of the matches, the intervention of aerobic metabolism is also necessary since it is considered the most important energy support system in this sport (Castellar, Pradas, Quintas, Arraco, & Pérez, 2015).

The intensity developed during paddle tennis practice is close to that experienced in the individual tennis modality. However, even though the oxygen consumption of paddle tennis players is similar to that achieved by tennis players, both in peak and relative values, the actual requirements of each practice are different (de Hoyo, Sañudo, & Carrasco, 2007).

Biotype analysis that characterizes players is another important issue to consider because of its direct relation with sports performance. If we focus on racket sports, it can be observed that numerous studies are concerned with accurately determining anthropometric characteristics in disciplines such as squash (Mellor et al., 1995), badminton (Vicén, Abián-Vicén, & Sampedro, 2012), tennis (Sánchez-Muñoz, Sanz, & Zabala, 2007) or table tennis (Pradas et al., 2013; Sepúlveda, Barraza, Soto, Báez, & Tuesta, 2015).

However, despite the fact that there are currently interesting studies attempting to describe the anthropometric profile in paddle tennis, it is certainly difficult to standardize the data presented by its heterogeneity, since in some cases the

studies have been performed with university athletes (Martinez-Rodriguez, Collado, & Vicente-Salar, 2015), with very small elite samples (Pradas et al., 2014), and even comparing players of different game levels (Castillo-Rodríguez, Hernández-Mendo, & Alvero-Cruz, 2014).

On the other hand, the important impetus, development and professionalism that paddle tennis has undergone in recent years, have posed a significant reduction in the number of players practicing this discipline coming from other racket sports, especially tennis, increasing gradually the players who have specialized only in this sport.

The incorporation to the elite in recent years of players formed exclusively from an early age in this sport, allows researchers to approach the knowledge of a more specific biotype of reference, closer and according to the sport´s reality of high level paddle practiced currently.

Considering what has been stated so far, determining the anthropometric characteristics and body composition that currently characterizes this discipline could be of interest because of its relevance to obtain an adequate sports performance. In this sense, the objective of this study is to describe and compare the anthropometric profile, the body composition and the somatotype of high-level padel players of both sexes.

## MATERIAL AND METHODS

### PARTICIPANTS

An international sample of 29 elite paddle tennis players, 15 men (age: 28.2±7.9 years) and 14 women (age: 29.7±3.7 years) voluntarily participated in this study. The selected athletes had an experience of 7.6±3.3 years and trained an average of 10±2.8 hours per week on the court, regularly participating in national top-level competitions, in Paddle Pro Tour tournaments and World Paddle Tour events during the last ten years.

### PROCEDURES

The sampling applied in the context of this research was a non probabilistic sampling of convenience. To know the possible differences between sexes, the sample was divided into two groups: men and women. Measurements for anthropometric determinations included: body mass (kg), height (cm), eight skinfolds (biceps, triceps, subscapular, suprailiac, supraspinal, abdominal, thigh and leg (mm)), four girths (relaxed, contracted and flexed arm, thigh and leg (cm)) and three breadths (biepicondylar femur, biepicondylar humerus and bistiloyd wrist (cm)). Protocols proposed by the International Society for the Advancement of Anthropometry (ISAK) and the recommendations of the Spanish Group of Cineanthropometry (GREC) were used to record all measurements and determine the anthropometric profile. All measurements

were performed by an expert accredited by the ISAK, helped by an assistant to record the values obtained.

To ensure the validity and reliability of the measurements during the process, the recommendations were followed to maintain a technical error of inter-evaluating and intra-evaluating measurement below 5% in skinfolds and less than 2% in all other measurements.

For skinfold measurements, a plicometer (Holtain Ltd, Crymych, UK) was used with an accuracy of 0.2 mm. Height and body mass were measured with a Seca 714 scale (Seca Instruments Ltd, Hamburg, Germany). The breadths were determined with a pachymeter and the girths with a flexible metal tape with 1 mm precision (Holtain Ltd, Crymych, UK) using a dermographic pencil.

Based on the evaluations performed, different indices and percentages were calculated in order to determine the body mass index (BMI), body composition and somatotype of the athletes participating in the study. The BMI was calculated using the formula: [mass (kg) x height (m)]$^2$. Body composition was estimated using a tetra-compartment model, determining the fatty, bone and muscular components. The percentage of body fat was calculated using the formula of Withers, Craig, Bourdon & Norton (Withers, Craig, Bourdon, & Norton, 1987). The somatotype analysis was performed using the method proposed by Heath-Carter (Carter & Heath 1990), obtaining the value of the three components: endomorphic, mesomorphic and ectomorphic.

Before starting the study, the athletes were verbally informed about the objective, the procedure followed as well as the risks and benefits of their participation. All athletes signed an written informed consent. The research was approved by the Clinical Research Ethics Committee of the Government of Aragon (Spain), following the guidelines of the Declaration of Helsinki.

## STATISTICS

SPSS© version 22.0 for Windows (Inc, Chicago, Illinois) was used as statistical software. A descriptive statistic analysis was performed to obtain the measures of central tendency: mean, standard deviation (SD), minimum and maximum. To verify the possible differences between groups, different hypothesis tests were carried out, checking the normality of the sample using the Shapiro-Wilk test and the homoscedasticity of variances through the Levene test. When the samples normality and homoscedasticity conditions were complied, the Student's T-test was used for independent data; when this failed, the non-parametric Mann-Whitney U-test was applied. For all the comparisons, a 95% confidence interval ($p \leq 0.05$) was established.

## RESULTS

The overall characteristics of the players who participated in the study were differentially reflected by sex in Table I. The male sample presented significantly

higher values than the female one in the biometric variables of body mass (p <0.001), height (p <0.001) and BMI (p <0.001).

**Table 1.** Comparison of general characteristics by sex.

| | Male | | Female | | p |
|---|---|---|---|---|---|
| **Variable** | **Mean (±SD)** | **Rank** | **Media (±SD)** | **Rank** | **value** |
| **Age (years)** | 28.2 (±7.9) | 19-46 | 29.7 (±3.7) | 24-37 | 0.526* |
| **Body weight (kg)** | 78.2 (±8.5) | 68-95 | 60.3 (±4.4) | 49-65 | <0.001† |
| **Height (cm)** | 178.3 (±4.4) | 170-189 | 166.7 (±5.1) | 155-173 | <0.001* |
| **BFP (%)** | 10.6 (±2.5) | 7-16 | 17.6 (±2.7) | 14-24 | <0.001* |
| **IMC (kg/m$^2$)** | 24.5 (±1.9) | 22-28 | 21.7 (±1.1) | 19-23 | <0.001* |

*Student's T-test; †Mann-Whitney U-test

The variables associated with the training volume of the sample are summarized by sex in Table II.

**Table 2.** Experience and training volume characteristics by sex.

| | Male | | Female | |
|---|---|---|---|---|
| **Variable** | **Mean (±SD)** | **Rank** | **Mean (±SD)** | **Rank** |
| **Paddle tennis experience (years)** | 7.3 (±3.3) | 4-12 | 7.8 (±3.4) | 4-14 |
| **Court sessions (hours/week)** | 8.1 (±0.3) | 8-9 | 11.2 (±3.1) | 8-15 |

Skinfold, muscle girth and bone breadth profiles are shown in Table III. The analysis performed on these variables revealed significantly higher values in females than in males in tricipital, thigh and leg skinfolds (p <0.001).

**Table 3.** Anthropometric variables comparison by sex.

| | Male | | Female | | p |
|---|---|---|---|---|---|
| **Skinfolds (mm)** | **Mean (SD)** | **Rank** | **Mean (SD)** | **Rank** | **value** |
| Bicipital | 4.1 (±1) | 2.8-6.2 | 5.2 (±10) | 3.2-8.2 | 0.782* |
| Tricipital | 9.9 (±3.1) | 6.2-16 | 16 (±4) | 10-22 | <0.001* |
| Subscapular | 10 (±3.7) | 5.8-17.4 | 9.4 (±2.7) | 6.2-16 | 0.664† |
| Suprailiac | 10 (±4.8) | 5.6-21 | 11.1 (±4) | 6.2-22 | 0.176† |
| Supraspinal | 9.3 (±4.2) | 5.6-21 | 10 (±2.7) | 6.2-13.8 | 0.974* |
| Abdominal | 17.4 (±8.9) | 7-38 | 17.9 (±6.6) | 8.2-35 | 0.873† |
| Thigh | 15.3 (±5.5) | 9-26 | 23 (±4.6) | 15.4-29.4 | <0.001* |
| Leg | 9.5 (±4.3) | 5-19.4 | 15.1 (±3.9) | 9-20 | <0.001† |
| Σ 6 skinfolds | 72.4 (±26.9) | 41.8-129.6 | 92.6 (±18.8) | 66.8-142.2 | <0.02* |
| **Girthss (cm)** | | | | | |
| Flexed arm | 34.4 (±2.3) | 31.1-39.3 | 28 (±1.2) | 25-29.8 | <0.001† |
| Medium thigh | 56.8 (±4.1) | 51.1-64.5 | 51.9 (±1.6) | 49.1-54.3 | <0.001† |
| Leg | 38.4 (±2.8) | 35-44.5 | 35.6 (±1.6) | 33.1-38.4 | <0.03† |
| **Breadths (cm)** | | | | | |
| Biepicondyle | 7.1 (±0.3) | 6.7-8 | 6.4 (±1.3) | 5.8-6.8 | <0.001* |
| Biepicondylian | 9.7 (±0.4) | 9.1-10.7 | 8.8 (±0.4) | 8.2-9.4 | <0.001* |
| Bistyloid | 5.8 (±0.3) | 5.5-6.5 | 4.9 (±0.2) | 4.7-5.5 | <0.001* |

*Student's T-test; † U of Mann-Whitney test.

The sum of the six skinfolds (Figure 1) is 72.4 mm and 92.6 mm in men and women, respectively (p <0.02). The fat component was distributed in 51.8% for the trunk (37.4 mm) and 48.1% for the limbs (34.7 mm) in males, whereas in females this relation was more pronounced in the limbs with 58.4% (54.1 mm) of the fat component with respect to the trunk values (41.5% and 38.4 mm).

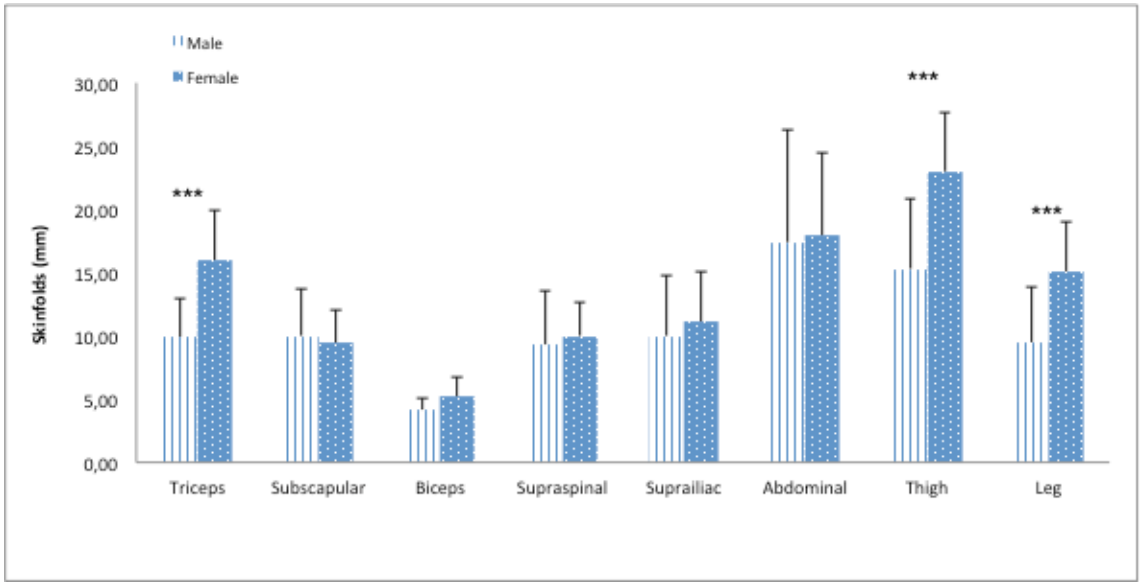


**Figure 1.** Paddle tennis players' skinfolds comparison by sex (***p<0.001).

The data obtained for the body composition presentation (Table IV) are derived from the categories proposed by Carter & Heath (1990). Muscular weight percentages in males are greater than in females (p <0.001), while the percentages of fat are smaller (p <0.001). Paddle tennis players of both sexes are characterized by having a dominant mesomorphy (5.4±0.9 vs 4.0±0.7) and an endomorphy (2.8±0.9 vs 3.8±0.7) greater than the ectomorphy (2.0±0.7 vs. 2.6±0.6). A statistical significance was found between sexes in the endomorphic (p<0.01), mesomorphic (p<0.001) and ectomorphic (p<0.05) components.

**Table 4.** Body composition comparison by sex.

| | Male | | Female | | p* |
|---|---|---|---|---|---|
| **Variable** | **Mean (SD)** | **Rank** | **Mean (SD)** | **Rank** | **value** |
| % Fat mass | 10.6 (±2.5) | 7.7-16.2 | 17.6 (±2.7) | 14.1-24.9 | <0.001 |
| % Muscle mass | 43.4 (±2.4) | 39.4-48.7 | 36.6 (±2.8) | 32.7-42.5 | <0.001 |
| % Bone mass | 15.8 (±0.8) | 14.4-17.4 | 15.5 (±0.6) | 14.5-16.4 | 0.328 |
| Endomorphy | 2.86 (±0.9) | 1.6-5.2 | 3.8 (±0.7) | 2.7-5.9 | <0.01 |
| Mesomorphy | 5.47 (±0.9) | 3.2-7.6 | 4.0 (±0.7) | 2.8-5.3 | <0.001 |
| Ectomorphy | 2.02 (±0.7) | 1.0-3.1 | 2.6 (±0.6) | 1.6-3.5 | <0.05 |

*Student's T-test

Statistically significant differences were found in the percentage of fat and muscle weight (p<0.001) when comparing players by sex. There was a remarkable increase in fat percentage from 10.6 to 17.6% and a decrease from 43.4 to 36.6% in the muscle component between men and women, respectively. The mean somatotype obtained by the male players was 2.8-5.4-2.0 (Figure 2) while that of the female players was 3.8-4.0-2.6 (Figure 3).

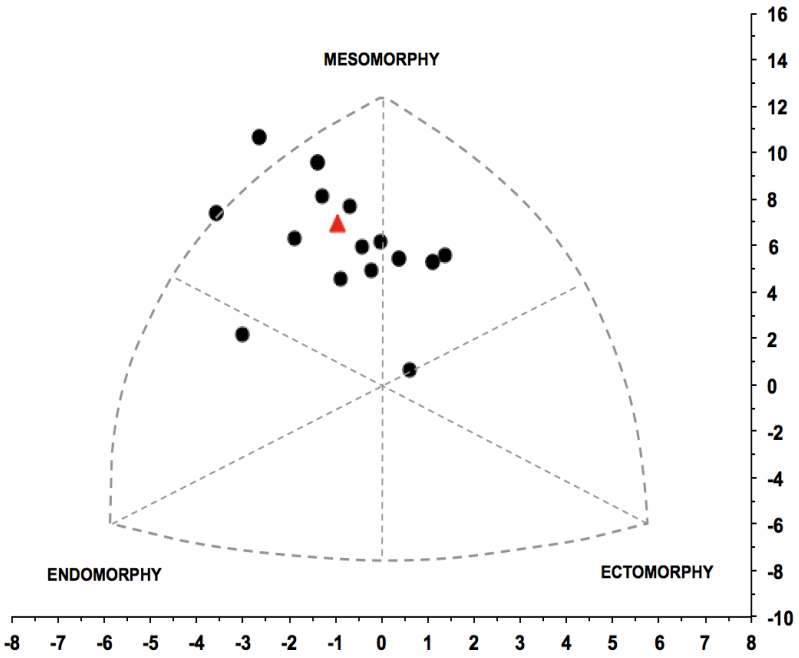


**Figure 2.** Somatochart's male somatotype distribution.

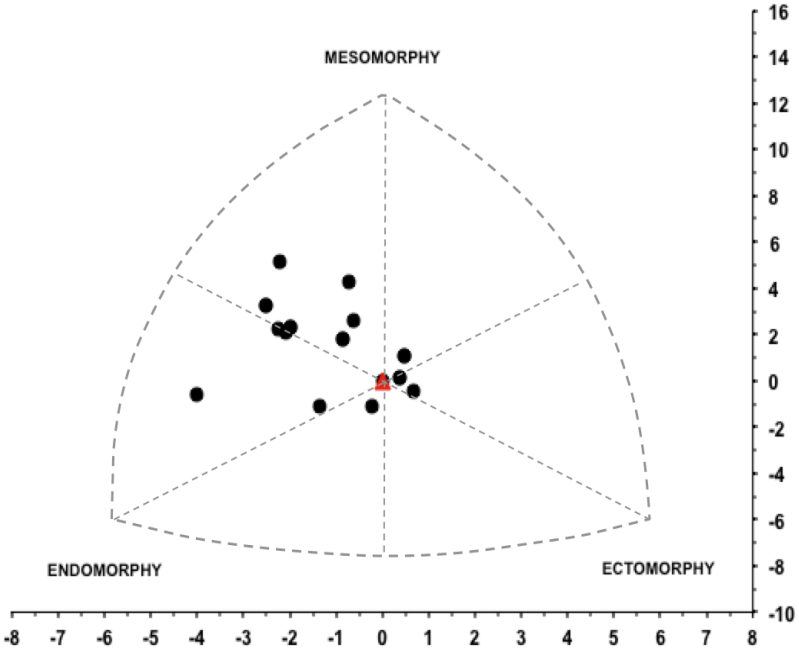


**Figure 3.** Somatochart's female somatotype distribution.

## DISCUSSION

At present, paddle tennis is a sport discipline in a full expansion, evolution and development period, thus it continues to be a rather unknown sport, especially regarding the biotypological indicators that characterize it. This study aims to

improve the knowledge about the anthropometric and somatotype characteristics of elite paddle tennis players of both sexes.

The anthropometric characteristics analysed in this research revealed differences between sexes. Men presented higher values than women in body mass (78.2 vs. 60.3 kg), height (178.3 vs. 166.7 cm) and BMI (24.5 vs. 21.7). The data obtained in this study by the players for these three variables are very similar to those found by Castillo-Rodríguez et al. (2014) in national level paddle tennis players and slightly higher than those recorded by Martinez-Rodriguez et al. (2015) in university athletes.

If we compare the data obtained by the male sample with that of other athletes in different racket sports disciplines, it can be seen that paddle tennis players present slightly higher values than those found in table tennis (178.3±4.4 vs. 177±0.06) (Pradas et al., 2013), but lower than those found in badminton (181±5.7) (Faccini & Dal Monte, 1996) and professional tennis (184±7.1) (Hornery, Farrow, Mújika, & Young, 2007). The high level players analyzed in squash presented different heights (172.6±4.3 cm, 174.5±0.7 cm and 182±7 cm) (Chin et al., 1995; Johansen & Jensen, 1999), which could be related to the phenotype of the populations studied in each case.

The values found for the anthropometric variables (mass, height and BMI) in females are similar to those obtained by Castillo-Rodríguez et al. (2014) in Spanish national level paddle tennis players. As there are not enough studies on this sport, it is necessary to compare these results with other racket sports. It is noted that female paddle tennis players' height is slightly higher than in table tennis (Pradas et al., 2013), and lower than tennis players (Hornery et al., 2007), but it is contained within the height range described in female badminton players (Vicén et al., 2012).

The values presented by paddle tennis players of both sexes lead to think that the height variable may not be as important in this sport as in other disciplines such as tennis or badminton. Probably, one of the possible explanations related to height can have a direct relation with the game's dynamics developed in this sport. In paddle tennis it is possible to let the ball pass to hit it after its bounce, impact and later rebound on the bottom enclosure, which is why it is not essential to carry out hits on high balls, being skills more important than power play in this sport, especially for the most produced game actions, which are those that are developed close to the net, with these being considered as the most relevant and transcendent ones in paddle tennis (Courel-Ibáñez, Sánchez-Alcaraz, & Cañas, 2015).

Female players recorded a body mass very similar to that obtained by Castillo-Rodríguez et al.(2014) but higher than that found in sports such as table tennis (Pradas et al., 2013), although very close to that recorded in badminton (Vicén et al., 2012), but lower than that found in tennis (Hornery et al., 2007).

The male sample had a body mass similar to that found by Castillo-Rodríguez et al. (2014) in national level paddle tennis players, and slightly higher (78.2±8.5 vs. 74.3±8.6) than university players (Martinez-Rodriguez et al., 2015). In comparison to other racket sports, the players analyzed have shown greater body mass. In table tennis, values of 73.6±5.6 and 71.9±9.1 were found in elite players of the Chilean and Spanish teams, respectively (Pradas et al., 2013; Sepúlveda et al., 2015). They are also heavier than the squash players analyzed by Chin et al. (1995), with values of 67.7±6.9 kg. In comparison to the tennis players investigated by Ooi et al. (2009), the sample analyzed also showed higher values, although with a smaller weight difference.

This greater weight recorded in paddle tennis players compared to other racket sports could be closely related to the intensity to which this sport is developed, being inferior to disciplines like badminton, tennis, squash or table tennis, where the game actions occurred are performed at a high speed (Cabello-Manrique & Gonzalez-Badillo, 2003; Chin et al., 1995; Fernández et al., 2006; Pradas et al., 2013). In this sense, an excessive body weight in a paddle player, in particular of the adipose component, can generate a clear disadvantage against the adversary, producing a negative effect on the performance, fundamentally to carry out specific movements, like those that take place close to the net, or to return balls very close to the side and bottom walls, by the greater displacement of non-propulsive tissue, considering the performance of more severe muscular efforts by the degree of acceleration and deceleration that they require (Chin et al., 1995; Pradas et al., 2013).

Within the skinfolds analyzed, and despite the fact that women presented higher values in seven of the eight skinfolds measured, significant differences have been found in only three of them, corresponding to the extremities.

The differences found among sexes in the anthropometric variables of mass, height and BMI, as well as in the different girths and breadths evaluated, are the consequence of a marked sexual dimorphism between men and women (Cox & Calsbeek, 2010).

The body fat percentage (BFP) obtained was lower in men than in women, which is consistent with what is described in the literature for different racket sports (Pradas et al., 2013). Martinez-Rodriguez et al., (2015) describe BFP values in university paddle tennis players far above those found in the elite players analyzed in the present study. These results show that the percentages of BFP are inversely proportional to the players' level of performance.

When comparing the BFP of the male sample with the existing studies on racket sports, it is observed that paddle tennis players present the lowest BFP. Pradas et al. (2013) found BFP values in high level table tennis male players of 12±2.7%. In badminton Majumdar (1997) and Ooi et al. (2009) obtained values slightly above 12%. In squash, BFP values below 12% have been found in high level players (Chin et al., 1995).

Data relating to the BFP of female paddle tennis players were not found among the literature consulted. The values obtained in this study (17.6±2.7%) are higher than those found by (Pradas et al., 2013) in elite table tennis players (14.7±1.5%), but slightly lower than those found in badminton and tennis players with values of 23.6±3.3% and 18.1±2.3%, respectively (Hughes, Reilly, Hughes, & Lees, 1995; Pyke, Elliott, & Pyke, 1974). BFP may be considered as a factor that may limit paddle tennis players´ performance. Moreover, as pointed out by Chin et al. (1995), an excess of body fat could increase the energy expenditure required during a competition, causing a negative impact on physical and technical-tactical performance, which is accentuated as the game goes by.

The somatotype analysis of high level paddle tennis players reveals a mesomorphic-endomorphic type in men, very similar to that found in other similar investigations (Castillo-Rodríguez et al., 2014; Martinez-Rodriguez et al., 2015), where the mesomorphic component is the predominant one, but with important differences in values referring to the endomorphic component, which is probably related to the higher technical and physical level of the high level sample analyzed.

The somatotype analysis reveals a wide distribution of the players throughout the somatochart and specifically the mesomorphic zone. However, women are located closer to the central zone and in the endo-mesomorphic sector, similarly to female tennis players (Solanellas, Tuda, & Rodríguez, 1996).

Even though mesomorphy is the major component in both sexes, body composition results show a higher percentage of BFP in women and a higher body muscular and bone mass percentage in men, with these sexual differences being common among men and women (Cox & Calsbeek, 2010).

It was not possible to make a comparison of the somatotypes obtained since there is currently no data on a reference somatotype in the sport of paddle tennis.

## CONCLUSION

Height does not seem to be such an important variable in this sport compared to other racket sports.

Triceps, thigh and leg skinfolds are significantly lower in men.

The adipose component, expressed both in percentages and in the sum of six skinfolds, presents significantly higher values in women.

Body composition in this sport presents a dominant mesomorphy and a greater endomorphy than ectomorphy in both sexes.

The somatotype obtained by men is mesomorph-endomorphic while that of women is endomorph-mesomorphic.

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**Número de citas totales / Total references:** 25 (100%)
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# Effect of a Padel Match on Biochemical and Haematological Parameters in Professional Players with Regard to Gender-Related Differences

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Received: 25 August 2020; Accepted: 14 October 2020; Published: 18 October 2020


**Abstract:** Haematological and biochemical parameters have not yet been analysed in professional padel players. The aim of this study was to determine the basal values of these parameters and to observe the effect of a simulated competition on them, including gender-related differences. A total of 14 male professional players (age: 28.2 ± 7.9 years), and 16 female professional players (age: 29.7 ± 3.7 years) participated in this study. Players were allowed to hydrate ad libitum during the matches. Haematological and biochemical values were obtained before and after a simulated competitive padel match. The men's group showed higher baseline values in red blood cells, haematocrit, haemoglobin, urea, creatinine, uric acid, albumin, glutamic oxaloacetic transaminase (GOT), glutamic-pyruvic transaminase (GPT), lactate dehydrogenase (LDH) and creatine kinase (CK) ($p < 0.01$) than the women's group. Attending to match effect, significant differences were obtained in urea, creatinine, CK and glucose ($p < 0.05$). Finally, the group x match interaction revealed significant differences in serum concentrations of sodium and chloride ($p < 0.05$). In conclusion, high-level padel matches provoke several changes in biochemical parameters related to muscle damage and protein catabolism. Recovery and fluid intake strategies could be added regarding gender. The results obtained could be due to the differences in the intensity and volume of the simulated competition.

**Keywords:** racket-sport; performance; men; female; blood

## 1. Introduction

Padel is a popular sports activity that has become a mass phenomenon in some countries such as Spain, in the last decade. This sport is practised by populations of any age, gender or physical condition [1]. Padel is an intermittent, racket sport played in pairs (two vs. two) on a small-sized grass court (20 × 10 m) surrounded by glass and mesh walls on which the ball can bounce [2]. These different characteristics with respect to other racket sports have increased interest among researchers. Therefore, it seems essential to know its acute effects on the organism.

Physiologically, padel can be considered a predominantly aerobic sport, with short periods of high and very high intensity actions [3]. Like tennis, padel requires the complex interaction of several physical components (i.e., strength, agility and speed) and metabolic pathways (i.e., aerobic and anaerobic) [4]. Players have to develop fast movements and continuous changes of direction in very short periods, using mainly the phosphagen system (ATP-Pc) to obtain energy. On the other hand, anaerobic glycolysis could be less important. In this sense, maximal lactate values obtained during the game (2.4 mmol/L) confirm this fact [3]. Previous studies have reported low intensity and rest periods about 60.3% of the total time of the game, showing the relevance of the aerobic system [5].

In addition, several authors have analysed the physiological demands in padel competition. During the game, the mean of oxygen consumption ($VO_2$) is about 40–50% of $VO_2$ max measured in a laboratory test [6,7]. Similar results have been observed in other racket sports such as tennis [8]. Maximal $VO_2$ obtained in men and women padel players have been about 50–55 mL/kg/min [3,7], similar values to other racket sports like tennis [9].

Heart rate (HR) is considered an important parameter to determine the physiological demands in padel. The maximal HR obtained in a woman padel player (measured in a laboratory test) was about 177 ± 9.2 bpm [3]. These authors reported a mean HR of 151 ± 8.1 bpm (76.3% of maximal HR) during the game. Maximal HR observed in young men padel players (laboratory incremental test until exhaustion) was 170 ± 18.4 bpm, with a mean HR of 148.3 ± 13.6 ppm (84.9% respect to maximal HR) during the game [6].

Traditionally, studies in padel have been focused on physiological responses [3,6,10], game pattern analysis [11–13] or technical and tactical descriptions [14–17]. Regarding gender differences, a higher total time, in play time and rallies per match are observed in women's padel matches compared to men players [11,18]. However, greater score equality has been found in men's than women's matches [19], which could also indicate a higher intensity in men's padel match play. However, few studies have focused on high level padel players and the gender-related differences.

Previous studies analysed haematological and biochemical values in similar racket sports like tennis [20,21] or badminton [22,23]. However, no studies have evaluated the haematological and biochemical changes in high-level padel players after a padel match. The knowledge of these values could be very interesting to control the training load and program future training. No previous studies have been found on this topic [24,25]. Thus, the main objective of this study was to observe the effects of a simulated padel competition on haematological and biochemical parameters in professional padel players and to evaluate the gender differences.

## 2. Materials and Methods

### *2.1. Subjects*

A total of 30 professional padel players, divided into two groups depending on their gender, participated in this study: 14 male players (age: 28.2 ± 7.9 years; height: 178.3 ± 4.4 cm; weight: 78.2 ± 8.5 kg), and 16 female players (age: 29.7 ± 3.7 years; height: 166.7 ± 5.1 cm; weight: 60.3 ± 4.4 kg). All of them had participated in the professional circuit World Padel Tour during the previous seven years. Anthropometric parameters are presented in Table 1.

**Table 1.** Anthropometric parameters of the participants (mean ± standard deviation).

| Parameters | Men ($n$ = 14) | Women ($n$ = 16) |
|---|---|---|
| Age (years) | 28.2 ± 7.9 | 29.7 ± 3.7 |
| Weight (kg) | 78.2 ± 8.5 | 60.3 ± 4.4 |
| Height (cm) | 178.3 ± 4.4 | 166.7 ± 5.1 |
| Fat mass (%) | 10.6 ± 2.5 | 17.6 ± 2.7 |
| Muscle mass (%) | 43.4 ± 2.4 | 36.6 ± 2.8 |
| $VO_{2max}$ (mL/kg/min) | 55.4 ± 7.0 | 46.8 ± 4.6 |
| Maximum heart rate (bpm) | 179 ± 7.5 | 175 ± 6.4 |
| Training per week (h) | 23.5 ± 3.9 | 24.1 ± 3.3 |

All participants were informed about the aim of the study and gave their informed consent. A code was assigned to each participant for the collection and treatment of the samples in order to maintain their anonymity. This research was carried out according to the Helsinki Declaration ethic guidelines, updated at the World Medical Assembly in Fortaleza (Brazil) in 2013 for research with human subjects. The Clinical Research Ethics Committee of the Department of Health and Consumption of the Government of Aragon (Spain) approved the research project.

### *2.2. Procedures*

The sample was selected by convenience due to the difficulty of finding these types of athletes. Padel players, included in the world ranking, compete around the world. Therefore, a specific moment was selected to evaluate the maximum number of players when they competed in Spain. The volume of training per week was determined by asking the player. In order to record the biochemical and haematological response produced during a competition and considering the difficulties to perform it during a World Padel Tour (WPT) test, a simulated competition (SC) was designed. SC characteristic are presented in Table 2. The SC consisted in the organisation of a padel match where a competitive situation similar to one of an official nature was reproduced, following the rules of the International Padel Federation [26]. The matches were held on an outdoor court with environmental humidity conditions of 43 ± 4.2% and temperature of 22.5 ± 0.8 degrees Celsius. Training intensity and volume were reduced on the two previous days of SC.

**Table 2.** Simulated competition (SC) characteristics (mean ± standard deviation).

| Parameters | Men ($n$ = 14) | Women ($n$ = 16) |
|---|---|---|
| Total Time (min) | 79.4 ± 16.6 | 69.7 ± 17.9 |
| Real Time (min) | 31.2 ± 7.6 | 25.2 ± 17.9 |
| Real Time (%) | 40.7 ± 9.8 | 43.5 ± 11.8 |
| Rest Time (min) | 47.1 ± 9.9 | 33.7 ± 10.6 |
| Rest Time (%) | 59.3 ± 10.2 | 56.5 ± 12.3 |
| Water Intake (mL) | 861.4 ± 369.8 | 737.5 ± 326.1 |

The development of the SC was according to the official regulations applied in professional tournaments playing all the matches to the best of three sets. If the situation of six equal games was reached, a tie break was played. Before starting the SC, the players performed a standardised warm-up of a duration of 15 min, divided into 5 min of generic physical activity and 10 min of a technical specific warm-up on the court. Total time is the full time of the match, from the beginning to the end, considering the periods of game and rest. Real time is the time that passes since a point begins (at the moment it hits the ball the player serving) until the end. Rest time means the time that passes from the end of one point to the beginning of the next point [16].

### *2.3. Determination of Maximum Oxygen Consumption and Maximum Heart Rate*

A maximum incremental test was used to evaluate the physical performance variables. The test consisted of running on a treadmill (Pulsar HP. Cosmos, Nussdorf, Germany) until exhaustion. The treadmill was equipped with a gas analyser (Oxycon Pro. Jaegger, Germany) and pulsometer (Cosmos. Nussdorf, Germany). To guarantee a warm-up phase before the test, all participants ran for 5 min at 6 km/h. The protocol consisted in running in incremental stages, until voluntary exhaustion (no possibility of continuing running) starting at an initial speed of 8 km/h and increasing it by 1 km/h every minute, with a stable slope of 1%.

### *2.4. Blood Samples*

Two extractions of 5 mL of venous blood were drawn from the antecubital vein of each participant. Venous blood samples were collected in Vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA) as anticoagulant. The first sample was extracted 90 min before the matches after a fasting period of 8 h and the second, just after the matches (10 min after). After the first blood extraction, the participants ingested a similar breakfast, which consisted of a bottle of a 5% glucose solution drink. Once extracted, the samples were collected into a metal-free polypropylene tube (previously washed with diluted nitric acid).

Once collected, the blood samples were centrifuged at 2500 revolutions per minute for 10 min at room temperature to isolate the serum. The samples were coagulated for 25–30 min. The serum was aliquoted into an Eppendorf tube (previously washed with diluted nitric acid) and conserved at −80 °C until biochemical analysis. During the matches, the drink ingested was controlled and consisted of bottled mineral water. Players were allowed to hydrate freely during the matches (ad libitum). Body weight was measured before and after the SC.

### *2.5. Determination of Haematological and Biochemical Parameters*

Haematological parameters (red blood cells, haematocrit, haemoglobin and mean corpuscular volume) were determined through an analyser model Coulter model $A^cT$ diff. Urea, creatinine, uric acid, glutamic-oxaloacetic transaminase (GOT), glutamic-pyruvic transaminase (GPT), albumin, lactate dehydrogenase (LDH), creatine kinase (CK), glucose, triglycerides and electrolytes (sodium (Na), potassium (K), chloride ($Cl^-$) and magnesium (Mg)) were determined by spectrophotometric techniques. Complete biochemistry was processed at the laboratory of San Jorge University Hospital, with a Chemistry Analyzer model Advia 1650 (Bayer, Germany).

### *2.6. Statistical Analysis*

A descriptive analysis was performed to show means and standard deviations. The normality of the distribution of the variables was analysed using the Shapiro-Wilk test and the homogeneity of the variances using the Levene test. A two-way ANOVA (Group effect and Match effect) was used to show differences between study variables. The differences between after and before (delta values = Δ) were determined. $p < 0.05$ differences were considered statistically significant. Data were processed in IBM SPSS 25.0 Statistics for Macintosh (IBM Corp., Armonk, NY, USA).

## 3. Results

The results obtained in the body weight and haematological parameters before and after the matches are presented in Figure 1.

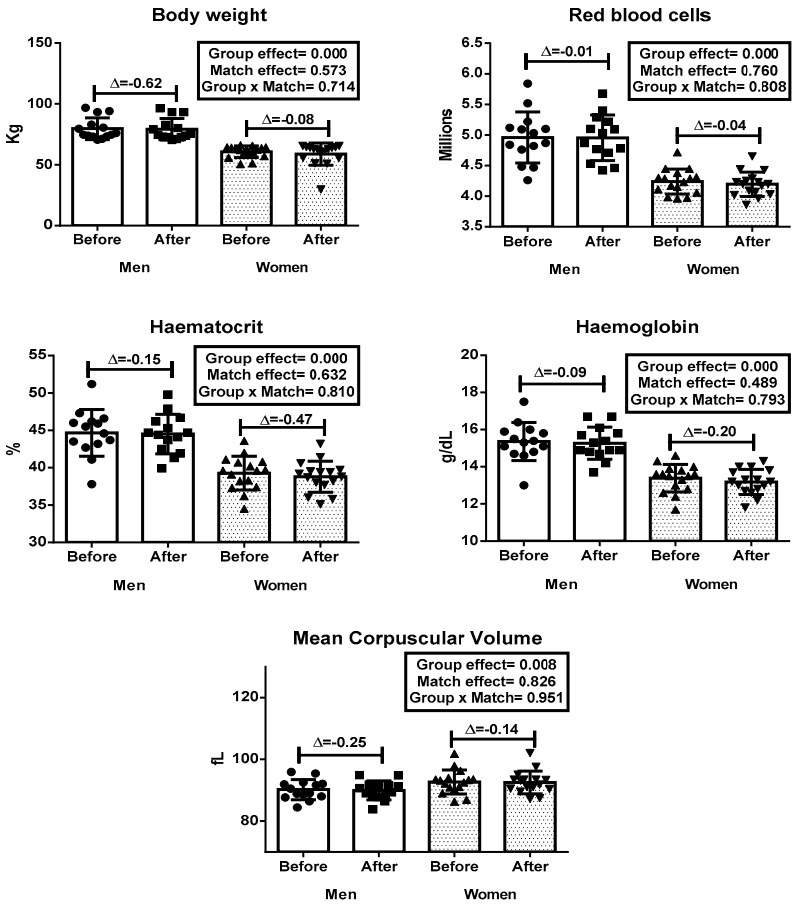


**Figure 1.** Body weight and serum concentrations of the haematological parameters before and after the match in both groups. Δ = delta.

When examining the group effect, significant differences were observed in all parameters ($p < 0.01$). No differences in match effect or group x match interaction were observed.

Biochemical parameters are shown in Figures 2 and 3.

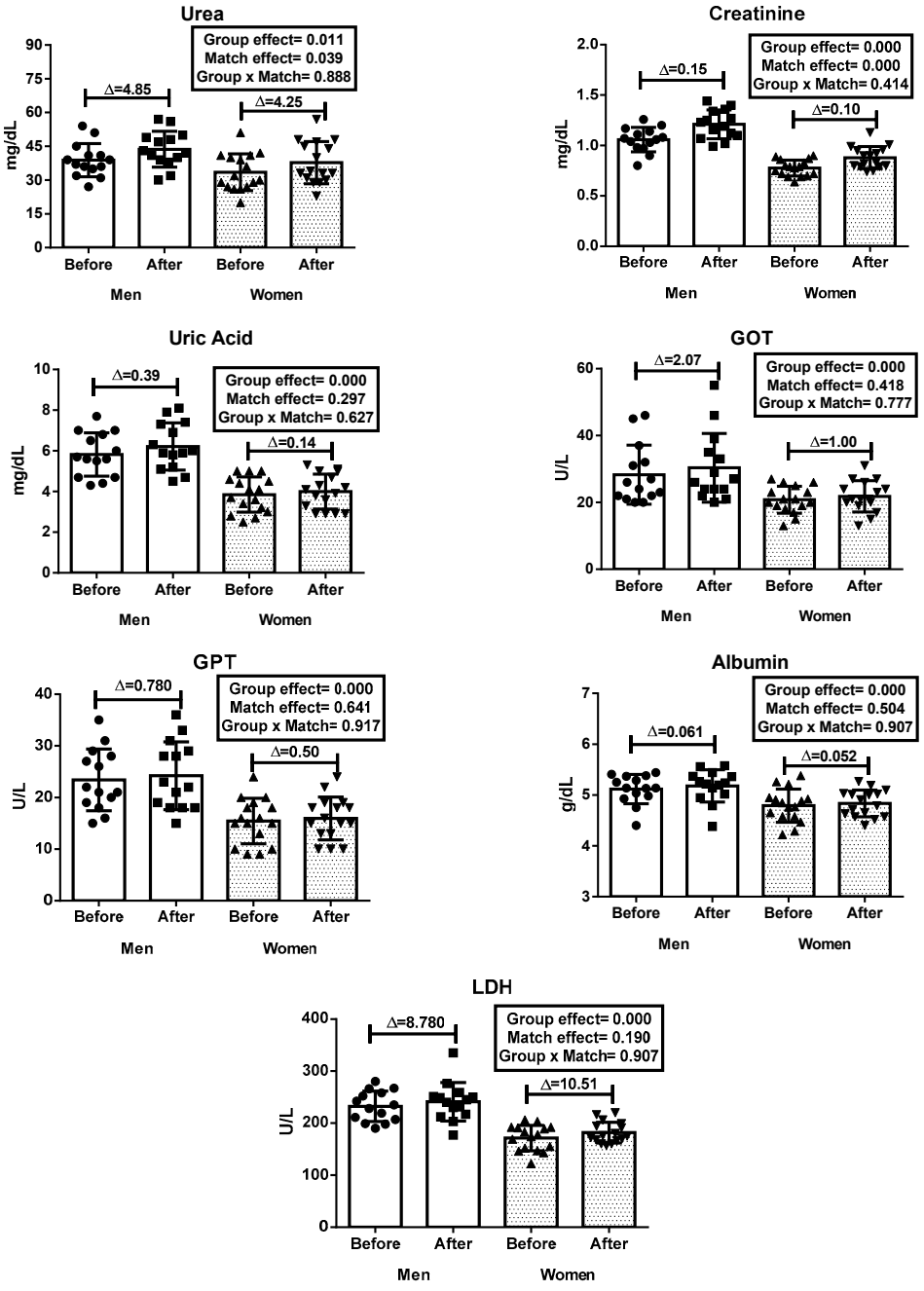


**Figure 2.** Serum concentrations of urea, creatinine, uric acid, GOT, GPT, albumin and LDH before and after the matches in both groups. GOT = Glutamic-Oxaloacetic Transaminase; GPT = Glutamic-Pyruvic Transaminase; LDH = Lactate Dehydrogenase; Δ = delta.

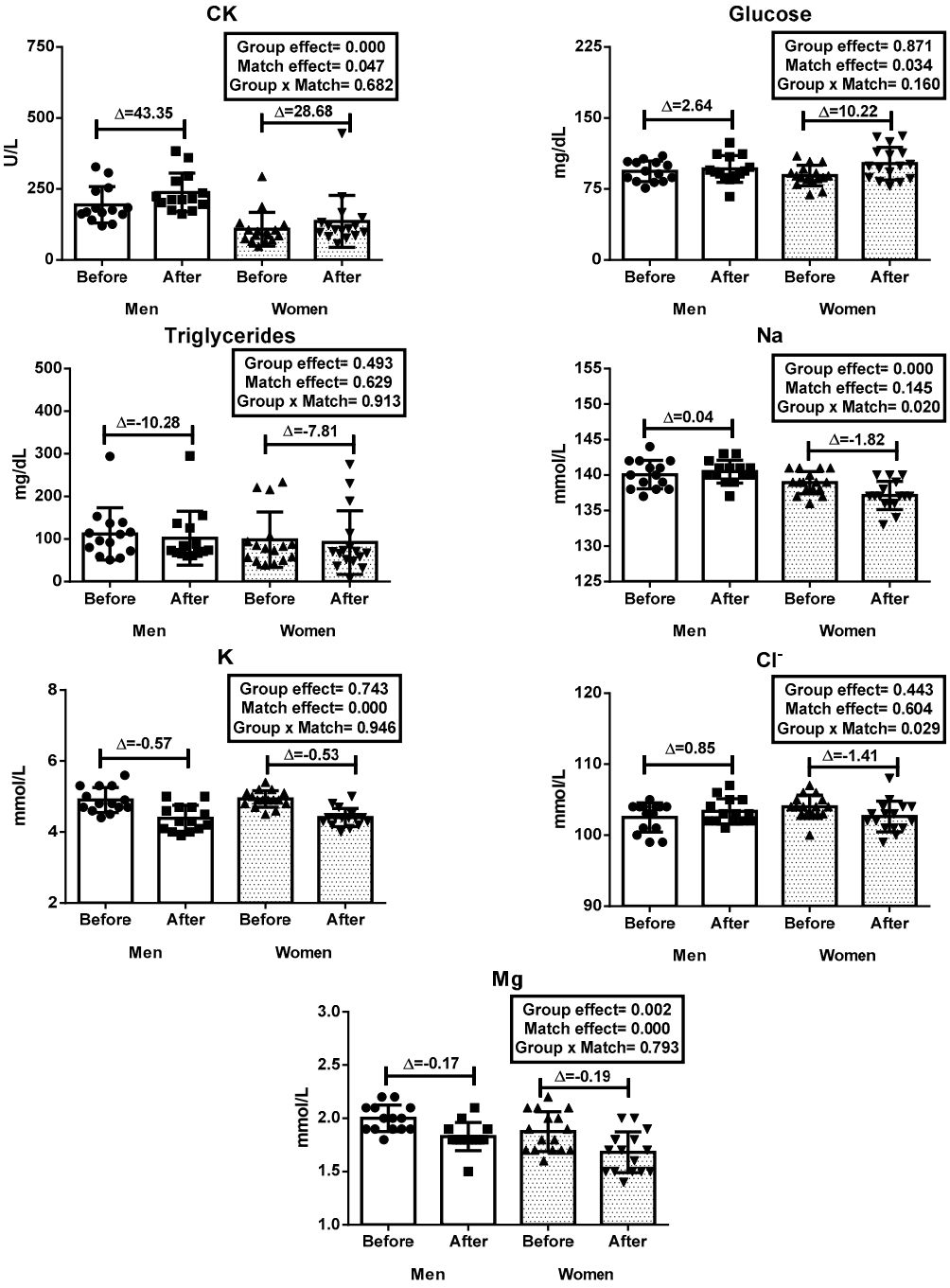


**Figure 3.** Serum concentrations of CK, glucose, triglycerides, Na, K, $Cl^-$ and Mg before and after the matches in both groups. CK = Creatine Kinase; Na = Sodium; K = Potassium; $Cl^-$ = Chloride; Mg = Magnesium; Δ = delta.

Significant differences were observed between groups in all parameters ($p < 0.05$). Higher values were observed in men compared to women. Attending to match effect, significant differences were observed in urea and creatinine ($p < 0.05$).

When examining the group effect, significant differences were observed in CK, Na and Mg ($p < 0.05$). According to match effect, significant differences were obtained in CK, glucose, K and Mg ($p < 0.05$). Finally, in the group x match interaction significant differences were observed in Na and $Cl^-$.

## 4. Discussion

The main objective of this study was to determine the effects of a padel match (simulated competition) on haematological and biochemical parameters in professional padel players, and to observe the gender-related differences. No previous studies have been found in the literature about this topic in padel.

Other racket sports, such as tennis or badminton, have similar physiological characteristics to padel. Badminton is a combination of high-intensity short rallies and longer or moderate-intensity rallies with recovery periods between rallies. Approximately 80% of rallies last less than 10 s and competitive matches last 40 min to 1 h [27]. On the other hand, tennis has average points that last <10 s, but competitions can last >5 h. Tennis is a predominant anaerobic activity requiring high levels of aerobic conditioning to avoid fatigue and recover between points [28].

Firstly, a high-level padel match produced changes in several parameters (especially in biochemical ones), in both the men's and women's groups. All of the haematological [29] and biochemical results [30,31] were in normal ranges.

Regarding haematological parameters, no changes were observed after the matches in any group. In contrast to our study, Abián et al. observed significant changes in men players after a simulated badminton match in haemoglobin and haematocrit [23]. Attending to group effect, significant differences were observed in all parameters. Higher values were observed in men compared to women. These gender-related differences have been previously observed in other sports [32,33]. The difference in testosterone values between genders could explain the higher values observed in the men's group [34], not only related to protein synthesis and tissue growth, but also to erythropoiesis [35,36]. Also, the different muscle mass values and fitness levels of each group may explain gender-related differences in haematological values [37].

Urea, creatinine and uric acid concentrations increased after the SC in both groups. Higher values were observed in men's group. Creatinine and uric acid levels are associated with increased strength and muscle mass [38,39]. Similar results were obtained by Majumdar et al. after a simulated badminton match [22]. In the same way, other authors observed uric acid, urea and creatinine increases after strength training [40]. Uric acid is a final product of purine metabolism, and it has been suggested to be an important antioxidant molecule [40–43]. Antioxidant properties of uric acid have been attributed to the capacity of reacting with biological oxidants [40]. Thus, the increases observed in this parameter after the padel matches could be a mechanism to face the greater production of reactive oxygen species (ROS) cause by the physical exercise [44]. On the other hand, the increases observed in urea after the SC could be associated with an enhanced protein catabolism due to the game intensity. Similar results were observed in previous studies in tennis [45].

An increase in glucose concentration was observed after the match. Similar results were obtained by Akşit et al. in well trained tennis players after a performance test [46]. These changes in glucose values are facilitated by a diminution of insulin hormone concentration and an increase in glucagon and catecholamine plasma levels [47]. During exercise, endogenous glucose production is higher in order to minimise the possible hypoglycaemia risks [48].

Regarding exercise-induced muscle damage, basal values of CK and LDH were higher in the men's than the women's group. A significant increase of CK was observed after the match and this change was higher in the men's group. Previous studies obtained similar results in national badminton players, with increased CK and LDH concentrations after a SC [22,23]. However, Abián et al. observed higher changes in men players after a simulated badminton match compared to our study [23]. In the same way, similar results were obtained by Ojala & Häkkinen after some tennis matches in a tournament [20]. The presence of CK and LDH in blood is a cell-membrane damage indicator [49]. Exercise-induced muscle damage is related to eccentric activities and to highly repeated muscle contractions [50,51]. It has been observed that CK and LDH increases could provoke a loss of strength, reduced range of motion and an increase in muscle soreness [52]. Padel players have to develop fast movements and continuous changes of direction in very short periods, with eccentric and high intensity muscle

contractions, which could explain the increases in serum CK and LDH concentrations [53]. Differences in muscle mass between the genders could explain the higher values of CK and LDH in men.

The results showed increases in transaminases (GOT and GPT) and albumin after a padel match in both groups. Basal concentrations of these parameters were higher in the men than the women. Other studies obtained the same results in bodybuilders [54] and marathon runners [55]. GOT and GPT have been reported as liver status markers. However, they are also present in muscles, heart, kidney, red blood cells, brain and the small intestine [56], and their increase could be more related to muscle damage [57] than to a hepatic disorder. As happened with CK and LDH, the high-intensity actions, changes of direction and powerful hits required in padel could provoke this response.

Finally, electrolyte concentrations (Na, K, $Cl^-$ and Mg) suffered a decrease after the matches; these differences were significant in K and Mg ($p < 0.01$). Attending to group effect, significant differences were observed in Na and Mg ($p < 0.01$). Abián et al. observed the same results after a badminton match [23]. However, no changes in plasma electrolyte values were reported after an indoor tennis match [58], where participants drank fluids ad libitum. The intensity of game [59], dehydration, or distribution of electrolytes in other compartments may affect serum concentrations of electrolytes [60,61]. Also, the weight loss observed in the present study, higher in the men's than the women's group, could be related with an increment in sweat excretion caused by the exercise. Sweat is comprised of several electrolytes, including Na, $Cl^-$ and K [59], and a high sweating is related to an electrolyte deficit, especially $Cl^-$ and Na [62]. On the other hand, other authors suggest that exercise intensity has an impact on sweat K losses in practice [59]. In addition, electrolyte losses observed in other studies demonstrate the large variability among individuals [58]. Thus, these diminished mineral concentrations in serum after the match could be related to a sweat increase in order to reduce metabolic heat production. Great losses could negatively affect performance or provoke some injuries [63]. Our results suggest that different fluid/electrolyte intake strategies may be needed depending upon variations in exercise intensity between training sessions/competitions and gender.

Some limitations of the study should be noted. First, a simulated competition is different from a real competition, so that could affect the results. Second, an indoor surface could be different from outdoor matches. Temperature and humidity conditions and sweat vary according to the conditions. Third, changes in plasma volume after SC were not evaluated. Future research should examine the haematological and biochemical parameters in more detail and consider the conditions under which the matches are played. Monitoring of training load and control of nutritional intake is necessary for future studies.

## 5. Conclusions

This is the first research observing the effects of a high-level padel match on haematological and biochemical parameters and the differences between genders representing a preliminary approach. In addition, these results could be used as a reference for padel players, as they let us know the impact of a padel match on the players. Recovery and fluid intake strategies could be added regarding gender.

In conclusion, with respect to the gender differences, all values analysed were higher in the men's group than the women's group, probably due to the intensity of training and anthropometric characteristics of male padel players. High-level padel matches provoke several changes in parameters related to muscle damage, protein catabolism and electrolytes due to the game intensity. More research is needed in order to clarify these facts.

**Author Contributions:** Conceptualization, F.P. and C.C.; methodology, A.G.-G.; formal analysis, V.T.-R.; investigation, A.G.-G. and B.J.S.-A.; data curation, N.O.; writing—original draft preparation, F.P., N.O. and A.G.-G.; writing—review and editing, V.T.-R., C.C. and B.J.S.-A.; supervision, F.P. and C.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Acknowledgments:** The authors gratefully acknowledge the collaboration of padel players.

**Conflicts of Interest:** The authors declare no conflict of interest.

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International Journal of
*Environmental Research and Public Health*

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# Gender Differences in Neuromuscular, Haematological and Urinary Responses during Padel Matches

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**Abstract:** Research on the acute physiological response to a padel match is limited. The present study aimed to: (a) evaluate neuromuscular, urinary, and hematological responses after simulated padel competition (SC) and (b) analyze possible gender differences. In this study, 28 high-level padel players participated (men = 13, age = 26.83 ± 6.57 years; women = 15, age = 30.07 ± 4.36 years). The following parameters were analyzed before and after SC: neuromuscular (hand grip strength, squat jump (SJ), countermovement jump (CMJ), and Abalakov jump (ABK)), hematological (red blood cells, hemoglobin, and hematocrit), and urinary (pH, specific gravity, microalbuminuria, and red blood cells). Significant gender differences were found in neuromuscular and hematological responses, with men obtaining higher values ($p < 0.05$). For the SC influence, changes were noted in ABK and microalbuminuria ($p < 0.05$). The percentages of change in hand grip strength, SJ (height and watts), CMJ (height), and ABK (height) were higher for men than women ($p < 0.05$). SC negatively influenced the neuromuscular parameters to a greater extent in women. Our results could be related to gender differences in game actions, the temporal structure, and anthropometric and physiological characteristics. Game dynamics and a different organic response between male and female padel playing were confirmed.

**Keywords:** racket sports; jump; fatigue; hand grip strength; performance



**Citation:** Pradas, F.; García-Giménez, A.; Toro-Román, V.; Ochiana, N.; Castellar, C. Gender Differences in Neuromuscular, Haematological and Urinary Responses during Padel Matches. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5864. https://doi.org/10.3390/ijerph18115864

Received: 13 May 2021
Accepted: 28 May 2021
Published: 29 May 2021



## 1. Introduction

Padel is an intermittent racket sport that is played in pairs on a small artificial lawn court (20 × 10 m) surrounded by glass walls and metal meshing, on which balls bounce [1]. Playing padel has become a sport preference for society today [2,3]. In recent years, padel sport practice has exponentially grown in Spain and elsewhere in the world for both genders [2]. This increase could lie in the various advantages that padel offers over other racket sports; for example, no special technical skills are required to start this sport, it can be played both indoors and outdoors, and padel materials are not expensive [2,4,5]. Interest in this sport has grown as different benefits for physical condition and body composition from regularly playing padel have been reported [6].

Regarding its game dynamics, during rallies, padel combines short, highly intensive actions (0.7–1.5 s) and other longer, less intensive actions (9–15 s), which are alternated with pauses and rests between points that normally last 10–20 s [7]. Padel is characterized by being an intermittent sport that is predominantly aerobic and one that includes short high-intense and very high-intense game actions, during which the phosphagen system prevails (ATP-PCr) [8–10]. Indeed, low-intensity and rest periods occupy around 60% of playing time [11]. During a padel match, players have to perform rapid movements and constantly change direction in very short times. This means that strength, agility, and speed

are important physical qualities to play this sport [10]. Compared to other racket sports, padel's characteristics have drawn more researchers' interest in recent years [4,10,12,13].

In gender terms, previous studies report major differences between men and women in the temporal structure and for game actions while playing padel matches [13–15]. Tactical game actions, such as number of lobs per point or number of smashes per point, are more numerous for women than men [16]. Women padel players also more frequently use forehand services and backhand services than their male counterparts, and they perform fewer backhand volleys than men [17]. Men perform a higher percentage of winning smashes than women [13]. For the temporal structure, the total time, playing time, and pieces of play per match are longer, and there are more pieces of play per match in a female padel player than a male padel player, in which short and more intense actions predominate [17,18]. Thus, according to match characteristics per gender, both the load and physiological responses can differ.

Racket sports seem to lead to relevant acute responses on the organism [19,20]. Some authors have previously reported more delayed onset muscle soreness (DOMS) and reduced maximum voluntary contractions (MVC) after several tennis matches [19]. In simulated badminton matches, changes in hemoglobin and hematocrit levels have been found [20]. In other racket sports, alterations to neuromuscular function have also been noted after playing matches [21,22]. Yet, despite the marked increase in the number of scientific publications on padel, today's scientific literature regarding an acute physiological response after a padel match is still limited and unknown [10], and no research works can be found that have analyzed neuromuscular responses in both genders after a padel match. As with other racket sports, a padel match is believed to possibly modify players' neuromuscular responses. Knowledge of acute neuromuscular and physiological response after a padel match could prove to be a key parameter to control and program future training loads. Therefore, the objectives of this study were to analyze (a) neuromuscular, urinary, and hematological responses after a simulated padel competition (SC) and (b) possible gender differences.

## 2. Materials and Methods

### 2.1. Participants

In the present study, 28 high-level padel players participated (men = 13; women = 15), who had all participated in the professional World Padel Tour (WPT) circuit in the past 7 years. The sample was selected by convenience due to the difficulty of finding these types of athletes. All the evaluations were performed after the last day of the WPT. The sample's characteristics are shown per gender in Table 1.

**Table 1.** Participants' characteristics.

| Parameters | Men (n = 13) | Women (n = 15) | *p* |
|---|---|---|---|
| Age (years) | 26.83 ± 6.57 | 30.07 ± 4.36 | 0.056 |
| Weight (kg) | 75.75 ± 7.88 | 63.52 ± 4.14 | <0.001 |
| Height (m) | 1.76 ± 0.03 | 1.67 ± 0.04 | <0.001 |
| Fat (%) | 14.40 ± 5.07 | 20.65 ± 2.64 | <0.001 |
| $VO_{2max}$ (mL/kg/min) | 57.10 ± 5.37 | 46.91 ± 4.31 | <0.001 |
| Maximum heart rate (bpm) | 188.16 ± 10.52 | 182.16 ± 10.52 | 0.655 |
| Experience (years) | 7.25 ± 2.76 | 10.87 ± 3.66 | 0.009 |
| Weekly training (h) | 21.42 ± 3.37 | 22.47 ± 4.01 | 0.973 |

$VO_{2max}$: maximal oxygen consumption.

All the participants were informed about the aim of the study and gave their informed consent. A code was assigned to each participant to collect and process samples to maintain their anonymity. This research work was carried out according to the Declaration of Helsinki ethic guidelines, updated at the World Medical Assembly in Fortaleza (Brazil) in 2013 for research with human subjects. The Clinical Research Ethics Committee of the

Department of Health and Consumption of the Government of Aragón (Spain) approved the research project (code: 21/2012).

The participants had to meet the following criteria to be included in this study: having played in the WPT in at least the last 5 years, finishing SC, not following any special diet, not being on specific medication or over-the-counter medication, and not having any injuries or illness during the research or at least 5 months before the study began.

### 2.2. Procedures

Given the difficulties of analyzing acute neuromuscular and physiological parameters during WPT matches, SC was designed. The SC characteristics appear in Table 2. SC consisted of organizing a padel match to reproduce a competitive situation similar to an official one and in line with International Padel Federation rules [23]. Matches were played on an open-air court. Players' training intensity and volume were reduced in the 2 days before SC to reduce fatigue.

**Table 2.** SC characteristics.

| Parameters | | Men (n = 13) | Women (n = 15) | *p* |
|---|---|---|---|---|
| Side played (%) | Forehand | 38.5 | 40.0 | 0.933 |
| | Backhand | 61.5 | 60.0 | |
| Mean heart rate (bpm) | | 152.46 ± 9.96 | 144.75 ± 18.56 | 0.179 |
| Maximum heart rate (bpm) | | 175.26 ± 9.27 | 173.25 ± 18.23 | 0.712 |
| Total time (min) | | 75.81 ± 18.34 | 70.32 ± 14.04 | 0.318 |
| Real time (min) | | 26.78 ± 8.49 | 25.31 ± 7.43 | 0.730 |
| Rest time (min) | | 50.13 ± 9.21 | 47.65 ± 8.14 | 0.415 |
| Relative humidity (%) | | 42.17 ± 7.69 | 46.02 ± 3.12 | 0.109 |
| Temperature (°C) | | 25.93 ± 5.58 | 24.33 ± 9.24 | 0.662 |
| Water intake (mL) | | 795.21 ± 254.12 | 713.41 ± 301.81 | 0.211 |

SC was organized in accordance with the official regulations for professional tournaments, and all the matches were played with the best of three sets [23]. Matches ended in a tie break if there was a tie after six games. Before starting SC, players did a standard 15-min warm up divided into a 5-min movement and general warm up session and a 10-min specific technical warm up on the court. Players were monitored during SC by pulsometers (Vantage M, Polar, Finland). During matches, what the players drank was controlled. Drinks consisted of bottled mineral water. Players could drink ad libitum during matches.

The total time was the full match time, from the time it began to the time it ended and included game and rest periods. Real time was the time from when a point began (when the serving player hit the ball) until the end. Rest time was from the end of one point to the beginning of the next point [10].

### 2.3. Anthropometric Measurements

The participants' morphological characteristics were evaluated in the morning and always under the same conditions. Body height was measured to the nearest 0.1 cm, using a wall-mounted stadiometer (Seca 220, Hamburg, Germany). Body weight was measured to the nearest 0.01 kg on calibrated electronic digital scales (Seca 769, Hamburg, Germany) in the nude and barefoot. A Holtain© 610ND (Holtain, Crymych, UK) skinfold compass, accurate to ±0.2 mm, was employed for the anthropometric assessments. These measurements were height, weight, and six skinfolds (abdominal, suprailiac, subscapular, tricipital, thigh, leg). Yushaz equations were used to calculate the fat percentage [24]. All the measurements were taken by the same operator, who was skilled in kinanthropometric techniques, in accordance with the International Society for the Advancement of Kinanthropometry recommendations [25]. Body weight was measured both pre-SC and post-SC.

### 2.4. Testing Protocol

One week before SC, a maximum progressive test was run in the laboratory on a treadmill (Pulsar HP, Cosmos, Nussdorf, Germany) to determine the physical performance parameters. This test was performed at a 1% slope, starting at a speed of 8 km·h$^{-1}$ and incorporating 1 km·h$^{-1}$ increments every minute. Before strength testing began, the participants warmed up on a treadmill at the speed of 6 km·h$^{-1}$ for 5 min. Gases were analyzed by an Oxycon Pro analyzer (Jaegger, Germany). A pulsometer (Vantage M, Polar, Finland) was used to evaluate the maximum heart rate.

### 2.5. Neuromuscular Test

Neuromuscular function was evaluated by hand grip strength, the squat jump (SJ), the countermovement jump (CMJ), and the Abalakov jump (ABK) [26,27]. Assessments were carried out 1 h before and after SC (2–5 min after). The jump tests were selected to measure the neuromuscular function of leg extensor muscles because they can achieve this at a high reliability level [28,29]. A jump mat system (Chronojump Boscosystems, Barcelona, Spain) was employed to measure jump heights, watts, and times. Three attempts were allowed for all jumps, with a 30 s rest period between jumps. The best jump was chosen to be later analyzed. All the jump tests were carried out in line with the guidelines of both Markovic et al. [30] and Rodríguez-Rosell et al. [28].

Hand grip strength was measured by a Takei 5101 dynamometer (Takei Instruments Ltd., Tokyo, Japan). The participants did two MVCs while fully extending hands and arms. Both the dominant and non-dominant arms were assessed. The dynamometer gripping piece was adapted to the participants' hands [31]. They had two attempts, and the mean value was selected to be later analyzed.

### 2.6. Blood Samples and Analyses

Two venous blood samples were taken (5 mL) from the antecubital vein from each participant. Blood samples were collected in coded Vacutainer tubes containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant. The first sample was taken 120 min before SC after a minimum period of approximately 8 h since the last eaten meal. The second sample was taken when matches ended (7–10 min after). After the first blood sample, the participants ingested a similar breakfast, which consisted of a bottle of drink with 5% glucose solution.

Hematological parameters (red blood cells, hematocrit, hemoglobin) were determined with an analyzer model Coulter model AcT diff in the laboratory of the San Jorge University Hospital (Huesca, Spain).

### 2.7. Urine Samples and Analyses

The first urine sample in the morning and the first urine sample after SC were taken from all the subjects. They were collected in polyethylene tubes previously washed with diluted nitric acid and frozen at −80 °C until analyzed, and once the container was handed over, it was measured and codified. Prior to analyses, samples were thawed and homogenized by shaking.

A 10 mL quantity was used to obtain the different evaluated parameters. Specific gravity was analyzed in situ with a precalibrated refractometer (URC-Ne, Atago, Japan), as previously described [32]. Biochemical variables (pH, microalbuminuria (MA), erythrocytes) were measured by placing a reagent strip (Combur Test, Roche, Spain) in a small portion of urine samples. Next, the strip was placed inside an automatic reflection photometer (Urisys 1100, Roche, Spain) to measure the parameters after a 1 min incubation time.

### 2.8. Statistical Analysis

Data were processed in IBM SPSS 25.0 Statistics for Macintosh (IBM Corp., Armonk, NY, USA) and expressed as the mean ± standard deviation. The normality of the distribu-

tion of variables was analyzed by the Shapiro–Wilk test and the homogeneity of variances by the Levene test. The Student's *t*-test was employed to determine the differences in percentages of change (pre-SC vs. post-SC). A two-way ANOVA (gender effect and SC effect) was used to show any differences in the studied variables. Effect size was calculated by the two-way ANOVA, using partial eta-squared (η2), where 0.01–0.06 was a small effect size, 0.06–0.14 was a moderate effect size, and >0.14 was a large effect size [33]. $p < 0.05$ differences were considered to be statistically significant.

## 3. Results

The results obtained in this study are provided below. A two-way ANOVA was used, as shown in Tables 3–6. Table 1 presents the results for the variables body weight and hand grip strength. Significant gender differences appeared in all the variables ($p < 0.001$).

**Table 3.** The sample's body weight and hand grip strength.

| Parameters | Time | Men (n = 13) (M ± SD) | Women (n = 15) (M ± SD) | Gender Effect | η2 | SC Effect | η2 | Gender × SC | η2 |
|---|---|---|---|---|---|---|---|---|---|
| Weight (kg) | Pre | 75.75 ± 7.88 | 63.52 ± 4.14 | <0.001 | 0.623 | 0.789 | 0.001 | 0.482 | 0.010 |
| | Post | 76.29 ± 8.06 | 62.12 ± 5.30 | | | | | | |
| Dominant hand grip strength (kg) | Pre | 50.50 ± 9.59 | 34.46 ± 4.94 | <0.001 | 0.663 | 0.507 | 0.009 | 0.083 | 0.058 |
| | Post | 55.24 ± 9.20 | 32.32 ± 4.27 | | | | | | |
| Non-dominant hand grip strength (kg) | Pre | 44.42 ± 7.60 | 27.95 ± 2.62 | <0.001 | 0.721 | 0.842 | 0.001 | 0.174 | 0.036 |
| | Post | 47.00 ± 8.72 | 26.03 ± 3.83 | | | | | | |

SC: simulated padel competition; η2: eta-squared.

**Table 4.** Results obtained in the jump tests for both groups.

| Parameters | Time | Men (n = 13) (M ± SD) | Women (n = 15) (M ± SD) | Gender Effect | η2 | SC Effect | η2 | Gender × SC | η2 |
|---|---|---|---|---|---|---|---|---|---|
| SJ (m) | Pre | 0.270 ± 0.09 | 0.214 ± 0.04 | <0.001 | 0.222 | 0.173 | 0.036 | 0.260 | 0.025 |
| | Post | 0.262 ± 0.09 | 0.164 ± 0.062 | | | | | | |
| SJ (W) | Pre | 2835.08 ± 675.04 | 2037.98 ± 476.46 | <0.001 | 0.508 | 0.233 | 0.028 | 0.121 | 0.047 |
| | Post | 2906.31 ± 509.93 | 1638.66 ± 462.43 | | | | | | |
| SJ (W/kg) | Pre | 36.27 ± 8.09 | 33.69 ± 7.80 | 0.011 | 0.121 | 0.210 | 0.031 | 0.128 | 0.035 |
| | Post | 36.45 ± 4.87 | 28.44 ± 8.07 | | | | | | |
| CMJ (m) | Pre | 0.319 ± 0.08 | 0.243 ± 0.05 | <0.001 | 0.276 | 0.859 | 0.001 | 0.240 | 0.027 |
| | Post | 0.343 ± 0.141 | 0.210 ± 0.04 | | | | | | |
| CMJ (W) | Pre | 3135.00 ± 713.17 | 2213.06 ± 480.28 | <0.001 | 0.544 | 0.489 | 0.009 | 0.180 | 0.035 |
| | Post | 3230.06 ± 479.42 | 1918.52 ± 436.69 | | | | | | |
| CMJ (W/kg) | Pre | 39.98 ± 8.95 | 36.64 ± 7.99 | 0.007 | 0.135 | 0.424 | 0.013 | 0.284 | 0.022 |
| | Post | 40.51 ± 3.72 | 33.02 ± 6.60 | | | | | | |
| ABK (m) | Pre | 0.376 ± 0.09 | 0.289 ± 0.05 | <0.001 | 0.296 | 0.036 | 0.084 | 0.926 | 0.000 |
| | Post | 0.336 ± 0.07 | 0.246 ± 0.04 | | | | | | |
| ABK (W) | Pre | 3437.58 ± 864.36 | 2539.93 ± 486.07 | <0.001 | 0.480 | 0.136 | 0.043 | 0.235 | 0.027 |
| | Post | 3387.61 ± 517.14 | 2109.06 ± 442.69 | | | | | | |
| ABK (W/kg) | Pre | 43.79 ± 10.91 | 42.22 ± 8.94 | 0.080 | 0.059 | 0.103 | 0.051 | 0.294 | 0.022 |
| | Post | 42.49 ± 4.31 | 36.32 ± 6.61 | | | | | | |

SC: simulated padel competition; SJ: squat jump; CMJ: countermovement jump; ABK: Abalakov jump; η2: eta-squared.

**Table 5.** Urinary parameters before and after CS in both groups.

| Parameters | Time | Men (n = 13) (M ± SD) | Women (n = 15) (M ± SD) | Gender Effect | η2 | SC Effect | η2 | Gender × SC | η2 |
|---|---|---|---|---|---|---|---|---|---|
| Specific gravity (g/mL) | Pre | 1.024 ± 0.004 | 1.020 ± 0.005 | 0.015 | 0.110 | 0.576 | 0.006 | 0.981 | 0.000 |
| | Post | 1.023 ± 0.005 | 1.019 ± 0.006 | | | | | | |
| pH | Pre | 5.83 ± 0.88 | 6.50 ± 0.73 | 0.268 | 0.024 | 0.332 | 0.018 | 0.099 | 0.052 |
| | Post | 6.00 ± 0.84 | 5.86 ± 1.02 | | | | | | |
| MA (g/L) | Pre | 47.25 ± 18.81 | 46.52 ± 33.67 | 0.609 | 0.005 | 0.001 | 0.210 | 0.599 | 0.005 |
| | Post | 207.51 ± 147.11 | 260.47 ± 328.64 | | | | | | |
| RBC (cells/µL) | Pre | 0.833 ± 2.88 | 0.661 ± 0.25 | 0.242 | 0.027 | 0.136 | 0.043 | 0.211 | 0.031 |
| | Post | 3.076 ± 4.80 | 25.332 ± 63.76 | | | | | | |

SC: simulated padel competition; η2: eta-squared; MA: microalbuminuria; RBC: red blood cells.

**Table 6.** The participants' hematological parameters.

| Parameters | Time | Men (n = 13) (M ± SD) | Women (n = 15) (M ± SD) | Gender Effect | η2 | SC Effect | η2 | Gender × SC | η2 |
|---|---|---|---|---|---|---|---|---|---|
| RBC ($x10^{12}$/L) | Pre | 4.99 ± 0.42 | 4.23 ± 0.21 | <0.001 | 0.637 | 0.803 | 0.001 | 0.791 | 0.001 |
| | Post | 4.99 ± 0.35 | 4.19 ± 0.20 | | | | | | |
| Hb (g/L) | Pre | 154.16 ± 10.92 | 133.06 ± 6.89 | <0.001 | 0.656 | 0.555 | 0.007 | 0.758 | 0.002 |
| | Post | 153.53 ± 8.46 | 131.06 ± 6.31 | | | | | | |
| Hct (L/L) | Pre | 0.44 ± 0.03 | 0.38 ± 0.02 | <0.001 | 0.622 | 0.602 | 0.005 | 0.844 | 0.001 |
| | Post | 0.447 ± 0.02 | 0.385 ± 0.01 | | | | | | |

SC: simulated padel competition; η2: eta-squared; RBC: red blood cells; Hb: hemoglobin; Hct: hematocrit.

Table 4 shows the results obtained in the jump tests. Significant gender differences appeared in all the variables, except for watts, relating to body weight in ABK ($p < 0.05$). Significant post-SC differences were found for ABK ($p < 0.05$).

Table 5 presents the results obtained in the urinary analysis. Significant gender differences were found for specific gravity ($p < 0.05$). For the SC effect, differences appeared for MA ($p < 0.01$).

Table 6 provides the study participants' hematological parameters. Significant gender differences were found in all the studied variables ($p < 0.001$).

Figures 1 and 2 illustrate the percentages of change in the analyzed neuromuscular parameters. Student's *t*-test was used to determine differences in percentage change (pre-SC vs. post-SC). Data were expressed as the mean ± standard deviation. Significant differences in hand grip strength were found: SJ (height and watts), CMJ (height), and ABK (watts), with more marked changes for men ($p < 0.05$).

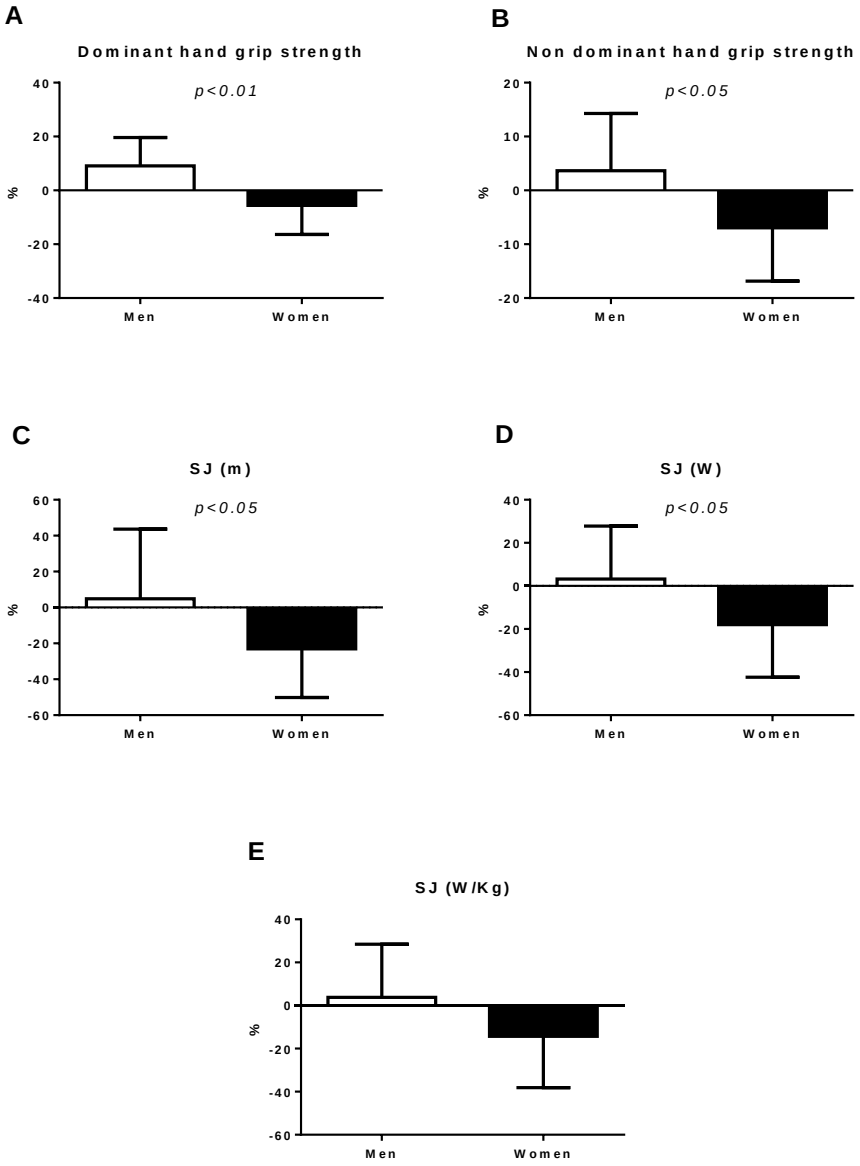


**Figure 1.** The percentages of change in the hand grip strength and neuromuscular parameters: (**A**) The percentage of change in the dominant hand grip strength; (**B**) the percentage of change in the non-dominant hand grip strength; (**C**) the percentage of change in SJ; (**D**) the percentage of change in the SJ watts; (**E**) the percentage of change in the watts in relation to body weight SJ; SJ: squat jump.

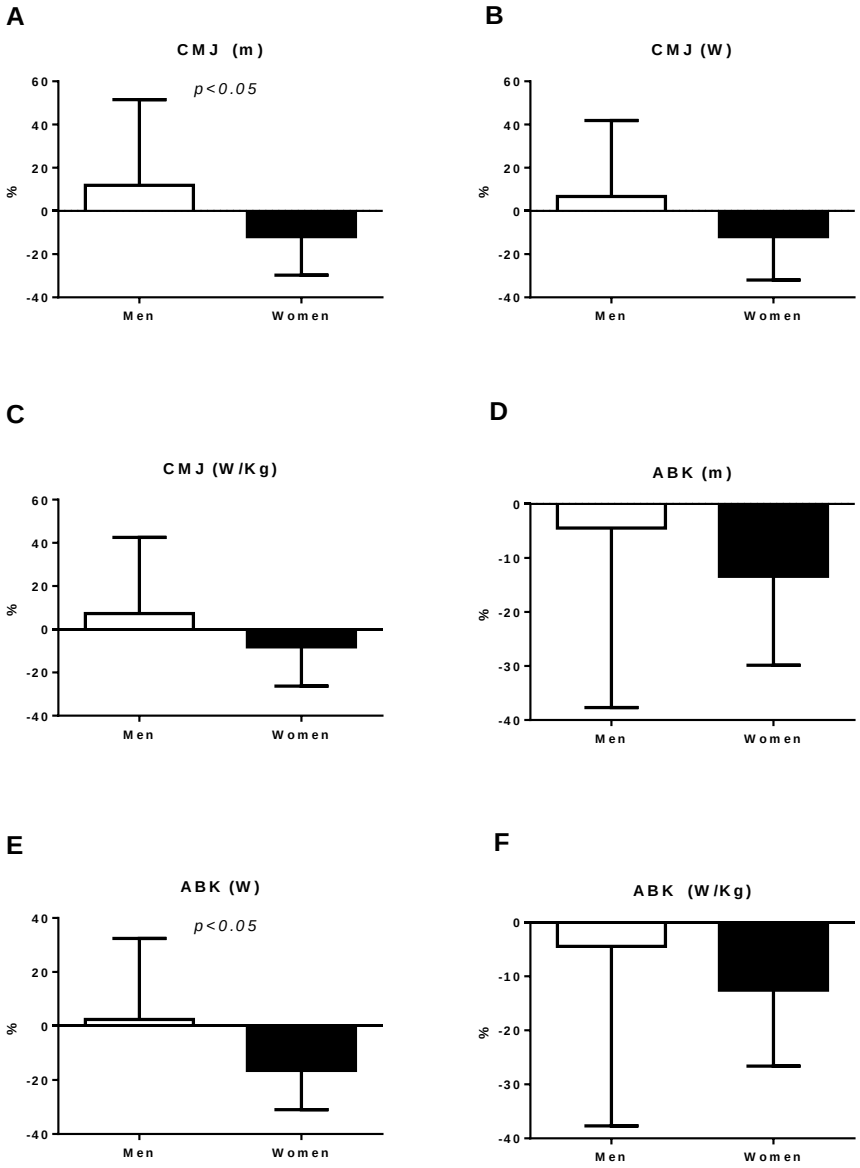


**Figure 2.** The percentages of change in the neuromuscular parameters (CMJ and ABK): (**A**) The percentage of change in CMJ height; (**B**) the percentage of change in CMJ watts; (**C**) the percentage of change in the watts in relation to body weight CMJ; (**D**) the percentage of change in ABK height; (**E**) the percentage of change in ABK watts; (**F**) the percentage of change in the body weight watts. CMJ: countermovement jump; ABK: Abalakov jump.

## 4. Discussion

The objectives of the present study were to analyze (a) neuromuscular, urinary, and hematological responses after a match and (b) possible gender differences. The SC brought about significant changes in both ABK height and MA in all the study participants. For gender differences, the percentages of change in hand grip strength, SJ (height and watts), CMJ (height), and ABK (height) were higher in men than women. As far as we know, this is the first study to analyze neuromuscular response after padel matches. Although the hematological changes after padel matches have been previously reported [10], the present research work provides information about neuromuscular and urinary changes. The participants' hematological [34] and urinary [35] parameters fell within the normal ranges.

The hand grip strength evaluation is employed in many sports [36], especially racket sports [37]. The present study found gender differences in both the absolute values

($p < 0.001$) and the post-SC percentage of change ($p < 0.05$). The values obtained herein in men for hand grip strength were similar to those reported for padel by Sánchez-Muñoz et al., [7] in male elite players. Regarding gender differences, previous studies have found higher hand grip strength values generally for men [38] and for tennis [39,40] and badminton players [37], compared to women. The present study found asymmetric hand grip strength regarding padel, similar to other studies [7] and sports [41,42]. Lack of post-SC hand grip strength changes coincides with the results obtained for badminton [43]. Apparently, racket sports report no gender differences in forearm muscle fatigability during intermittent fist submaximal contractions, regardless of muscle strength [44]. This means that the physical stress induced during SC did not affect upper limb capacity to generate strength.

Significant gender differences were noted in the jump tests for all the variables, except the watts, related to body weight for ABK ($p < 0.05$). The percentage of post-SC change was found in men, who performed slightly better in SJ (height and watts), CMJ (height), and ABK (watts) than women ($p < 0.05$). The post-SC differences were significant in ABK height ($p < 0.05$). In general terms, the power recorded in jumps did not change after SC and even slightly improved in men. Jump tests were employed to evaluate neuromuscular and metabolic fatigue [45]. The reported data herein suggest that SC did not cause neuromuscular fatigue in the lower body. These results fall in line with those reported in other racket sports, such as tennis [19,46–49] or badminton [37,43]. Nevertheless, other authors have obtained contradictory results for the height and mean power in CMJ after playing a tennis match [50]. These findings could be attributed to not only different court surfaces, but also each typical intermittent-type physiological response of these sports, because padel matches involve long breaks that might even prevent neuromuscular fatigue. While playing high-intensity intermittent sports, recovery periods play a key role in limiting fatigue [21]. Moreover, the gender differences found for the jump variables agree with those previously obtained in padel players, regardless of their level [4,51]. The significantly higher height/power values obtained by men in jumps versus women might be due to anthropometric and strength differences between both genders, a circumstance that also appears not only with high-level tennis and badminton players but also with other sport disciplines [52].

Hematological differences appeared in men, obtaining higher values for RBC, hematocrit, and hemoglobin than women ($p < 0.001$). These differences have also been previously reported for padel players [10], swimmers [53], and other sports [54]. Hormone differences and differences in muscle mass and physical condition between genders could influence hematological values [55–57].

The urinary values revealed a significant gender difference for specific gravity ($p < 0.05$). The SC effect also led to a difference in MA ($p < 0.01$). Urine specific gravity has been used to measure sportspeople's hydration status [58,59]. A specific gravity value of >1020 g/mL is used to indicate dehydration [60]. Thus, according to the results reported herein, our participants presented dehydration when they began SC. After the match, men's dehydration status became worse, but it improved in women. Similar to our study, Silva et al. [58] reported lower values for women than men, while Volpe et al. [61] demonstrated that 13% of student athletes were significantly hypohydrated, with a higher percentage for men hypohydrated (47%) than hypohydrated women (28%). The observed gender differences in specific gravity could be related to women's anthropometric and game characteristics. Women tend to perform pieces of play more slowly and have a smaller body size and lower metabolic rates, which can all imply less sweating than men [62], which would facilitate better rehydration while playing matches. Regarding increased MA, some studies have observed how this parameter increases after intense physical exercise [63,64]. High-intensity physical exercise can lead to hematuria and proteinuria appearing. These urinary anomalies are related to constricting kidney blood vessels that slow down renal plasma flow during exercise [65]. The increase in MA noted in the present study could be the

result of greater glomerular permeability or filtered load or due to a reduction in tubular absorption caused by physical exercise [63,66].

The present study has some limitations. First of all, the match was not real, which could affect the results because players' expectations and motivations could differ. Secondly, no changes in plasma were included. Thirdly, our small sample size limited the generalization of the obtained results. Fourthly, this study was conducted on an outdoors court, whereas, today, padel is increasingly played indoors. The results could differ on indoor courts because of the distinct temperature and humidity conditions. Finally, game surfaces have been recently modified, which could influence the results obtained in the present research work. Therefore, conducting new studies could be very interesting.

## 5. Conclusions

According to our results, SC did not negatively affect men's neuromuscular fatigue, unlike women, who were more affected. Regarding urinary and hematological changes, SC affected only MA excretion in both genders.

These differences could be due to both genders' physiological and anthropometric characteristics and to differences in game actions and the temporal structure while playing padel matches. Further research is necessary to elucidate these facts.

**Author Contributions:** Conceptualization, F.P. and C.C.; methodology, F.P., N.O. and A.G.-G.; formal analysis, V.T.-R.; investigation, F.P., A.G.-G. and C.C.; data curation, N.O.; writing—original draft preparation, F.P., N.O. and A.G.-G.; writing—review and editing, V.T.-R., F.P. and A.G.-G.; supervision, F.P. and C.C. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** The study was conducted according to the guidelines of the Declaration of Helsinki, updated at the World Medical Assembly in Fortaleza (Brazil) in 2013, and approved by the Ethics Committee of the Department of Health and Consumption of the Government of Aragon (Spain) (code: 21/2012).

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

**Acknowledgments:** Special thanks to the entire medical team of the Sports Medicine Centre of the Government of Aragon, especially Juan José Lacleta. Thanks to each and every one of the athletes participating in this study.

**Conflicts of Interest:** The authors declare no conflict of interest.

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International Journal of
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# Performance Outcome Measures in Padel: A Scoping Review

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**Abstract:** Padel is a modern doubles racket sport which has become popular around the world in the last decades. There has been an increase in the quantity of scientific research about this sport in the last years. Therefore, the main objective of this scoping review is to provide an updated contextualization of research regarding padel. PRISMA ScR was used in order to search for articles fulfilling the inclusion criteria in five fields of interest: the anthropometric profile, physiology and physical performance, biomechanics, the epidemiology of injuries, and match analyses Seventy-seven records were included in the study. Padel is an emerging sport both in sport and research terms. This scoping review provides coaches and researchers with all the knowledge available in the five fields of interest. Furthermore, this study enables them to make a map of the current state of the research about padel, and it opens up doors to future investigations.

**Keywords:** padel; anthropometry; physiology; physical performance; biomechanic; injury; match analysis



**Citation:** 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. https://doi.org/10.3390/ijerph19074395

Academic Editor: Paul B. Tchounwou

Received: 17 February 2022
Accepted: 4 April 2022
Published: 6 April 2022



## 1. Introduction

Padel is a modern doubles racket sport invented in Acapulco (Mexico) in 1962 [1]. After becoming very popular in Spain in the last decades, with more than 4 million regular practitioners, and positioned in the top 10 most practiced sports in the country [2], this sport has an international presence in 44 countries around the world [3]. Today, worldwide professional tournaments are celebrated in Spain, Portugal, Mexico, Argentina, Qatar, Italy, United Arab Emirates, United States, Sweden, Germany, Ecuador, Uruguay, Holland, Paraguay, Lithuania, Chile, Ireland, Japan, Denmark, and France [4].

In padel, two pairs of players confront each other following a tennis scoring system and similar rules regarding the timing, position of players, sides, service, returns, and scoring, with the difference being that it is played in an enclosed synthetic glass and metal court allowing the ball to bounce on lateral and back walls for rallies [5]. The court measures 20 m × 10 m (length × width) and it is divided by a normal tennis net (0.88 m at the center strap and 0.92 m at the post) in the middle [5]. The back wall is 3 m × 10 m (height × length) and the side walls are 3 m × 2 m, ending on another 2 m × 2 m wall [5]. The rest of the court, for each half and the later side, consists of two metallic panels of equal dimensions (3 m × 2.59 m) and one gate (2 m × 0.82 m) [5]. Each half court is composed of two service boxes, defined by the service line, which is parallel, and at 6.95 m distance with respect to the net and a perpendicular line dividing the service and net lines [5]. Hence, these characteristics—where players have a theoretical responsibility area of 5 m × 2.5 m, as well as the walls around the court—let them lengthen rallies in comparison to other racket sports, such as badminton and tennis, with bigger courts and no walls [6].

In the last years, an augment in scientific research around padel has arisen to a better understanding of its characteristics and requirements both for professional and non-professional players (Figure 1). Therefore, some studies have investigated its specific anthropometrics [7,8], biomechanics [9], epidemiology [10,11], physiological and physical

requirements [12], temporal structure, tactics, and strokes [13–16]. Otherwise, there have been few studies aimed at reviewing the data available concerning padel [17–19] with the purpose of a better global understanding of this sport. This might probably be due to the lack of research over the last years on the traditionally-called "major racket sports" [20], such as tennis [21,22], table tennis [23], badminton [24], and squash [25].

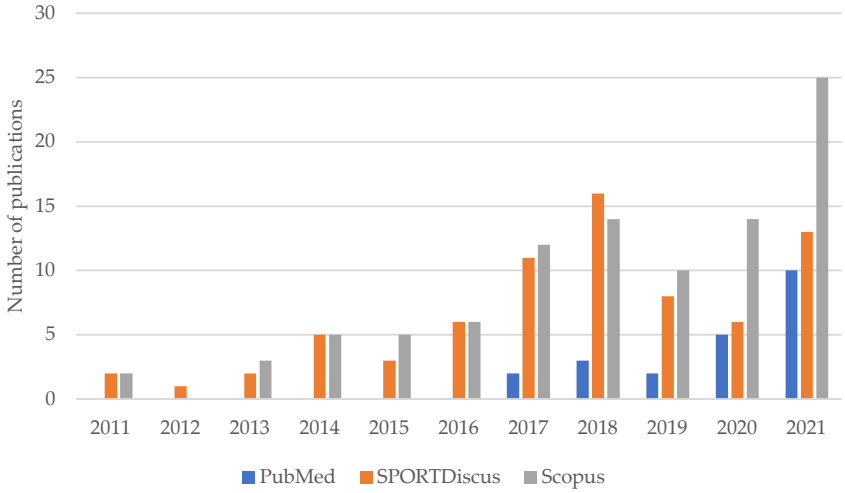


**Figure 1.** Articles containing the terms "padel" or "paddle tennis" in their title and/or abstract referring to the sport published in the databases PubMed, SPORTDiscus, and Scopus in the last 10 years (self-made figure).

With this background, the objective of this scoping review was to provide an updated contextualization of the sport of padel regarding its anthropometrics, physiological and physical demands, biomechanics, epidemiology, and match analyses to draw future research directions to a better understanding of the sport and to bring scientific knowledge closer to both coaches and athletes to enhance performance.

## 2. Materials and Methods

### *2.1. Search Strategy*

Data was obtained following the PRISMA ScR method [26] in order to identify articles published before 31 January 2022 in the five fields of research for the study: anthropometrics, physiology and physical performance, biomechanics, epidemiology of injuries, and match analyses. The PubMed, Scopus, and SPORTDiscus databases were searched for relevant articles. The search strategy in PubMed used the following search terms:

- For the anthropometric profile: ("padel" OR "paddle tennis") [Title/Abstract] AND ("anthropom*" [Title/Abstract] OR "body composition" [Title/Abstract])
- For the physiology and physical performance: ("padel" OR "paddle tennis") [Title/Abstract] AND ("physiolog*" [Title/Abstract] OR "athletic performance" [Title/Abstract] OR "exercise test" [Title/Abstract] OR "metabolism" [Title/Abstract] OR "aerobic" [Title/Abstract] OR "anaerobic" [Title/Abstract] OR "oxigen consumption" [Title/Abstract] OR "biochemical" [Title/Abstract] OR "haematol*" [Title/Abstract])
- For the biomechanics: ("padel" OR "paddle tennis") [Title/Abstract] AND ("biomechanic*" [Title/Abstract] OR "kinematic*" [Title/Abstract] OR "kinetic*" [Title/Abstract] OR "dynamic*" [Title/Abstract] OR "angle" [Title/Abstract] OR "speed" [Title/Abstract] OR "rotation" [Title/Abstract] OR "moment" [Title/Abstract] OR "force" [Title/Abstract] OR "forehand" [Title/Abstract] OR "backhand" [Title/Abstract])
- For the epidemiology of injuries: ("padel" OR "paddle tennis") [Title/Abstract] AND ("injur*" [Title/Abstract] OR "illness" [Title/Abstract] OR "pathology" [Title/Abstract] OR "disease" [Title/Abstract] OR "epidemiology" [Title/Abstract])

- For the match analyses: ("padel" OR "paddle tennis") [Title/Abstract] AND ("game" [Title/Abstract] OR "match analysis" [Title/Abstract] OR "total time" [Title/Abstract] OR "stroke" [Title/Abstract] OR "time-motion" [Title/Abstract])

### 2.2. Inclusion Criteria

Only full-text articles written in English or Spanish and published before January 2022 were included in this study. Only able-bodied players were considered, regardless of their level (amateur to elite). The inclusion criteria for each field were articles regarding these topics:

- Anthropometric profile: body composition, morphology, and anthropometric measurements;
- Physiology and physical performance: physiological responses, energetic demand, aerobic and anaerobic metabolism, strength, and power;
- Biomechanics: kinematics and kinetics of the padel player;
- Epidemiology of injuries: acute and chronic pain and traumatology during practice;
- Match analysis: temporal, game and/or stroke analysis, hand dominance, and situational variables.

Review articles and articles focused on padel instructions or racket/ball analyses were excluded.

The study selection was performed by two independent reviewers, which would avoid abusively eliminating an article, based on the abstracts and keywords. A data-charting form was jointly developed by the reviewers which was continuously updated in an interactive process. Discrepancies among reviewers were discussed involving a third author until they reached a consensus. Data was abstracted based on article characteristics (year, authors, and title) and grouped according to the main focus (anthropometric profile, physiology and physical performance, biomechanics, injury, and match analyses).

## 3. Results

The initial search returned 483 studies in database searching and five studies via other sources—two via citation searching and three reported by the authors. After the removal of duplicates, we screened 156 records, from which 72 articles were reviewed and included based on the inclusion and exclusion criteria (Figure 2). Included sources of evidence are synthesized in Table 1.

**Table 1.** Studies included in the review, authors, year of publication, areas of intervention, number, gender, and level of the subjects.

| Authors | Year | Areas of Intervention | *n* | Level |
|---|---|---|---|---|
| Amieba et al. [28] | 2013 | Physiology and physical performance | 8 males | Amateur |
| Bartolomé et al. [29] | 2016 | Physiology and physical performance | 16 males | Regional |
| Carbonell et al. [30] | 2017 | Physiology and physical performance | 9 females | Amateur |
| Carrasco et al. [31] | 2011 | Physiology and physical performance | 12 males | Top-level |
| Castillo-Lozano, R. [32] | 2017 | Epidemiology of injuries | 107 males<br>24 females | Amateur<br>Amateur |
| Castillo-Lozano, R. [33] | 2015 | Epidemiology of injuries | 54 males<br>6 females | Amateur<br>Amateur |
| Castillo-Lozano, R. [34] | 2017 | Epidemiology of injuries | 54 males<br>59 females | Amateur<br>Amateur |
| Castillo-Rodríguez et al. [12] | 2014 | Physiology and physical performance | 24 males | National |
| Castillo-Rodríguez et al. [35] | 2014 | Anthropometric profile | 36 males<br>12 females | Elite<br>Elite |
| Courel-Ibáñez et al. [36] | 2017 | Match analysis | 10 males | Elite |
| Courel-Ibáñez et al. [37] | 2015 | Match analysis | 15 males | Elite |
| Courel-Ibáñez et al. [38] | 2018 | Match analysis | 4 males | Elite |
| Courel-Ibáñez et al. [39] | 2017 | Match analysis | 16 males | Elite |
| Courel-Ibáñez et al. [40] | 2019 | Match analysis | 4 males | Elite |
| Courel-Ibáñez et al. [41] | 2018 | Physiology and physical performance | 60 females | Amateur |
| Courel-Ibáñez et al. [42] | 2020 | Physiology and physical performance | 18 males | Amateur |

**Table 1.** *Cont.*

| Authors | Year | Areas of Intervention | *n* | Level |
|---|---|---|---|---|
| Courel-Ibáñez et al. [43] | 2021 | Physiology and physical performance | 19 males | Amateur |
| | | | 15 females | Amateur |
| Courel-Ibáñez, J. [44] | 2021 | Match analysis | # males | Elite |
| Díaz-García et al. [45] | 2021 | Physiology and physical performance | 9 males | Elite |
| | | | 5 females | Elite |
| Díaz-García et al. [46] | 2017 | Physiology and physical performance | 8 males | Amateur |
| Escudero-Tena et al. [13] | 2020 | Match analysis | # females | Elite |
| Escudero-Tena et al. [47] | 2021 | Match analysis | # males | Elite |
| | | | # females | Elite |
| Escudero-Tena et al. [48] | 2021 | Match analysis | # males | Elite |
| | | | # females | Elite |
| García-Benítez et al. [49] | 2017 | Match analysis | 16 males | National |
| | | | 16 females | National |
| García-Benítez et al. [50] | 2016 | Match analysis | 18 males | Elite |
| | | | 10 females | Elite |
| García-Fernández et al. [11] | 2019 | Epidemiology of injuries | 332 males | Regional |
| | | | 146 females | Regional |
| García-González et al. [51] | 2015 | Epidemiology of injuries | 1172 males | Amateur |
| | | | 444 females | Amateur |
| Granda-Vera et al. [52] | 2019 | Biomechanics | 4 males | Elite |
| | | | 1 female | Elite |
| Hoyo et al. [53] | 2007 | Physiology and physical performance | 12 males | National |
| Lozano-Sánchez et al. [54] | 2020 | Epidemiology of injuries | 1 male | Amateur |
| Lupo et al. [55] | 2018 | Match analysis | 12 males | Elite |
| | | | 10 females | Elite |
| Martínez-Rodríguez et al. [56] | 2015 | Anthropometric profile | 21 males | National |
| Mellado-Arbelo et al. [57] | 2019 | Match analysis | 20 males | Elite |
| Müller et al. [58] | 2018 | Physiology and physical performance | 21 males | Regional |
| | | | 14 females | Regional |
| Muñoz et al. [59] | 2016 | Match analysis | # males | Elite |
| Muñoz et al. [60] | 2016 | Match analysis | # males | Elite |
| | | | | Regional |
| Muñoz et al. [7] | 2021 | Anthropometric profile | 40 males | Regional |
| Muñoz, D. [61] | 2017 | Match analysis | # males | Regional |
| Pradas et al. [62] | 2019 | Anthropometric profile | 15 males | Elite |
| | | | 14 females | Elite |
| Pradas et al. [63] | 2014 | Anthropometric profile, physiology, and physical performance | 6 females | Elite |
| Pradas et al. [64] | 2021 | Physiology and physical performance | 10 males | Elite |
| | | | 14 females | Elite |
| Pradas et al. [65] | 2021 | Physiology and physical performance | 13 males | Elite |
| | | | 15 females | Elite |
| Pradas et al. [66] | 2020 | Physiology and physical performance | 14 males | Elite |
| | | | 16 females | Elite |
| Pradas et al. [67] | 2021 | Physiology and physical performance | 15 males | Elite |
| | | | 15 females | Elite |
| Priego-Quesada et al. [68] | 2018 | Epidemiology of injuries | 46 males | Amateur |
| | | | 34 females | Amateur |
| Priego-Quesada et al. [69] | 2013 | Match analysis | 20 males | Elite |
| Priego-Quesada et al. [9] | 2014 | Biomechanics | 10 males | Amateur |
| Ramón-Llin et al. [16] | 2020 | Match analysis | 24 males | National |
| Ramón-Llin et al. [70] | 2018 | Match analysis | 7 males | Elite |
| | | | 7 males | National |
| Ramón-Llin et al. [71] | 2017 | Match analysis | 20 males | National |
| | | | 20 males | Regional |
| | | | 20 males | Amateur |
| Ramón-Llin et al. [72] | 2013 | Match analysis | # males | National |
| | | | # males | Regional |
| | | | # males | Amateur |
| Ramón-Llin et al. [73] | 2019 | Match analysis | 26 males | Elite |
| Ramón-Llin et al. [74] | 2021 | Match analysis | 36 males | National |
| Ramón-Llin et al. [75] | 2021 | Match analysis | 36 males | National |
| | | | 36 males | Regional |
| Ramón-Llin et al. [76] | 2020 | Match analysis | 36 males | National |
| | | | 36 males | Regional |

**Table 1.** *Cont.*

| Authors | Year | Areas of Intervention | *n* | Level |
|---|---|---|---|---|
| Ramón-Llin et al. [77] | 2021 | Match analysis | 24 males | Elite |
| Ramón-Llin et al. [78] | 2021 | Match analysis | 16 males | National |
| Rivilla-García et al. [79] | 2019 | Match analysis | 14 males | National |
| | | | 30 males | Regional |
| Sánchez-Alcaraz et al. [10] | 2019 | Epidemiology of injuries | 75 males | Regional |
| | | | 73 females | Regional |
| Sánchez-Alcaraz et al. [14] | 2020 | Match analysis | 7 males | Elite |
| | | | 7 females | Elite |
| Sánchez-Alcaraz et al. [80] | 2020 | Match analysis | # males | Elite |
| | | | # females | Elite |
| Sánchez-Alcaraz et al. [81] | 2021 | Match analysis | 12 males | Elite |
| | | | 12 females | Elite |
| Sánchez-Alcaraz et al. [82] | 2016 | Match analysis | 12 males | Regional |
| Sánchez-Alcaraz et al. [83] | 2019 | Match analysis | # males | Regional |
| Sánchez-Alcaraz et al. [84] | 2020 | Match analysis | # males | Elite |
| Sánchez-Alcaraz et al. [15] | 2020 | Match analysis | 10 males | Elite |
| | | | 10 females | Elite |
| Sánchez-Alcaraz et al. [85] | 2021 | Match analysis | 48 males | Regional |
| Sánchez-Alcaraz et al. [86] | 2020 | Match analysis | # males | Elite |
| | | | # females | Elite |
| Sánchez-Alcaraz et al. [87] | 2018 | Physiology and physical performance | 8 males | Amateur |
| | | | 9 females | Amateur |
| Sánchez-Alcaraz, B. [88] | 2014 | Physiology and physical performance | 16 males | Regional |
| Sánchez-Muñoz et al. [8] | 2020 | Anthropometric profile, physiology, and physical performance | 25 males | Elite |
| | | | 35 females | Subelite |
| Torres-Luque et al. [6] | 2015 | Match analysis | 8 males | Elite |
| | | | 8 females | Elite |

# Number of subjects not specified.

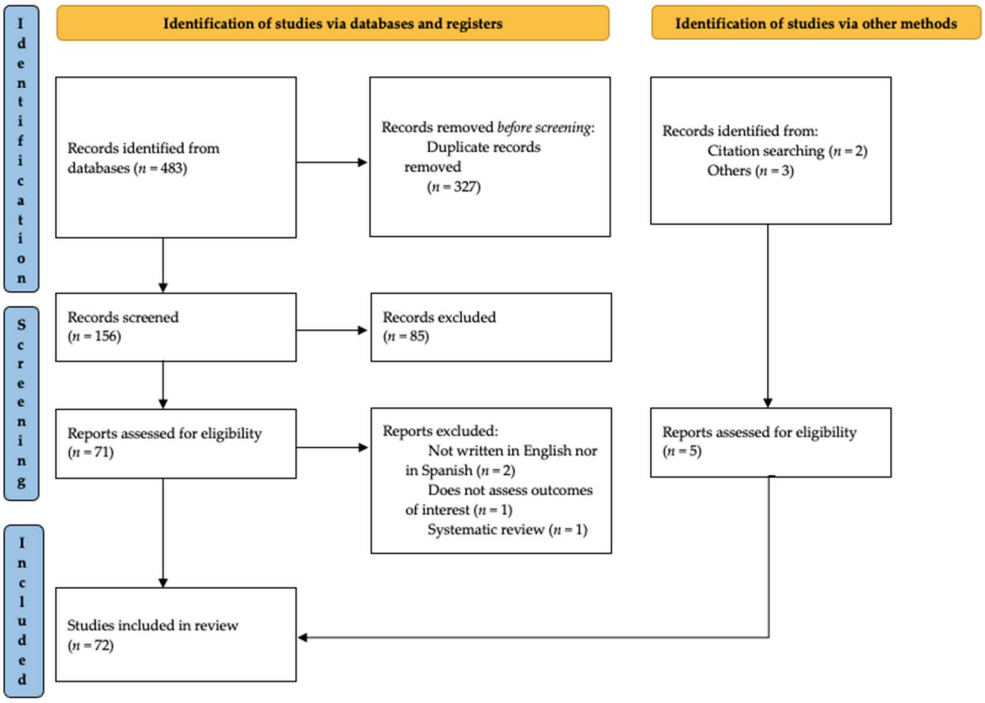


**Figure 2.** Workflow adapted from the PRISMA statement [27] showing the method to identify and select full-text articles for eligibility.

### *3.1. Anthropometric Profile*

Regarding the six articles related to padel anthropometrics [7,35,56,62,63], men showed higher values in body weight, height, and body mass index (BMI) and a lower body fat percentage than women when comparing national and world-class level players [35,62]. Contrary to this, Martínez-Rodríguez et al. [56] found higher body fat percentage values

in college male players compared to those reported by Pradas et al. [62,63] in elite female players. The predominant anthropometric profile both in male and female players is meso-endomorphic when playing at high level [8,35,56,62,63] and a predominantly endomorphic profile was found at lower competition levels [7]. These anthropometric differences among playing levels may be due to the greater amount of training hours invested by national and world-class players.

### 3.2. Physiology and Physical Performance

Laboratory tests show that, in padel players, the $VO_{2max}$ is in a range between 38.4 ± 0.7 mL/kg/min and 55.64 ± 8.84 mL/kg/min depending on gender and level. In addition, their first ($VT_1$) and second ventilatory thresholds ($VT_2$) are placed between 72%$VO_{2max}$ and 84–85%, respectively [31,46,53].

During matches, Carrasco et al. [31] and Hoyo et al. (2007) [53] found $VO_2$ values below 50%$VO_{2max}$. The maximum and mean heart rate follows a similar pattern both in top-level and amateur padel players, where some authors reported values between 154–179 bpm and 130-151 bpm, respectively. When comparing those values to the absolute maximum heart rate, they correspond to 80–85% of the maximum heart rate ($HR_{max}$) and 68–74%$HR_{max}$ for the mean heart rate. In their study, Díaz-García et al. [46] found that amateur players stayed 97.75% of the time below the aerobic threshold and 2.25% between $VT_1$ and $VT_2$ which confirms, at the cardiovascular level, that amateur padel yields predominantly aerobic efforts.

Lactate concentration seems to follow a similar stable pattern during games, starting below $VT_1$ in the beginning (1.83–1.90 mmol/L) and reaching values between $VT_1$ and $VT_2$ (2.40–3.38 mmol/L) [12,28,63]. Regarding the rate of perceived exertion, it appears to be similar ($p < 0.05$) after the first set and the end of the game [28], wich reinforces the previously described aerobic stable pattern followed by $VO_{2max}$, HR and lactate.

When comparing different competitive levels, Castillo-Rodríguez et al. [12] found a significantly lower cardiovascular response ($p < 0.05$) in high, than in middle and lower level players, shown as a higher time spent between 50–70% of maximum heart rate (43.7% vs. 15.2%), a lower amount of time between 80–90% (12.9% vs. 32.8–30.4%), and a lower RPE, suggesting a better cardiovascular fitness at better levels. Equally, but with no statistical significance, maximum lactate values were lower in high (2.87 mmol/L) than in medium (2.74 mmol/L) and low (3.38 mmol/L) level players.

#### 3.2.1. Physical Performance

Various studies have researched physical performance in padel through different standardized tests [8,42,64,67,87]. Significant differences ($p < 0.05$) have been found between sexes in distances covered during YOYO IR1, vertical jump (VJ), squat jump (SJ), countermovement jump (CMJ), Abalakov jump (ABK), medicine ball throwing (MBT), maximum handgrip isometric strength (MHIS), resistance handgrip isometric strength (RHIS), 10 m sprint, and 20 m sprint [58,65,67,87].

When comparing different amateur levels, lower HRs after YOYO IR1 have been reported for high level players both in men and women ($p < 0.05$), which could reflect their better cardiovascular fitness. On the other hand, high levels of men's values were lower than medium and low level players in the distance covered during YOYO IR1, MBT, and maximum HIS. The authors hypothesized that high level players would have better technical and tactical development to compensate for this limitation. As for women, high level players covered more distance during YOYO IR1 and jumped higher in VJ than medium level players ($p < 0.05$), showing better cardiovascular fitness and lower body strength [58]. Courel-Ibáñez and Herrera-Gálvez [42] found in high level players a better groundstroke accuracy ($p < 0.05$) and a better heart rate recovery after 60 s ($p < 0.05$) than low level players. On the other hand, they reported worse anterior and posteromedial balance ($p < 0.05$), suggesting a high potential injury risk. As for elite and sub-elite players, a better lumbar isometric strength ($p < 0.05$) has been found for elite players [8].

Finally, Courel-Ibañez et al. [41] reported better fitness conditioning in adult women (35–55 years old) padel players than in a sedentary group, shown as better results in abdominal endurance, vertical jumps, one-foot balancing, and cardiovascular fitness ($p < 0.001$). This could serve as a point of departure for future research in physical activity interventions through padel in this age group.

#### 3.2.2. Mental Performance

Díaz-García et al. [45] observed an increase in mental fatigue from pre- to post-world padel tour matches ($p < 0.01$) and an impairment in reaction time ($p < 0.04$).

#### 3.2.3. Haematology and Biochemistry

Bartolome et al. [29] studied the responses of seven trace minerals to a competition match in high level male players. They found a significant increase ($p < 0.05$) in Cu, Ni, and Zn values, suggesting an increase in the antioxidant and energetic demands as a consequence of catabolism after an acute effort involving frequent mechanical impact due to jumps, turns, and explosive actions. On the other hand, they observed a decrease ($p < 0.05$) in Li values, which may indicate a biological redemption process in the organism to avoid its lack and to ensure an optimal development of several biological systems, as well as hormonal, metabolic, neurologic, and immunologic processes.

In the study by Pradas et al. [66] both hematological and biochemical parameters were analyzed in elite padel players through blood sample extractions before and after a simulated competition. Authors found that men showed higher baseline values ($p < 0.05$) in red blood cells, hematocrit, hemoglobin, urea, creatinine, uric acid, albumin, glutamic oxaloacetic transaminase (GOT), glutamic-pyruvic transaminase (GPT), lactate dehydrogenase (LDH), and creatine kinase (CK) than women. When attending to the match effect, significant differences ($p < 0.05$) were obtained in urea, creatinine, CK, glucose, sodium, and magnesium. Finally, the group x match interaction revealed significant differences in serum concentrations of sodium and chloride ($p < 0.05$). They attached these gender differences to the higher intensity and anthropometric characteristics of male padel players. Equally, the game intensity could be the cause of muscle damage, protein catabolism, and electrolyte loss, where recovery and fluid intake strategies could play an important role in enhancing the training quality and performance.

### *3.3. Biomechanics*

Granda-Vera et al. [52] analyzed, through a kinematic analysis of national and international padel players, the existence of visual signals (pre-cues) in drive strokes made from the back of the court after the ball hits a wall. They found, in right-handed players, that the hand height and the position of the left heel ($r = 0.896$ $p < 0.001$ and $r = 0.777$ $p < 0.001$) at the beginning and at the end of the movement were strongly related to the ball direction through the opposite court. This means a right-handed player hitting the ball in a high hand and an opened left heel position, in reference to the court's longitudinal axis, results in a shot to the left half of the court, with the striking player as reference, and vice versa for left-handed players. These findings could serve to improve perceptual anticipation ability at all playing levels.

The foot role during padel play was analyzed by Priego-Quesada et al. [9] in order to prevent foot and ankle joint damage caused by padel movements. They found that the forefoot area supports the greatest stresses during lateral shifts, forward movements, split-steps, and pivot turns, which could lead to an excess plantar overload and provoke foot-related injuries such as sesamoiditis, plantar fasciitis, or stress fractures. These results highlight the importance of adequate specific padel footwear, as well as the training of the foot core, ankle joint mobility, and foot–ankle proprioception.

### 3.4. Epidemiology of Injuries

García-Fernández et al. [11] found, in their epidemiology research, an injury rate of 2.75 injuries per 1000 h of padel exposure, occurring most frequently towards the end of any given game or practice (42%). Priego-Quesada et al. [68] reported that 40% of the players had at least one injury during the past year. This data is below that confirmed by Sanchez-Alcaraz et al. [10] with a 71.6% incidence of injury.

Tendon injuries are the most common in padel players, followed by muscle and ligament/joint injuries [11,68]. As for their severity, mild injuries were related to muscle-tendinous upper body injuries ($p < 0.05$) and moderate injuries were related to lower body ligament injuries ($p < 0.05$). Most injuries were without any contact (68%), with muscle overload as the most common reason [11].

Regarding injury locations, lower limbs seemed to be the most common location among padel players [10,68] with a close relationship to muscle overloading ($p < 0.001$) and recurrent injuries ($p < 0.05$) [11]. Other frequent injury locations, such as the lower back, knee, shoulder, hamstrings, calf, and plantar fascia have been reported [11,32–34,68].

Castillo-Lozano et al. [32–34] observed that age, body mass index, and laterality ($p < 0.05$) were injury incidence determinants which could explain between 7.5% and 68.5% of injuries. These results were similar to those found by Garcia-Fernandez et al. [11] who reported a higher injury rate in relation to age ($p < 0.05$) and IMC increase ($p < 0.01$). Age also appears to be related to the type and incidence of injuries. Sanchez-Alcaraz et al. [10] found a higher rate of muscular lesions in players older than 35 years (23.2%) and tendinosis in players younger than 35 years (17.2%) ($p < 0.01$).

### 3.5. Match Analysis

According to Sánchez-Alcaraz 2020 [80], approximately 70% of professional padel matches are resolved in two sets. Considering the players' gender, a significantly higher number of balanced sets and tie-break sets were observed in the male category.

#### 3.5.1. Temporal Analysis

The time of play and break time per rally have been reported in high level players as being 12.70 ± 10.05 s and 14.95 ± 6.32 s, respectively. The total time of play corresponded to 45.92% of the total time of the match, with a work:rest ratio of 0.84 [60]. The rallies' duration distribution is commonly between 3 to 6 s (23.2%), 6 to 9 s (29.3%), and 9 to 12 s (19.6%) [6]. Break times and number of breaks seems to be influenced both by the duration of the set ($p < 0.05$) [60], the importance of the point ($p < 0,001$), and the use of "no-ad" scoring ($p = 0.007$) [86]. Regarding game duration during a tournament, Sanchez-Alcaraz et al. [86] reported higher durations ($p = 0.004$) at the semi-finals. No differences between male and female matches were found [81]

Gender differences have been reported according to temporal variables in padel games, with higher values in female than in male matches concerning the duration of rallies, number of strokes per rally, real play time, resting time, resting time per rally, and rallies per match [6,49,50,55]. Nevertheless, García-Benítez et al. [49] reported a higher effective playing time (%), more games per set, and a longer rally duration in U-18 players ($p < 0.01$). Sex similarities in work:rest ratio were found.

According to age, a shorter game duration ($p < 0.05$), rally duration ($p < 0.01$) and rest interval time between rallies ($p < 0.01$) were found in U-16 male players compared with U-18 players. In females, shorter rest interval times between rallies in U-18 players was observed ($p < 0.01$) [49].

When comparing different levels, a higher rate of play (shots per second) was found in national players compared to regional players ($p < 0.05$). As for recreational players ($p < 0.001$), they differed from national and regional players in the rally time, number of shots per point, distance covered, rate of play, and speed during active play [71].

#### 3.5.2. Technique Analysis

Volley, direct smash, and backhand strokes have been reported to be the most common types of strokes among players [6,40,57,69]. Lobs seems to be the most common shot to approach the net. In fact, performing deep lobs increased the likelihood of the continuity of rallies ($p = 0.004$) [59,61,73] as the tray does, with a percentage of point continuity of almost 90% [15].

In order to win the rally, an advantage for the serving pair has been reported [14,73]. To this aim, the smash followed by a forehand drop shot, forehand and backhand volleys, and the tray shot seem to be the most successful shots for winning points [57]. Besides, comparing winners to losers, winners made a higher percentage of smashes and trays and a lower number of side-wall shots, side and back wall, and wall boast than the losers ($p < 0.001$) [16]. Furthermore, the shot effectiveness seems to be a key factor in professional padel that distinguishes between winning and losing players ($p < 0.05$) [48].

Shots are also determined by the game style defined by the court zone: net, middle, and baseline. Some authors have found that in the net (offense) stood the use of volleys, trays and smashes, where the last were more likely to fail by an unforced error [44]. Conversely, in the baseline (defense), the use of corner side walls, groundstrokes, and lobs were shown to be relevant. The middle game (transition) was characterized by a greater use of a backhand volley in the center, direct, and tray in the sides and smash to solve the point [40,85].

Hand dominance and gender have been reported to also affect strokes, where those who are right-handed made more lobs and crossed shots. Otherwise, those who are left-handed made more directs [38,78]. Comparing hand dominance effectiveness, those who are left-handed scored more points using smashes, made more errors using the wall, and used direct shots to continue the rally. On the other hand, those who are right-handed scored more points using wall groundstrokes, with larger errors in volleys, and used more lobs to continue the rally ($p < 0.05$) [38]. Regarding gender, a higher number of strokes per rally, number of first service faults, percentage of strokes from the midfield zone, winners and errors per game, breakpoints, and lobs per match in female games, compared to male games, have been reported [47,50,55]. Conversely, higher values of percentages of the backhand lob, backhand volley, indirect forehand lob, and strokes close to the net and first service faults ($p < 0.05$) were found in male matches [6,55]. Furthermore, males obtained a higher percentage of successful first serves ($p < 0.05$) and won a higher percentage of points in a serve situation ($p < 0.01$) than females [14].

Finally, the stroke distribution seemed to be also affected by age. García-Benítez et al. [49] reported less strokes and lobs per rally in U-16 than U-18 male players ($p < 0.01$). Contrary to this, U-16 female players made more lobs per rally than U-18 ($p = 0.01$).

#### 3.5.3. Movements and Positioning Dynamics

Movements and positioning dynamics have been tracked by some authors [77]. Their results showed a significant relationship between offensive player movements (forward, backward, or sideways) according to the position of the ball in defensive zones. Regarding players' width positioning, when the ball is in one corner of the defensive zone, both offensive players move to that side of the court. However, if one offensive player moves close to the net, his partner moves some meters back. Regarding tactic formations, Ramón-Llin [75] found how high level players used a significantly higher percentage of the Australian formation than beginners, even though it has been reported that serving pairs won a higher percentage of points using traditional tactics instead of the Australian formation [74].

## 4. Discussion

### *4.1. Summary of Evidence*

The augment of research regarding padel in the last decade has contributed to a better understanding of the sport and has helped us to characterize the main topics of interest and detect less researched areas in the scientific literature. This scoping review reveals that

match analyses were the primary focus of the included reports, covering more than half of the total. This wider and increasing knowledge in the last two years included timing, strokes, movements, positioning, and differences between genders and playing levels is probably due to their strong influence on the match outcome.

Physiology, physical, and mental performances were other important topics of interest in which authors were focused, comprehending about 25% of the articles included in our research. On the one side, players' $VO_{2max}$, heart rates, and thresholds were determined in order to quantify the cardio-respiratory demands of the sport [12,28,31,53,58]. On the other hand, biochemical and hematological parameter research showed that padel causes muscle damage and protein catabolism [66], which could be taken into account both for coaches and athletes to plan better recovery strategies. Apart from that, some authors reported physical performance tests involving strength, power, and the ability to repeat sprints [8,42,58,65,67,87], serving as a reference for those athletes aiming to improve their performance. Another interesting—and less researched—issue was mental performance, with only one report focused on it, suggesting that inter-game mental fatigue could impair reaction times [45].

The anthropometric profile, epidemiology of injuries, and biomechanics comprised less than a quarter of all the reviewed studies. Authors showed that higher level players presented a predominant meso-endomorphic profile, while lower level players had a predominantly endomorphic profile [7,8,35,56,62,63]—something which could serve as a reference to build a nutritional plan for the athletes. The main interest of injury-focused reports was the incidence of injury, its severity, the locations, and the possible causes, giving a quite complete overview of the sport epidemiology. Lower limbs—plantar fascia, the calf, knee, and hamstrings, the lower back, and the shoulder are the most common injury locations [11,32–34,68] and an injury-prevention intervention should be taken into account to avoid them and achieve player consistencies among the season. Finally, the only two biomechanics-focused studies included reports that had completely different approaches. On the one hand, an injury-related study [9] highlighted the importance of adequate specific padel footwear, as well as the training of the foot core, ankle joint mobility, and foot–ankle proprioception. On the other hand, a kinematic analysis was used in order to find pre-cues in certain drive strokes, suggesting the importance of improving the perceptual anticipation ability in players [52].

Once we observed all the scientific knowledge regarding padel, we identified some gaps, such as mental performance and fatigue, which is an unresearched field which could lead to a better understanding of how players deal with match outcomes, unforced errors, and several matches in a short period of time. In the field of injuries, the effectiveness, or not, of an injury-prevention plan during a given period would be a powerful tool for both coaches and players in order to avoid injuries and lengthen players careers. Last but not least, deeper research on how visual signals and anticipation affects match outcomes could play an important role at all playing levels.

### 4.2. Limitations

A limitation was the inability to access certain records whose abstracts suggested they would be highly relevant. Another limitation of this review was the decision not to include books, book chapters, or literature in languages other than English. The identification of many books and book chapters addressing interventions for eco-anxiety during the selection process suggests that the inclusion of these materials in future reviews could provide rich insight.

### 4.3. Conclusions

Padel is an emerging sport both in sport and research terms. This scoping review could serve as a point of reference for coaches and researchers, with the ultimate goal of making athletes better by showing all the knowledge available in the five studied fields of interest—the anthropometric profile, physiology and physical performance, biomechanics,

epidemiology of injuries, and match analyses. Furthermore, this study enables us to make a map of the current state of the research about padel and opens up doors to future investigations regarding those possible gaps in knowledge, mentioned before, such as mental performance, injury prevention interventions, and the role of anticipation and visual signals on match outcomes.

**Author Contributions:** Conceptualization, F.P.d.l.F. and A.G.-G.; methodology, A.G.-G., F.P.d.l.F. and L.C.P.; investigation, F.P.d.l.F., A.G.-G., C.C.O. and L.C.P.; writing—original draft preparation, A.G.-G., L.C.P. and F.P.d.l.F.; writing—review and editing, F.P.d.l.F., L.C.P. and A.G.-G.; visualization, F.P.d.l.F. and C.C.O.; funding, F.P.d.l.F. and C.C.O. All authors have read and agreed to the published version of the manuscript.

**Funding:** This study has been funded by the ENFYRED research group of the Government of Aragón (code: S53_20D).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** We thank the research group Training, Physical Activity, and Sports Performance (ENFYRED) of the University of Zaragoza for their active collaboration in this study.

**Conflicts of Interest:** The authors declare no conflict of interest.

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# 8. DISCUSIÓN

El pádel es el deporte que más ha crecido en España en los últimos años, convirtiéndose en uno de los diez deportes más practicados, y superando los cuatro millones de practicantes regulares, entre jugadores federados y no federados (Courel-Ibañez et al., 2017). Su evolución y expansión a nivel internacional también ha sido muy rápida, y su presencia alcanza, a día de hoy, noventa países y dieciocho millones de practicantes (Federación Internacional de Pádel, 2022b). Además, su práctica ha ganado en interés y relevancia al profesionalizarse este deporte, a través de la red completa de torneos profesionales internacionales WPT (anteriormente denominados PPT), celebrados en veinte países diferentes (Federación Internacional de Pádel, 2022c). Del mismo modo, el pádel se ha convertido en los últimos diez años en un deporte de interés científico, por lo que su crecimiento deportivo se encuentra en estos momentos acompañado de un importante aumento de investigaciones, en donde el pádel es investigado como objeto de estudio, siendo analizado desde diferentes áreas de conocimiento como la cineantropometría y el somatotipo de los jugadores (Castillo-Rodríguez, Hernández-Mendo, et al., 2014; Muñoz et al., 2021), los requerimientos fisiológicos y condicionales del juego (Borges & Boscolo, 2018; Carrasco et al., 2011; Castillo-Rodríguez, Alvero-Cruz, et al., 2014; Pradas et al., 2014; Sánchez-Alcaraz et al., 2018), la biomecánica del jugador (Granda-Vera et al., 2019; Priego-Quesada et al., 2014), la epidemiología de lesiones (García–Fernández et al., 2019; García González et al., 2015) y el análisis del partido comprendiendo aspectos tácticos, técnicos, situacionales y temporales (Courel-Ibáñez et al., 2015, 2017; Courel-Ibáñez & Sánchez-Alcaraz, 2017; Courel-Ibáñez et al., 2019; Escudero-Tena, Courel-Ibáñez, et al., 2021; Escudero-Tena, Sánchez-Alcaraz, et al., 2021; Muñoz et al., 2016; Ramón-Llin, Sánchez-Alcaraz, et al., 2021; Ramón-Llin, Guzmán, et al., 2021; Sánchez-Alcaraz et al., 2019; Sánchez-Alcaraz et al., 2021).

Observando los trabajos previos publicados y contando con el acceso a una muestra de alto nivel, tanto femenina como masculina, se consideró de interés evaluar el perfil antropométrico de estos jugadores, y el impacto fisiológico y neuromuscular que un partido de pádel supone para el organismo. Por otro lado, y no menos importante, se planteó una recopilación y síntesis de los conceptos tratados sobre este deporte en la literatura científica, con el fin de examinar la tendencia de las investigaciones, organizar y contextualizar los trabajos previos, así como identificar nuevas líneas de investigación.

El primer artículo valora las características antropométricas de una muestra de jugadores y jugadoras de alto nivel con experiencia en torneos WPT, PPT y de máxima categoría nacional. Si bien, es cierto que existen algunas publicaciones previas respecto a este tema (Castillo-Rodríguez, Hernández-Mendo, et al., 2014; Martínez-Rodríguez et al., 2015; Pradas et al., 2014), la heterogeneidad de las muestras analizadas y de los datos

aportados no permite estandarizar los resultados. Además, la profesionalización del deporte en los últimos años ha reducido la cantidad de jugadores provenientes de otros deportes de raqueta como el tenis, y ha aumentado el número de jugadores que se han formado exclusivamente en este deporte. Por ese motivo, ahora es posible valorar un biotipo de referencia de los jugadores de pádel más preciso y acorde a la realidad actual.

Los resultados obtenidos muestran diferencias en la estatura de los jugadores respecto a otros deportes de raqueta. En ambos sexos los jugadores de pádel presentan una mayor estatura que la registrada en el tenis de mesa (Pradas et al., 2013), pero menor que la descrita por otros autores en jugadores de bádminton (Faccini & Dal Monte, 1996) o tenis (Hornery et al., 2007). Estos datos pueden estar relacionados con la dinámica de juego del pádel, donde la estatura no es tan importante como en deportes como el tenis o bádminton, al poder dejar pasar la pelota para golpearla después de rebotar en la pared posterior. En cuanto a la masa corporal, los valores registrados por los jugadores de pádel son mayores que los hallados en jugadores de bádminton (Abián et al., 2012), squash (Chin et al., 1995), tenis de mesa (Pradas et al., 2013; Sepúlveda et al., 2015) y tenis (Hornery et al., 2007) (excepto en tenis femenino), probablemente relacionada con la menor intensidad requerida en el pádel. En cambio, el porcentaje de grasa corporal en hombres es menor que el observado en tenis de mesa (Pradas et al., 2013), bádminton (Majumdar, 1997; Ooi et al., 2009) y squash (Chin et al., 1995). En mujeres, este valor es mayor que el hallado en tenis de mesa (Pradas et al., 2013) pero menor que el de jugadoras de bádminton (Hughes et al., 1995) y tenis (Pyke et al., 1974).

Las diferencias entre géneros encontradas en este primer artículo, en referencia al somatotipo (meso-endomorfo en hombres y endo-mesomorfo en mujeres), altura, peso (mayor en hombres) ($p < 0,001$), y porcentaje de grasa corporal (mayor en mujeres) ($p < 0,001$) de los jugadores, se encuentra acorde a lo descrito en la bibliografía de referencia al comparar el biotipo entre sexos (Cox & Calsbeek, 2010).

En el segundo trabajo de investigación se analiza el impacto fisiológico que implica un partido de pádel de alto nivel. En él, se evalúan los cambios hematológicos y bioquímicos producidos en los jugadores después de un partido de competición simulado comparando las posibles diferencias entre géneros. Trabajos previos realizados sobre esta temática se han centrado exclusivamente en la respuesta fisiológica (Carrasco et al., 2011), análisis del partido (Courel-Ibañez et al., 2017; 2019), o descripciones técnico-tácticas sobre el juego (Priego-Quesada et al., 2013; Ramón-Llin et al., 2019). Sin embargo, no se han encontrado publicaciones que atiendan a la diferente respuesta fisiológica entre géneros, analizando parámetros hematológicos y bioquímicos de manera similar a lo investigado en otros deportes de raqueta como el tenis (Bergeron et al., 1991; Ojala & Häkkinen, 2013) o el bádminton (Abián et al., 2015; Majumdar, 1997).

Los resultados obtenidos en esta investigación ponen de manifiesto que un partido de pádel no causa cambios en los parámetros hematológicos en ninguno de los dos sexos, al contrario de lo que sí sucede en el bádminton, con cambios significativos en los valores de hemoglobina y hematocrito (Abián et al., 2015). Respecto a las diferencias entre sexos, los mayores valores encontrados en hombres para todos los parámetros estudiados (glóbulos rojos, hematocrito, hemoglobina y volumen corpuscular medio) ($p < 0,01$), podrían estar explicados por su mayor cantidad de masa muscular (Gligoroska et al., 2020) y de niveles de testosterona (Telford & Cunningham, 1990), vinculados a la síntesis proteica, el crecimiento de los tejidos y la eritropoyesis (Bachman et al., 2014; Hero et al., 2005).

Por otro lado, el aumento de los valores bioquímicos de urea, creatinina y ácido úrico en ambos grupos ($p < 0,05$), se encuentra en la línea de lo observado en jugadores de bádminton (Majumdar, 1997). En estudios previos se ha comprobado que los valores de estos parámetros aumentan tras el entrenamiento de la fuerza (Deminice et al., 2010). Además, el aumento de ácido úrico, descrito como un importante elemento antioxidante (Battino et al., 2002; Deminice et al., 2010; González et al., 2007; Kondakova et al., 1999), podría ser un mecanismo de defensa ante la producción de especies reactivas de oxígeno (ROS), provocadas por el ejercicio físico (Beavers et al., 2014). Por otro lado, el aumento post-partido de urea podría estar asociado al aumento del catabolismo proteico debido a la intensidad del juego, al igual que se ha observado en estudios previos realizados con jugadores de tenis (Hoppe et al., 2016).

El cambio en los niveles de glucosa ($p < 0,05$), es similar al observado en jugadores de tenis (Akşit et al., 2013). Este aumento es facilitado por una menor concentración de insulina y mayores niveles de glucagón y catecolaminas en plasma (Wolfe et al., 1986). Durante el ejercicio, la producción endógena de glucosa es mayor para prevenir una posible hipoglucemia (Yardley & Sigal, 2015).

Los valores basales de CK, LDH, transaminasas (GOT y GPT) y albúmina fueron mayores en hombres que en mujeres ($p < 0,01$). Atendiendo al efecto del partido simulado, se observó un incremento significativo de los valores de CK, GOT, GPT y albúmina en ambos sexos, aunque fue mayor en hombres, probablemente por su mayor cantidad de masa muscular. Acorde a estos resultados, otros autores han hallado aumentos en la concentración de CK tras partidos de bádminton y tenis (Abián et al., 2015; Majumdar, 1997; Ojala & Häkkinen, 2013). La presencia de CK y LDH en la sangre es un indicador de daño en la membrana celular (Sorichter et al., 1999). Este daño muscular se ha visto que está asociado con acciones excéntricas y contracciones musculares repetidas (Del Coso et al., 2012; Del Coso et al., 2013), como las que se realizan en el deporte del pádel, donde se producen una gran cantidad de cambios de dirección en cortos periodos de tiempo. Un aumento de CK y LDH también puede provocar pérdida de fuerza, rango de movimiento y DOMS (McKune et al., 2012). Respecto a las transaminasas GOT y GPT, marcadores sobre el estado del hígado

y presentes también en riñones, glóbulos rojos, cerebro e intestino delgado (Pavletic et al., 2015), su aumento parece estar asociado también al daño muscular (Pettersson et al., 2008).

La concentración de los electrolitos K y Mg disminuyó ($p < 0,05$) tras la competición simulada. Al comparar ambos sexos, se encontraron diferencias estadísticamente significativas en la concentración de Na y Mg ($p < 0,01$), siendo mayor la de la muestra masculina. Estos resultados siguen una tendencia similar a los encontrados por Abián et al. (2015) en jugadores de bádminton, quienes observaron una disminución de los elecrolitos Na, K y $Cl^-$ ($p < 0,01$) tras un partido simulado. La disminución de la concentración de electrolitos en sangre puede estar asociada a la intensidad del ejercicio (Baker et al., 2019), deshidratación o distribución de los electrolitos en otros compartimentos (Barratt, 1977; Kardalas et al., 2018). Del mismo modo, la pérdida de peso observada en el estudio podría ser causa de un aumento de la sudoración de los jugadores con el objetivo de reducir la producción metabólica de calor. Estudios previos han puesto de manifiesto que la sudoración compromete a varios electrolitos, entre ellos Na, $Cl^-$ y K, y que la intensidad del ejercicio puede afectar también a la pérdida de K a través de la sudoración (Baker et al., 2019). De hecho, grandes pérdidas de agua y electrolitos, en concreto de Na, podrían afectar negativamente al rendimiento de los deportistas o incluso causar lesiones (Kovacs, 2006). Para evitar este detrimento, se sugiere que los jugadores de pádel sigan una adecuada reposición de líquidos/electrolitos, en función de la intensidad de los entrenamientos/partidos y del género de los deportistas.

El tercer artículo pretende dar respuesta a las limitaciones actuales en la literatura científica, con respecto al impacto fisiológico agudo que supone un partido de pádel para el organismo. En otros deportes de raqueta se han observado alteraciones en la función neuromuscular posterior a la disputa de partidos (Girard & Millet, 2009; Girard et al., 2008). En cambio, los estudios sobre la respuesta fisiológica aguda en pádel son limitados (Pradas et al., 2020) y no se ha encontrado ninguno que analice la respuesta neuromuscular en ambos sexos después de un partido.

Las diferencias entre géneros en valores absolutos en la fuerza de prensión manual ($p < 0,001$), se encuentra acorde a los mayores valores de fuerza hallados en hombres frente a mujeres en deportes de raqueta como el tenis (Kramer & Knudson, 1992; Lucki & Nicolay, 2007) y bádminton (Abián-Vicén et al., 2012). El bajo porcentaje de cambio post-partido coincide con los resultados obtenidos en jugadores de bádminton (Abián-Vicén et al., 2014), y podría deberse a que el estrés causado por una competición simulada no es suficiente para afectar la capacidad del antebrazo de generar fuerza. Los mayores valores para hombres en todas las variables de salto ($p < 0,001$), excepto en la variable vatios por kilogramo de peso, van en consonancia con las obtenidas también en jugadores de pádel independientemente de su nivel de juego (Borges & Boscolo, 2018; Courel-Ibáñez & Llorca-Miralles, 2021). Estas diferencias halladas en los valores de altura y potencia de salto pueden ser debidas a las

diferencias antropométricas y de fuerza entre sexos observadas en varios deportes (Valenzuela et al., 2020). Además, la competición simulada solamente afectó negativamente a la altura de salto ABK ($p < 0,05$). Estos datos sugieren que la competición simulada no causó fatiga neuromuscular en los miembros inferiores de los jugadores, similar a lo reportado previamente en jugadores de tenis (Amatori et al., 2020; Maraga et al., 2018; Ojala & Häkkinen, 2013; Reid et al., 2013) y bádminton (Abián-Vicén et al., 2014; Abián-Vicén et al., 2012). En cambio, otros autores han obtenido resultados contradictorios de altura y potencia media de salto CMJ posteriores a un partido de tenis (Gescheit et al., 2015).

Respecto a las variables fisiológicas, los mayores valores hematológicos observados de glóbulos rojos, hematocrito y hemoglobina en los hombres frente a las mujeres ($p < 0,001$), pueden estar influenciados por las diferencias hormonales, de masa muscular y condición física entre sexos (Bachman et al., 2014; Gligoroska et al., 2020; Telford & Cunningham, 1990). Dichas diferencias han sido también observadas en el segundo artículo de esta tesis (Pradas et al., 2020), en nadadores (Cai et al., 2019) y en otros deportes (Malczewska-Lenczowska et al., 2013). Los bajos valores de gravedad específica encontrados en las mujeres ($p < 0,05$), indican que los jugadores de sexo masculino comenzaron la competición en un estado de deshidratación mayor (Casa et al., 2000). Tales valores son contrarios a los de Silva et al. (2010) con atletas universitarios, donde la muestra femenina obtuvo mayores valores de deshidratación que los hombres. En cambio, Volpe et al. (2009), reportaron también mayor deshidratación previa en la muestra masculina que en la femenina. Finalmente, el incremento de los niveles de microalbuminuria en la orina ($p < 0,01$), puede ser causado por un aumento de la permeabilidad glomerular o reducción en la absorción tubular de los riñones debido a la intensidad de la competición simulada (Poortmans, 1977; Poortmans et al., 1989).

Por último, el cuarto trabajo presenta los trabajos publicados hasta la actualidad sobre el deporte del pádel, siguiendo las directrices de la extensión del método PRISMA para revisiones sistemáticas exploratorias (Tricco et al., 2018). La clasificación se realiza de acuerdo con los cinco aspectos que se han considerado más relevantes, que engloban las características y el rendimiento en este deporte: antropometría, fisiología, rendimiento físico, epidemiología de lesiones, biomecánica y análisis del partido. Asimismo, esta revisión sistemática exploratoria propone futuras líneas de investigación en aquellas áreas que se ha observado que están todavía por estudiar y podrían ser de interés científico.

En definitiva, esta Tesis Doctoral permite ampliar el conocimiento acerca del pádel, un deporte relativamente moderno, que presenta en estos momentos un importante interés científico, además de un sustancial crecimiento de su práctica deportiva. A través de los cuatro artículos que componen esta Tesis Doctoral, se ha tratado de dar respuesta a aspectos poco estudiados y analizados, como son las características antropométricas de los jugadores de alto nivel, el impacto fisiológico y neuromuscular que implica un partido atendiendo a las

diferencias entre sexos y, finalmente, recopilar, clasificar y discutir todas los estudios publicados hasta la fecha, de acuerdo a cinco temas que se han considerado de interés para contextualizar el conocimiento científico actual sobre este deporte.

# 9. CONCLUSIONES

- Los jugadores de pádel de alto nivel tienen un somatotipo predominantemente mesomorfo en ambos sexos con un mayor componente endomorfo que ectomorfo. Se acepta parcialmente la primera hipótesis planteada siendo el somatotipo de ambos sexos mesomorfo, y las características antropométricas de peso, altura, masa corporal y porcentaje de masa corporal diferentes a otros deportes de raqueta.

- Los partidos de pádel de alto nivel inducen cambios en los marcadores de daño muscular, catabolismo proteico y electrolitos. A nivel urinario y hematológico provocaron microalbuminuria de forma significativa en ambos sexos. Se acepta parcialmente la segunda hipótesis planteada produciéndose en el pádel un impacto agudo sobre marcadores hematológicos y urinarios en ambos sexos.

- La práctica del pádel provoca en las jugadoras un descenso de los niveles de fuerza máxima de prensión del brazo dominante y de la fuerza reactiva del tren inferior. Se acepta parcialmente la tercera hipótesis al comprobarse una fatiga neuromuscular solamente en el sexo femenino.

- El pádel es un deporte que presenta en la última década un importante crecimiento a nivel científico siendo el análisis de los partidos el tema más investigado. El rendimiento mental, las intervenciones de prevención de lesiones y el rol de la anticipación y señales visuales sobre el resultado de los partidos son campos todavía por estudiar en profundidad.

# 10. LIMITACIONES

1. La muestra analizada es de jugadores de élite con experiencia en competiciones nacionales e internacionales. Pese a representar la realidad del deporte de alto nivel, sería interesante ampliar la muestra de estudio para poder generalizar los resultados, así como realizarla en deportistas amateur para comprobar si el efecto agudo de la práctica del pádel sobre marcadores hematológicos, urinarios y neuromusculares es similar.

2. Dada la complejidad de llevar a cabo los estudios en situaciones competitivas reales, los análisis pre- y post-partido fueron realizados en situaciones competitivas simuladas, lo que podría afectar a la intensidad, dinámica de juego y motivación de los jugadores.

3. Los partidos de competición simulados se realizaron en pistas exteriores, mientras el pádel se juega habitualmente en pistas cubiertas. Esto puede afectar a las condiciones de temperatura y humedad, variando la respuesta fisiológica de los jugadores.

4. El material del que se componen las pistas de pádel, así como las modificaciones producidas sobre aspectos reglamentarios y de materiales de juego se han modificado recientemente por lo que podría afectar a los resultados obtenidos en esta investigación.

5. La decisión de no incluir en la revisión sistemática libros y capítulos de libros, además de publicaciones realizadas en idiomas diferentes al inglés o al castellano podrían suponer un sesgo bibliográfico.

# 11. PERSPECTIVAS DE FUTURO

1. Investigar el efecto de diferentes condiciones de juego (indoor vs. outdoor) considerando las variaciones de temperatura y humedad sobre parámetros hematológicos y bioquímicos en un partido de competición.

2. Monitorizar la carga interna y la ingesta nutricional de jugadores de pádel de ambos sexos durante el entrenamiento y/o la competición.

3. Comparar el impacto agudo de un partido de competición sobre variables hematológicas, bioquímicas y neuromusculares en jugadores de diferentes niveles de juego.

4. Evaluar cómo evoluciona la fatiga mental durante un torneo y su efecto sobre variables fisiológicas y metabólicas.

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# ANEXOS

Los anexos recogen el factor de impacto, áreas temáticas y certificados de aceptación/publicación correspondientes a las publicaciones que componen esta Tesis Doctoral.

Además, se incluye la justificación de la contribución del doctorando en cada uno de los trabajos publicados.

# Anexo A: Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte

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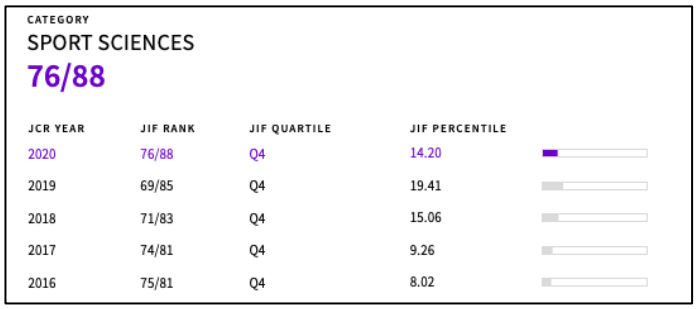

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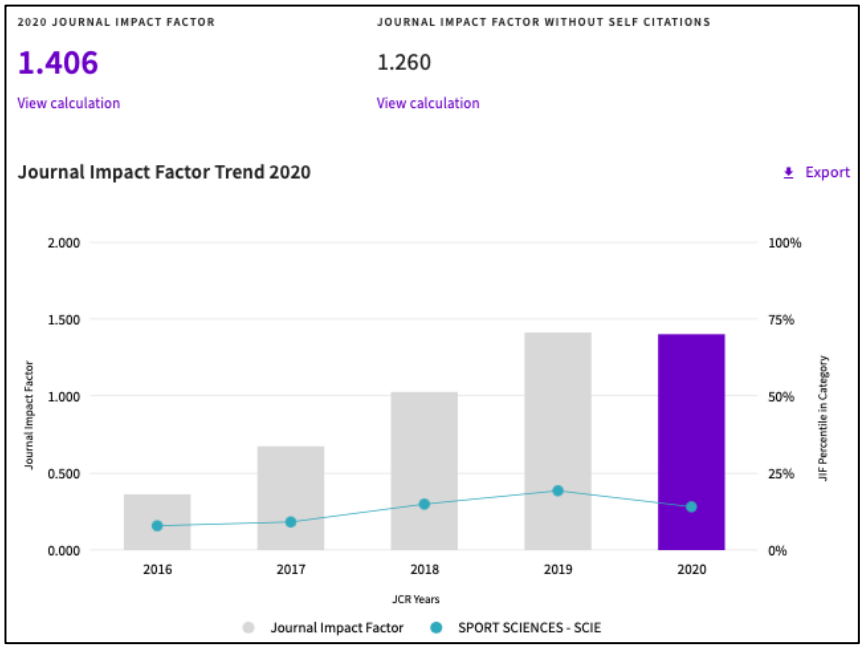
| JCR YEAR | JIF RANK | JIF QUARTILE | JIF PERCENTILE |
|---|---|---|---|
| 2020 | 76/88 | Q4 | 14.20 |
| 2019 | 69/85 | Q4 | 19.41 |
| 2018 | 71/83 | Q4 | 15.06 |
| 2017 | 74/81 | Q4 | 9.26 |
| 2016 | 75/81 | Q4 | 8.02 |



## Anexo B: Sustainability

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# sustainability

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## Message from the Editor-in-Chief

I encourage you to contribute a research or comprehensive review article for consideration for publication in *Sustainability*, an international open access journal which provides an advanced forum for research findings in areas related to sustainability and sustainable development. The journal publishes original research articles, reviews, conference proceedings (peer reviewed full articles) and communications. I am confident you will find the journal contributes to enhancing understanding of sustainability and fostering initiatives and applications of sustainability-based measures and activities.

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## Aims and Scope

Our aim is to encourage experts to publish their experimental, computational and theoretical research on sustainability. This encompasses topics related to social sciences, natural and applied science and engineering, in order to enable the application and development of sustainability.

### Subject Areas

- Defining, quantifying, measuring, and monitoring sustainability
- Environmental management and conservation
- Resources and sustainable utilization
- Climate change
- Sustainability of energy resources
- Sustainable regional planning and development
- Sustainable economic development and business management
- Sustainable supply chains, logistics, and transportation
- Food consumption and safety
- Sustainable agriculture
- Sustainability, biodiversity and conservation
- Education for sustainability
- Sustainable tourism, culture preservation, and heritage conservation
- Relation of geographical changes and social development to sustainability
- Psychological aspects of sustainability and sustainable development
- Health and sustainability
- Hazards and sustainability
- Sustainable materials

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Basel, May 2022

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IMPACT FACTOR 2.576

# CERTIFICATE OF ACCEPTANCE

Certificate of acceptance for the manuscript (**sustainability-926655**) titled:

Effect of a padel match on biochemical and haematological parameters in professional players. Gender-related comparisons

Authored by:

Francisco Pradas; Alejandro García-Giménez; Víctor Toro-Román; Bernardino Javier Sánchez-Alcaraz; Nicolae Ochiana; Carlos Castellar

has been accepted in *Sustainability* (ISSN 2071-1050) on 14 October 2020

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Basel, October 2020

## Anexo C: International Journal of Environmental Research and Public Health

# International Journal of *Environmental Research and Public Health*

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## Message from the Editorial Board

Addressing the environmental and public health challenges requires engagement and collaboration among clinicians and public health researchers. Discovery and advances in this research field play a critical role in providing a scientific basis for decision-making toward control and prevention of human diseases, especially the illnesses that are induced from environmental exposure to health hazards.

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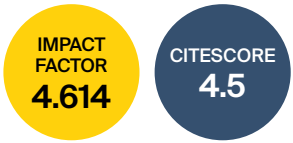
- **Rapid Publication** First decision provided to authors approximately 22.5 days after submission; acceptance to publication is undertaken in 2.8 days (median values for papers published in this journal in the first half of 2022)




## Aims and Scope

*IJERPH* (ISSN 1660-4601) is a peer-reviewed scientific journal that publishes original articles, critical reviews, research notes, and short communications in the interdisciplinary area of environmental sciences and public health. As a comprehensive multi-disciplinary journal, *IJERPH* is comprised of Thirty-five major sections including the following:

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- Digital health
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- Women's health
- Health care sciences & services
- Health communication and informatics
- Toxicology and public health
- Public health statistics and risk assessment
- Environmental microbiology
- Oral health
- Exercise and health
- Traumas
- Nursing
- Adolescents
- Skin health
- Disabilities
- Reproductive health
- Sport and health
- Aging
- Air
- Water science and technology
- Anthropogenic circularity
- Chemoenvironment
- Environmental earth science and medical geology
- Biosafety
- Disease prevention
- Health-related quality of life and well-being

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Basel, July 2022

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# CERTIFICATE OF PUBLICATION

Certificate of publication for the article titled:

Gender Differences in Neuromuscular, Haematological and Urinary Responses during Padel Matches

Authored by:

Francisco Pradas; Alejandro García-Giménez; Víctor Toro-Román; Nicolae Ochiana; Carlos Castellar

Published in:

*Int. J. Environ. Res. Public Health* **2021**, Volume 18, Issue 11, 5864

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Indexed in: PubMed | CITESCORE 3.4 SCOPUS | IMPACT FACTOR 3.390

# CERTIFICATE OF ACCEPTANCE

Certificate of acceptance for the manuscript (**ijerph-1622829**) titled:

Performance Outcome Measures in Padel: A Scoping Review

Authored by:

Alejandro García-Giménez; Francisco Pradas de la Fuente; Carlos Castellar-Otín; Luis Carrasco-Paéz

has been accepted in *Int. J. Environ. Res. Public Health* (ISSN 1660-4601) on 04 April 2022

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## Anexo D: Justificación de contribución del doctorando

### Anthropometric Characteristics of Elite Paddle Players. Pilot Study

Mis contribuciones en este artículo son las siguientes:

1. Metodología e investigación.
2. Redacción del borrador inicial del artículo.
3. Participación de manera activa en la distintas fases experimentales de la investigación realizada sobre el deporte del pádel

### Effect of a Padel Match on Biochemical and Haematological Parameters in Professional Players with Regard to Gender-Related Differences

Mis contribuciones en este artículo son las siguientes:

1. Metodología e investigación.
2. Redacción del borrador inicial del artículo.
3. Participación de manera activa en la distintas fases experimentales de la investigación realizada sobre el deporte del pádel

### Gender Differences in Neuromuscular, Haematological and Urinary Responses During Padel Matches

Mis contribuciones en este artículo son las siguientes:

1. Metodología e investigación.
2. Redacción del borrador inicial del artículo.
3. Redacción, revisión y edición del borrador final del artículo.
4. Participación de manera activa en la distintas fases experimentales de la investigación realizada sobre el deporte del pádel

### Performance Outcome Measures in Padel: A Scoping Review

Mis contribuciones en este artículo son las siguientes:

1. Conceptualización.
2. Metodología e investigación.
3. Redacción del borrador inicial del artículo.
4. Redacción, revisión y edición del borrador final del artículo.
5. Participación de manera activa en la distintas fases experimentales de la investigación realizada sobre el deporte del pádel