ISSN: 0212-8799

212

Volumen 39(6)
Noviembre - Diciembre 2022

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINALES

REVISIÓN

CELAD
Comisión Española para la Lucha Antidopaje en el Deporte

Consejo Superior de Deportes

UCAM Universidad Católica San Antonio de Murcia

Campus de los Jerónimos,
Nº 135 Guadalupe 30107

(Murcia) - España

Tlf: (+34)968 27 88 01 · info@ucam.edu

UCAM UNIVERSIDAD CATÓLICA DE MURCIA

Sociedad Española de Medicina del Deporte

Archivos de medicina del deporte

Revista de la Sociedad Española de Medicina del Deporte

Afiliada a la Federación Internacional de Medicina del Deporte, Sociedad Europea de Medicina del Deporte y Grupo Latino y Mediterráneo de Medicina del Deporte

Edita
Sociedad Española de Medicina del Deporte
C/ Cánovas nº 7, local
50004 Zaragoza (España)
Tel. +34 976 02 45 09
femede@femede.es
www.femede.es

Correspondencia:
C/ Cánovas nº 7, local
50004 Zaragoza (España)
archmeddeporte@semede.es
http://www.archivosdemedicinadeldeporte.com/

Publicidad
ESMON PUBLICIDAD
Tel. 93 2159034

Publicación bimestral
Un volumen por año

Depósito Legal
Zaragoza. Z 988-2020

ISSN
0212-8799

Soporte válido
Ref. SVR 389

Indexada en: EMBASE/Excerpta Medica, Índice Médico Español, Sport Information Resource Centre (SIRC), Índice Bibliográfico Español de Ciencias de la Salud (IBECS), Índice SJR (SCImago Journal Rank), y SCOPUS

Archivos de medicina del deporte

Volumen 39(6) - Núm 212. Noviembre - Diciembre 2022 / *November - December 2022*

Sumario / Summary

Dopaje en el deporte y riesgo cardiovascular

Doping in sport and cardiovascular risk

José Luis Terreros Blanco

Director de la Comisión Española para la Lucha Antidopaje (CELAD). Especialista en Medicina del Deporte.

doi: 10.18176/archmeddeporte.00107

Introducción

Aunque la definición que contiene el código mundial antidopaje (Código)[1] describe 11 diferentes acciones y comportamientos que pueden ser considerados dopaje, para el médico práctico el problema más habitual es el del manejo de medicamentos que pudieran encontrarse en la lista de sustancias y métodos prohibidos (Lista)[2]. La posesión o el uso o el intento de uso de alguna de esas sustancias, la administración o su intento o, por supuesto, el tráfico o intento de tráfico de las mismas, la presencia de alguna de ellas o de sus metabolitos o marcadores en una muestra fisiológica de un deportista puede acabar acarreando graves problemas al deportista y también al profesional.

La ética médica y los principios y reglas deontológicos deben guiar nuestra conducta, entre ellos el principio de "no maleficencia *(primum nil nocere)*" es el faro principal que marca el camino al profesional sanitario, nunca se debe actual sin analizar el balance riesgo-beneficio.

En el ámbito deportivo, pero también en el de los profesionales médicos, incluso en el de los que se dedican específicamente a la práctica de la medicina del deporte, está muy interiorizado que esas sustancias prohibidas pueden mejorar el rendimiento deportivo y la vez representan un peligro para la salud, hasta para la vida, de los deportistas, de modo que ese principio de "no maleficencia" impide al médico que obra de manera ética, manejar esas sustancias para mejorar el rendimiento deportivo.

No obstante, si estudiamos de modo detenido la definición de estas sustancias en el artículo 4.3 del Código, vamos a ver que son tres los criterios para que la Agencia Mundial Antidopaje (AMA) clasifique a una sustancia como prohibida:

- Evidencia científica o médica de que la sustancia tiene capacidad potencial de mejorar el rendimiento deportivo.
- Evidencia científica o médica de que la sustancia representa un riesgo para la salud del deportista.
- Que la AMA haya determinado que el uso de la sustancia viola el *"espíritu del deporte".*

La AMA define en el Código al *"espíritu del deporte"* como: *"la celebración del espíritu humano, cuerpo y mente. Es la esencia del Olimpismo y se refleja en los valores del deporte",* y aquí añade una lista de esos valores, tan altamente subjetivos como la misma definición. Esto quiere decir que en esta lista podemos encontrar sustancias que no mejoran el rendimiento deportivo y también sustancias que no representan un riego para la salud, todo ello otorga a la AMA un alto grado de discrecionalidad para declarar a cualquier sustancia que mejore el rendimiento o sea peligrosa, como prohibida.

En países con un sistema antidopaje avanzado, como es el caso de España, ello se traduce en que las normas antidopaje se aplican a todas las infracciones como normas administrativas (Ley Orgánica 11/2021, de 28 de diciembre, de lucha contra el dopaje en el deporte) y en el caso de existir riesgo para la salud se persiguen como delitos con castigo penal (Ley Orgánica 10/1995, de 23 de noviembre, del Código Penal, artículo 362 quinquies).

Respecto al comportamiento de los profesionales sanitarios, esta falta de claridad en las causas de inclusión en la lista de sustancias y medicamentos viene provocando que se trate de justificar el uso de sustancias prohibidas invocando falta de evidencia de riesgo para la salud e incluso hablando de "protección de la salud" con su uso.

Por todo ello es indispensable el contar con evidencias del riesgo real para la salud por el uso de sustancias prohibidas en deportistas sanos. En los últimos diez años las evidencias se han ido multiplicando[3-7]. Podemos afirmar que el sistema fisiológico más comprometido en el ejercicio deportivo y donde asientan la mayor parte de las

Correspondencia: José Luis Terreros Blanco
E-mail: secretaria.direccion@celad.gob.es

patologías graves y de la muerte súbita en el deporte es el sistema cardiovascular[8-18].

El principal motivo de esta editorial es proporcionar al médico del deporte datos objetivos sobre el riego real del dopaje a través de las evidencias de sus efectos en el sistema cardiovascular. Para ello queremos recordar y recomendar la lectura de la publicación en 2022 de Adami *et al.*[19] como posición oficial de la Sociedad Europea de Cardiología a través de su núcleo de cardiología del deporte, sobre los efectos cardiovasculares de las sustancias dopantes, así como otras medicinas de frecuente prescripción y de las ayudas ergogénicas.

Los autores actualizan en la publicación de la posición oficial del grupo de estudio en Cardiología del Deporte de la Sociedad Europea de Cardiología, publicada en 2006[11]. Se trata un trabajo con una revisión sistemática crítica de las evidencias sobre efectos cardiovasculares de estas sustancias (con 170 referencias). Incluye un estudio de los mecanismos farmacológicos y fisiopatológicos en el sistema cardiovascular, su impacto real sobre el rendimiento deportivo y la relación riesgo/beneficio que otorgan.

Creemos que todo médico que desarrolla su labor en el ámbito de la Medicina del Deporte debe estudiar cuidadosamente esta posición oficial.

Sustancias prohibidas y riesgo cardiovascular

Vamos a insistir en el riesgo cardiovascular y las principales sustancias que lo provocan. Esto no quiere decir que no haya otras sustancias peligrosas en la lista con riesgos para la salud de otro tipo, pero la que recordamos son aquellas que la Posición de la Sociedad Europea de Cardiología reconoce.

Sustancias no aprobadas

No nos parece necesario insistir en el peligro de las sustancias de este tipo, que no han sido aprobadas por no haber avanzado los estudios al haber evidenciado riesgos que impiden su uso en clínica humana, que fueron directamente desechados por evidenciar riesgos graves en fases clínicas o que todavía están en estudios clínicos no terminados. No creemos necesario incidir en los riesgos cardiovasculares y de todas las clases en esas sustancias no aprobadas.

Los moduladores metabólicos son sustancias de este tipo en las que una mínima ética médica debe desaconsejar de entrada su uso, son sustancias con efectos secundarios no conocidos y potencialmente graves ya que interfieren en aspectos centrales de metabolismo muscular y llegan a modificar la activación de la transcripción genética en una variedad de loci uniéndose a puntos específicos del ADN. La lista menciona a AICAR, stenabolic, PPAR-delta, cardarina o endurobol.

Agentes anabolizantes (AAS)

El uso de AAS ha evidenciado un aumento del 30% de mortalidad, debido a causas cardiovasculares[8] y define a ese aumento de mortalidad debido al aumento de aterogénesis, a trombosis y a vasoespasmo. Estos factores llevan a lesiones miocárdicas directas, hipertensión arterial, infarto de miocardio agudo, arritmias y muerte súbita[8,20]. Actualmente existen numerosas evidencias sobre las relaciones entre consumo de AAS y arterioesclerosis coronaria, así como con la aparición de miocardiopatías[21-26].

Por otra parte, debemos considerar a los moduladores selectivos de los receptores de los andrógenos (SARM) diseñados para aislar los efectos androgénicos de los efectos anabolizantes que causan los AAS. Se trata de sustancias consideradas experimentales en humanos, la lista menciona a andarina, enobosarm (ostarina), ligandrol, testolona, sarmbolona y el miostano, que son sustancias de origen ilegal. Las cantidades detectadas en recientes entradas y registros en laboratorios clandestinos por parte de los cuerpos de seguridad con colaboración de la CELAD, nos revelan que están siendo usadas en cantidades posiblemente masivas por deportistas. No están aprobados después de 20 años de investigación por graves efectos potenciales como carcinogénesis y alteraciones cardiovasculares[27].

Al clenbuterol, la lista lo clasifica entre estos anabolizantes, aunque parece más conveniente estudiar sus efectos entre los beta-2-agonistas.

Hormonas peptídicas, factores de crecimiento, sustancias relacionadas y miméticos

La lista incluye en este epígrafe las eritropoyetinas recombinantes (rhEPO) (incluyendo la darbopoyetina la CERA y similares) y a los agentes que afectan a la eritropoyesis, como los activadores del factor de hipoxia inducible, y el cobalto, el daprodustat, el molidustat, el roxadustat, el vadadustat, el xenón y los inhibidores de GATA.

Las rhEPO presentan numerosos efectos cardiovasculares secundarios con impacto potencialmente grave en la salud de los deportistas que las utilizan en un contexto de dopaje: aumento de la viscosidad de la sangre[14-15], aumento de la coagulación y de la reactividad plaquetaria y del riego de trombosis[7,16].

En el caso de otros moduladores del transporte de oxígeno, el cloruro de cobalto se asocia al desarrollo de miocardiopatías dilatadas[3,28], mientras el mecanismo de otros es el de alterar la curva de saturación en O_2, con lo que puede causar hipoxemias en condiciones de reposo y al nivel del mar, con un alto riesgo cardiovascular potencial.

Respecto al uso de la hormona de crecimiento humana (hGH) ya es de antiguo conocido que los pacientes con acromegalia desarrollan con frecuencia hipertensión arterial, insuficiencia cardiaca congestiva y miocardiopatías[6] con remodelado concéntrico del ventrículo izquierdo[10], que puede llevar a fibrosis, fenómenos inflamatorios y acabar en necrosis del miocardio[11].

Narcóticos

Los narcóticos tienen un fuerte efecto en los mecanismos eléctricos de la contracción del miocardio, sabemos que metadona y levometadil aumentan el tiempo y la dispersión del espacio QT del electrocardiograma, con el consiguiente riesgo de taquicardia ventricular polimorfa[29]. Además, se refiere la aparición de miocardiopatías de estrés similares al síndrome de Takotsubo y de síndromes similares al de Brugada[30].

Estimulantes

Es bien conocida la relación entre arritmias cardiacas, especialmente aquellas en las que se reconoce una base genética y el uso de estimulantes[4]. Estas sustancias provocan efectos profundos en el neurofisiología del sistema nervioso central y sobre el sistema cardiovascular y se describen como factores etiológicos o provocadores de insuficiencia cardiaca congestiva, infarto agudo de miocardio, fibrosis valvulares, fibrosis de las cámaras cardiacas, miocardiopatías, hipertensión pulmonar e infarto y hemorragia cerebrales[5,13,31,32], los cambios anatómicos y funcionales que estimulantes como las anfetaminas acaban provocando se han evidenciado como sustratos causantes de muerte súbita[33].

No podemos olvidar el cúmulo de evidencias del impacto negativo de los estimulantes sobre la termorregulación, por lo que unidos a un ejercicio deportivo en ambiente cálido y húmedo pueden causar casos efectos graves[34,35].

Beta-2-Agonistas

La lista recoge a: arformoterol, fenoterol, formoterol, higenamina, indacaterol, levosalbutamol, olodaterol, procaterol, reproterol, salbutamol, salmeterol, terbutaline tretoquinol, tulobuterol y vilanterol. Todos ellos como sustancias específicas.

Al clembuterol la lista lo coloca entre "otros anabolizantes" y como sustancia específica.

El salbutamol a altas dosis y por vía oral sería estimulante y mejoraría la potencia anaeróbica y la fuerza. El clembuterol además estimula la lipolisis, estos fármacos a dosis efectivas provocan taquicardia, temblor, molestias gastrointestinales, pueden tener efecto arritmogénico supraventricular y ventricular con isquemia miocárdica[14,36] e insuficiencia cardiaca aguda[9,37].

Glucocorticoides

Están prohibidos por inyectados cualquier vía, por vía oral y oromucosa y por vía rectal. Es conocido su efecto cardiovascular con hipertensión arterial y dislipemia[12,38].

Otras aportaciones

El documento de Posición igualmente recoge las evidencias de valoración de las potenciales mejoras para el deporte que provocan cada una de las sustancias estudiadas.

Igualmente queremos apuntar el interés de esta publicación debido a otros aspectos como la detallada descripción de los potenciales efectos cardiovasculares indeseables de numerosos fármacos que el médico del deporte que maneja frecuentemente en sus pacientes, aunque no están incluidos en la lista, como: antiarrítmicos, beta-bloqueantes (prohibidos solo en ciertos deportes) antiagregantes plaquetarios, anticoagulantes, benzodiacepinas, antidepresivos, antiepilépticos y antinflamatorios.

Finalmente, la revisión se extiende a los efectos de numerosos suplementos deportivos de uso legal en el deporte como: cafeína, creatina, carbohidratos, Beta-alanina, bicarbonato de sodio, nitratos, proteínas y bebidas energéticas. Igualmente, sobre sustancias y hábitos insalubres de tipo recreativo: alcohol, tabaco y nicotina.

Bibliografía

1. World Anti-Doping Agency. *World Antidoping Code 2021*. Stock Exchange Tower. 800 Place Victoria (Suite 1700) Montreal, Quebec Canada.
2. World Anti-Doping Agency. *World Anti-Doping Code International Standard Prohibited List 2023*. Stock Exchange Tower. 800 Place Victoria (Suite 1700) Montreal, Quebec Canada.
3. Alexander CS. Cobalt-beer cardiomyopathy. A clinical and pathologic study of twenty-eight cases. *Am J Med*. 1972;53:395–417.
4. Katselou M, Papoutsis I, Nikolaou P, Qammaz S, Spiliopoulou C, Athanaselis S. Fenethylline (captagon) abuse—local problems from an old drug become universal. *Basic Clin Pharmacol Toxicol.* 2016;119:133–40.
5. Milroy CM, Parai JL. The histopathology of drugs of abuse. Histopathology. 2011;59:579–93.
6. Pope HG Jr, Wood RI, Rogol A, Nyberg F, Bowers L, Bhasin S. Adverse health consequences of performance-enhancing drugs: an Endocrine Society scientific statement. *Endocr Rev*. 2014;35:341–75.
7. Rasmussen P, Kim Y-S, Krogh-Madsen R, Lundby C, Olsen NV, Secher NH, *et al.* Both acute and prolonged administration of EPO reduce cerebral and systemic vascular conductance in humans. *FASEB J*. 2012;26:1343–8.
8. Achar S, Rostamian A, Narayan SM. Cardiac and metabolic effects of anabolic androgenic steroid abuse on lipids, blood pressure, left ventricular dimensions, and rhythm. *Am J Cardiol.* 2010;106:893–901.
9. Boucher A, Payen C, Garayt C, Ibáñez H, Dieny A, Doche C, *et a*l. Salbutamol misuse or abuse with fatal outcome: a case-report. *Hum Exp Toxicol.* 2011;30:1869–71.
10. Cittadini A, Berggren A, Longobardi S, Ehrnborg C, Napoli R, Rose´n T, *et al.* Supraphysiological doses of GH induce rapid changes in cardiac morphology and function. *J Clin Endocrinol Metab.* 2002;87:1654–9.
11. Deligiannis A, Björnstad H, Carre F, Heidbüchel H, Kouidi E, Panhuyzen Goedkoop NM, *et al*.; on behalf of the ESC Study Group of Sports Cardiology. ESC study group of sports cardiology position paper on adverse cardiovascular effects of doping in athletes. *Eur J Cardiovasc Prev Rehabil*. 2006;13:687–94.
12. Deligiannis AP, Kouidi EI. Cardiovascular adverse effects of doping in sports. *Hellenic J Cardiol.* 2012;53:447–57.
13. Figueredo VM. Chemical cardiomyopathies: the negative effects of medications and nonprescribed drugs on the heart. *Am J Med.* 2011;124:480–8.
14. Furlanello F, Bentivegna S, Cappato R, De Ambroggi L. Arrhythmogenic effects of illicit drugs in athletes. *Ital Heart J*. 2003;4:829–37.
15. Heuberger JA, Cohen Tervaert JM, Schepers FM, Vliegenthart AD, Rotmans JI, Daniels JM, *et al*. Erythropoietin doping in cycling: lack of evidence for efficacy and a negative risk-benefit. *Br J Clin Pharmacol*. 2013;75: 1406–21.
16. Jelkmann W. Erythropoietin doping: cardiovascular effects in athletes. *Ann Sports Med Res.* 2020;7:1142.
17. La Gerche A, Brosnan MJ. Cardiovascular effects of performance-enhancing drugs. *Circulation.* 2017;135:89–99.
18. Perry JC, Schuetz TM, Memon MD, Faiz S, Cancarevic I. Anabolic steroids and cardiovascular outcomes: the controversy. *Cureus.* 2020;12:e9333.
19. Adami PE, Koutlianos N, Baggish A, Bermon S, Cavarretta E, Deligiannis A, *et al.* Cardiovascular effects of doping substances, commonly prescribed medications and ergogenic aids in relation to sports: a position statement of the sport cardiology and exercise nucleus of the European Association of Preventive Cardiology. *E J of Prev Cardiol.* 2022:9,559–75.
20. Liu JD, Wu YQ. Anabolic-androgenic steroids and cardiovascular risk. *Chin Med J (Engl)*. 2019;132:2229–36.
21. Baggish AL, Weiner RB, Kanayama G, Hudson JI, Lu MT, Hoffmann U, *et al*. Cardiovascular toxicity of illicit anabolic-androgenic steroid use. *Circulation.* 2017;135:1991–2002.
22. Cecchi R, Muciaccia B, Ciallella C, Di Luca NM, Kimura A, Sestili C, *et al.* Ventricular androgenic-anabolic steroid-related remodeling: an immunohistochemical study. *Int J Legal Med*. 2017;131:1589–95.
23. Darke S, Torok M, Duflou J. Sudden or unnatural deaths involving anabolic androgenic steroids. J Forensic Sci. 2014;59:1025–8.
24. D'Andrea A, Radmilovic J, Caselli S, Carbone A, Scarafile R, Sperlongano S, *et al.* Left atrial myocardial dysfunction after chronic abuse of anabolic androgenic steroids: a speckle tracking echocardiography analysis. *Int J Cardiovasc Imaging*. 2018;34:1549–59.
25. Far HR, Agren G, Thiblin I. Cardiac hypertrophy in deceased users of anabolic androgenic steroids: an investigation of autopsy findings. *Cardiovasc Pathol.* 2012;21:312–6.

26. Rasmussen JJ, Schou M, Madsen PL, Selmer C, Johansen ML, Ulriksen PS, *et al*. Cardiac systolic dysfunction in past illicit users of anabolic androgenic steroids. *Am Heart J*. 2018;203:49–56.

27. Shrivastava S, Srivastava D, Olson EN, DiMaio JM, Bock-Marquette I. Thymosin beta4 and cardiac repair. *Ann N Y Acad Sci.* 2010;1194:87–96.

28. Ebert B, Jelkmann W. Intolerability of cobalt salt as erythropoietic agent. D*rug Test Anal.* 2014;6:185–9.

29. Fanoe S, Jensen G, Ege P. Proarrhythmic effect of methadone: an alternative explanation of sudden death in heroine addicts. *PACE.* 2006;29:S30.

30. Alinejad S, Kazemi T, Zamani N, Hoffman RS, Mehrpour O. A systematic review of the cardiotoxicity of methadone. *EXCLI J.* 2015;14:577–600.

31. Al-Imam A. Adverse effects of amphetamines on the cardiovascular system: Review and retrospective analyses of trends. *Glob J Health Sci.* 2017;9:102.

32. Hennissen L, Bakker MJ, Banaschewski T, Carucci S, Coghill D, Danckaerts M, *et al*. The ADDUCE consortium. Cardiovascular effects of stimulant and non-stimulant medication for children and adolescents with ADHD: a systematic review and meta-analysis of trials of methylphenidate, amphetamines and atomoxetine. *CNS Drugs*. 2017;31:199–215.

33. Morentin B, Callado LF, García-Hernández S, Bodegas A, Lucena J. The role of toxic substances in sudden cardiac death. *Spanish J Legal Med.* 2018;44:13–21.

34. Keisler BD, Hosey RG. Ergogenic aids: an update on ephedra. *Curr Sports Med Rep*. 2005;4:231–5.

35. Roelands B, Hasegawa H, Watson P, Piacentini MF, Buyse L, De Schutter G, *et al*. The effects of acute dopamine reuptake inhibition on performance. *Med Sci Sports Exerc*. 2008;40:879–85.

36. Ghodse A, Galea S. O A, *Narcotic Antagonists I. Side Effects of Drugs Annual.* Amsterdam, The Netherlands: Elsevier; 2010;183–224.

37. Ferrua S, Varbella F, Conte M. Images in cardiology. Acute myocardial infarction due to coronary vasospasm and salbutamol abuse. *Heart*. 2009;95:673.

38. Duclos M. Glucocorticoids: a doping agent? *Endocrinol Metab Clin North Am*. 2010;39:107–126, ix–x.

Feliz
año
2023

Measurement of ankle dorsiflexion: comparison between two different positions

Paloma Guillén-Rogel[1], Judith Burton Hess[2], Pedro J Marín[3]

[1]Facultad de Ciencias de la Salud. Universidad Europea Miguel de Cervantes. Valladolid. España. [2]Facultad de Ciencias de la Salud. Universidad Midwestern. Downers Grove. USA. [3]CYMO Research Institute. Valladolid. España.

doi: 10.18176/archmeddeporte.00108

Recibido: 01/05/2020
Aceptado: 18/01/2021

Summary

Background: Several closed-chain activities, including walking, running, squatting or jumping, require normal flexibility of the ankle joint. Reduced ankle dorsiflexion range of motion will limit the forward progression of the tibia over the talus during these skills. A restriction ankle dorsiflexion range of motion has been associated with several clinical conditions in the lower extremities. Weight bearing dorsiflexion measurements has been shown to be more reliable than non-weight bearing and are more clinically relevant. In clinical practice and research, multiple protocols and positions have been utilized when measuring weight bearing ankle dorsiflexion range of motion, although the differences among have not been studied.
Objective: The purpose of this study was to come ankle dorsiflexion range of motion in two different positions: standing and kneeling.
Material and method: Sixty physically active participants (51 men, 9 women; average age 21.6 ± 1.2 years) participated in this study. Weight bearing ankle dorsiflexion range of motion was evaluated, in random order, in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the modified weight-bearing lunge test, one knee on the floor (WBL-Mod).
Results: Statistically significant differences were found ($p < 0.001$; η^2=0.513) between the values recorded during the WBL-Nor (12.5 ± 3.2 cm) vs. WBL-Mod (10.9 ± 3.5 cm).
Conclusion: The standing and kneeling tests of ankle dorsiflexion range of motion cannot be used interchangeably, if the objective is to measure peak ankle dorsiflexion range of motion. It is recommended that this test is performed in standing if the patient/research participant is capable.

Key words:
Foot. Weight-bearing. Range of motion. Articular.

Medición de la dorsiflexión del tobillo: comparación entre dos posiciones diferentes

Resumen

Antecedentes: Varias actividades en cadena cerrada, como caminar, correr, ponerse de cuclillas o saltar, requieren un rango de movimiento normal de la articulación del tobillo. La reducción del rango de movimiento de la dorsiflexión del tobillo limitará la progresión hacia adelante de la tibia sobre el astrágalo durante estas acciones. Una restricción de la dorsiflexión del tobillo se ha asociado con varias disfunciones clínicas en las extremidades inferiores. Se ha demostrado que las mediciones de dorsiflexión en carga son más fiables que las que no soportan carga y son más relevantes clínicamente. En la práctica clínica y en la investigación, se han utilizado múltiples protocolos y posiciones al medir el rango de movimiento de la dorsiflexión del tobillo en carga, aunque las diferencias entre ellas no se han estudiado.
Objetivo: El objetivo de este estudio fue obtener el rango de movimiento de la dorsiflexión del tobillo en dos posiciones diferentes: de pie y arrodillado.
Material y método: Sesenta participantes físicamente activos (51 hombres, 9 mujeres; edad promedio 21,6 ± 1,2 años) participaron en este estudio. Se evaluó el rango de movimiento de la dorsiflexión del tobillo en carga, en orden aleatorio, en dos posiciones: una posición estándar (WBL-Nor) y otra modificada, con una rodilla en el suelo (WBL -Modificación).
Resultados: Se encontraron diferencias estadísticamente significativas ($p <0,001$; $\eta^2 = 0,513$) entre los valores registrados durante el WBL-Nor (12,5 ± 3,2 cm) vs. WBL-Mod (10,9 ± 3,5 cm).
Conclusión: La posición de medición condicionan los valores de la dorsiflexión del tobillo. Si el objetivo es medir el rango de movimiento máximo de la dorsiflexión del tobillo, se recomienda que esta prueba se realice en WBL-Nor.

Palabras clave:
Pie. Carga. Rango de movimiento. Articular.

Correspondencia: Paloma Guillén-Rogel
E-mail: pguillen@uemc.es

Introduction

The knee and ankle are a complex joint that are mobile, flexible, stable, strong, and resistant, responsible to support the body mass, that allows to be engaged in a wide range of movements and activities of daily living[1,2].

Several closed-chain activities, including walking, running, squatting, landing or jumping, require normal flexibility of the ankle joint[3,4]. A restriction of ankle dorsiflexion range of motion (DF ROM) has been linked to lower extremity (LE) biomechanical faults and clinical conditions[5-9]. Restrictions in ankle DF ROM may be due to tightness of the triceps surae[5] or arthrokinematics restrictions in the posterior glide of the talus on the ankle mortise[10]. Reduced ankle DROM will limit the forward progression of the tibia over the talus during activities that require simultaneous knee flexion and ankle dorsiflexion[7]. During closed-chain activities, restricted DF ROM is often accompanied by decreased sagittal plane motion of the knee, hip, and trunk, as well as increased frontal plane motion of the LE[11]. For example, during a squat, restricted DF ROM may result in excessive subtalar joint pronation and midtarsal dorsiflexion[12], tibial and femoral internal rotation, medial knee displacement, and knee valgus[8,13]. Decreased DF ROM was also associated with reduced quadriceps activation and increased soleus activity during the descent portion of a squat[8].

Because of these biomechanical compensations, reduced ankle DF ROM has been associated with increased risk of several clinical conditions, including anterior cruciate ligament (ACL) injury[12], stress fractures[14], plantar fasciopathy[15], Achilles tendinopathy[16] patellar tendinopathy[17], patellofemoral pain syndrome[18] and iliotibial band syndrome[19]. Thus, physical therapists must recognize the importance of accurate assessment of DF ROM during pre-season screening for LE injury risk factors[20,21], as well as when evaluating and treating a variety of lower extremity clinical conditions[22,23].

Historically, DF ROM has been assessed in the clinic using a goniometer or inclinometer in a non-weight bearing position. Intra-rater reliability of measurements of non-weight bearing ankle DF ROM are moderate to good with a goniometer (ICC=0.65-0.89) and good with a digital inclinometer (ICC=0.84-0.95)[20]. However, inter-rater reliability of goniometric measurements has ranged from poor to moderate[24].

Recently, weight bearing tests have increased popularity[25], as this measurement is assumed to more precisely reflect ankle range of motion during functional activities[26]. The weight bearing lunge test (WBLT), as described by Bennell in 1998 measures ankle dorsiflexion isolated to the tibio-talar joint proportional to the patient's body weight[25]. The original WBLT aligned the subject perpendicular to wall and instructed the subject to bend the knee while keeping the heel on the ground. The subjects was repositioned further/closer to the wall until maximal dorsiflexion was achieved, defined as the maximal distance from the wall to the toe while maintaining contact with the wall and keeping the heel on the ground[27]. According to Bennell[26] (1998), 1.0 cm distance from the wall was equivalent to 3.6˚ of DF ROM.

Variations of the WBLT include using an inclinometer to measure the relative angle of the tibia to the ground. The weight-bearing lunge test has demonstrated good to excellent intra-rater (ICC= 0.88 and 0.97) and inter-rater reliability (ICC=0.82 and 0.97), both when measuring distance from the wall or tibial angle[21,26,27]. Along of the time, mobile applications that measure ankle dorsiflexion such as Tiltmeter[28], iHandy, and Dorsiflex iPhone app[29] have become more accessible and clinically useful. The Leg Motion® system (CheckyourMOtion®, Albacete, Spain) is a new, portable device designed to measure WB ankle DROM in a manner similar to the weight-bearing lunge test[3,30]. The Leg Motion® system has been demonstrated to be a reliable and valid measurement of WB ankle DF ROM in healthy participants and allows for test in virtually any location[3,31]. However, there is scarce information about different positions.

Multiple techniques have been utilized in the literature when measuring WB ankle DF ROM, including distance from the wall, digital inclinometry and goniometry[32]. Variations in the position of the contralateral lower extremity are seen as well. Bennell described the position of the untested limb as resting freely in a comfortable position on the floor[26]. The two most common positions utilize a tandem stance, one measuring the front ankle with the knee flexed and the other measuring the rear ankle with the knee extended[32]. While the majority studies perform the WBLT in standing, Balsalobre-Fernandez[29] took measurements with the subject kneeling on the opposite limb. Stanek[33] described the kneeling ankle dorsiflexion although the stepping distance was not standardized across participants.

The hypothesis of this study establishes the existence of significant differences in the result of the WBLT between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod).

To date, no published studies have compared WB DF ROM in a kneeling position with a standing position. The purpose of the present work was to compare ankle DF ROM measurements between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod). A secondary purpose of the investigation was to compare DF ROM measurements between right and left lower extremities in both conditions.

Material and method

Subjects

A priori sample size tests (G* Power 3.1.9.7) revealed that a total of 55 participants would be required to detect an effect side of 0.5, a statistical power of 0.8 and an alpha of 0.05. Therefore, 60 volunteers were recruited to avoid critical data loss.

Participants were recruited from a student population at a University. Sixty healthy, physically active adults (51 males and 9 females, age 21.6 ± 1.2 years, height 175.6 ± 0.3 cm, body mass 74.2 ± 7.3 kg) volunteered to participate in the study. Participants were excluded if they had any joint pathology in the hip, knee or ankle that a caused pain or restricted movement, neuromuscular disease, recent heel or knee pain; or a history of recent lower extremity trauma or elective surgery (in the last six months). The present study was approved by the institutional research ethics committee, and conformed to the recommendations of the Declaration of Helsinki. All participants read and signed an approved, written informed consent document before data collection.

Procedures

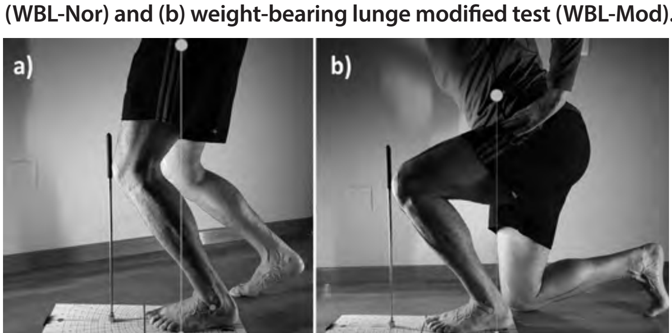
Ankle dorsiflexion ROM was evaluated using the LegMotion® system (CheckyourMOtion®, Albacete, Spain) in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the weight-bearing lunge modified test, one knee on the floor (WBL-Mod). The order of testing was determined by coin flip. All tests were conducted at the same time of the day (9:00 to 14:00) with 2 days (48 hours) between sessions.

For both tests (WBL-Nor and WBL-Mod), all subjects started with their hands on the hips and placed the assigned foot on the middle of the longitudinal line just behind the transverse line on the platform. During WBL-Nor the contralateral foot was placed lateral to the platform, with toes even with the posterior edge of the platform (Figure 1a). During WBL-Mod test the contralateral knee was placed posterolateral to platform, with the femur starting perpendicular to the ground, and the tested foot flat on the platform (Figure 1b). In both positions, the second toe and the center of the heel were placed directly over LegMotion® system (CheckyourMOtion®, Albacete, Spain), in order to attempt to reduce the subtalar joint pronation during the measurement procedure. While maintaining each position, subjects were instructed to perform a lunge in which the knee was flexed with the goal of making contact between the anterior knee and the metal stick. When the subjects were able to maintain heel and knee contact, the metal stick was moved away from the knee (Figure 1). The maximal distance achieved was recorded in centimeters. Three trials were performed for each ankle with ten seconds rest between trials. The third value in each ankle was selected for subsequent analysis of weight-bearing DF ROM[3,31,34].

Data analysis

Data were analyzed using PASW/SPSS Statistics 23 (SPSS Inc, Chicago, IL). After comparing the normality of the data by means of the Kolmogorov-Smirnov test, the Student t test for related samples was applied, establishing the level of significance at $p \leq 0.05$. All the measures were normally distributed, as determined by the Kolmogorov-Smirnov test. Sphericity was tested by the Greenhouse-Geisser method. The dependent variable (DF ROM) was evaluated with a two-way repeated measures analysis of variance (ANOVA) of test x leg. Where significant F values were achieved, pairwise comparisons were performed using the Bonferroni post hoc procedure. Effect size statistic, η^2, was analyzed to determine the magnitude of the effect independent of sample size. Values are presented as mean ± standard deviation (SD).

Figure 1. Leg Motion procedure (a) weight-bearing lunge test (WBL-Nor) and (b) weight-bearing lunge modified test (WBL-Mod).



Results

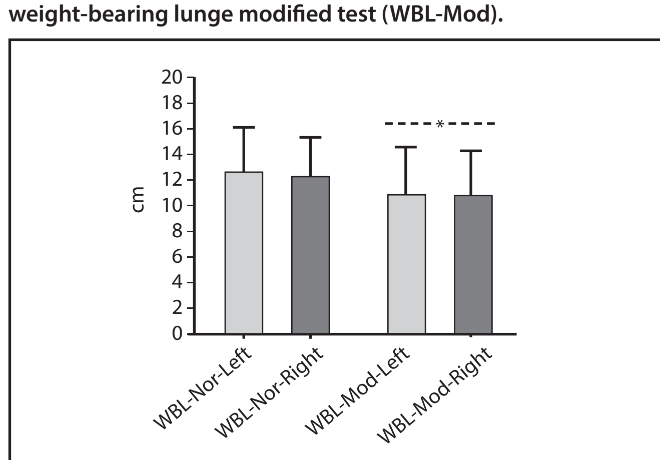
On average, participants in standing (WBL-Nor) achieved greater DF ROM (12.5 ± 3.2 cm) compared to kneeling (WBL-Mod) (10.9 ± 3.5 cm) (Figure 2). This difference, -1.6 cm, 95% CI [1.29, 1.94] was significant ($p < 0.001$), and represented a medium effect size, η^2=0.513.

There was no significant difference between right and left legs ($p > 0.05$; η^2=0.017). ANOVA showed no significant interaction effects between test procedure and legs ($p > 0.05$; η^2=0.014).

Discussion

This was the first investigation to compared the DF ROM between two versions of the weight bearing lunge test: standing (WBL-Nor) and kneeling (WBL-Mod). Significant differences in DF ROM were found between the two positions, with greater DF ROM recorded in the standing position. Several studies have demonstrated greater ankle DF ROM in weight bearing compared to non-weight bearing in healthy subjects. Most authors attribute these differences to the greater moments applied to the ankle joint during weight-bearing[24,32,35,36]. The present method did not allow us to quantify the contribution of the moment applied to the ankle, but some assumptions can be made, based on biomechanical principles. The WBL-Nor position allows a greater anterior excursion of the body's center of mass (COM), approximated just anterior to S2, than the WBL-Mod position (Figure 1). A more anterior center of mass increases the distance from the ankle joint to the body weight vector, this increasing the torque at the ankle joint. Additionally, in the kneeling position, a larger percentage of the individual's body weight is presumably accepted through the non-tested LE. Thus, the force of the body weight vector in the WBL-Mod position is less than in

Figure 2. DF ROM of weight-bearing lunge test (WBL-Nor) and weight-bearing lunge modified test (WBL-Mod).



* Significantly different than WBL-Nor.ms

the standing position. The combination of a greater moment arm and greater force through the body weight vector in the WBL-Nor position results in a much larger moment dorsiflexion moment about the ankle in standing. Thus, these findings of greater DF ROM in the standing WBL position are consistent with other studies demonstrating increased DF ROM with increased DF moment through the ankle[24,35,36].

Subjects in this study demonstrated a statistically significant difference in DF ROM between the WBL-Nor and WBL-Mod positions ($p < 0.001$). The mean WBL-Nor DF ROM in this study was 12.9 ± 3.2 cm, compared to 10.9 ± 3.5 cm in the WBL-Mod position. The WBL-Nor data is consistent with other studies that have utilized the tape measure or LegMotion system ® with healthy young adults, with mean distances ranging from 10.3 to 12.0 cm and standard deviations of 2.7-3.0 cm[3,21,30,37-39]. This difference is clinically relevant based previous publications that have determined the minimal detectable change of the WBL-Nor to be 1.1 - 1.6 cm[21,36,40].

This data did not show any differences between the right or left ankles for either the WBL-Nor or WBL-Mod positions. This is consistent with previous works that have found minimal differences between limbs in the WBLT[3,29,30,39]. Hoch and McKeon[38] noted that the majority of healthy subjects exhibited asymmetry of DF ROM of 1.5 cm or less, but there was not limb bias observed in the asymmetries. Reid[41] has suggested using a cutoff of 2.0 cm or greater of asymmetry as a clinically relative impairment.

A limitation to this investigation was the sample of participants used in this study took part physically active and therefore, the results cannot be generalized to a non-sporting population. Another limitation that there was no measurement to the the nature of the restriction in ankle DF-ROM[42].

There are two benefits of this study. First, the test can be performed on patients for whom weight-bearing is contraindicated in a standard position of the weight-bearing lunge test (WBL-Nor). Second, it isn´t difficult for a single observer to measure dorsiflexion with flexed knee. It is simple to administer, that allows health professional directly assess the ankle dorsiflexion range of motion while adopting a comfortable testing position.

Conclusion

Healthy subjects demonstrated greater DF ROM during the WBLT when performed in the standing position compared to a kneeling position. Given the results of the current study, if the objective of the test is to measure peak passive ankle dorsiflexion, it is recommended that this test is performed in standing if the patient/research participant is capable. Not only was there an effect of position on peak passive dorsiflexion where greater values were achieved in standing, but the difference was clinically relevant based on the published minimal detectable change (MDC)[21,32].

Declaration of interest statement

The last author declared potential conflicts of interest. He has patented the LegMotion® system (CheckyourMOtion®, Albacete, Spain).

Acknowledgments

The authors thank all the participants which, without their help, we were not able to conduct the study.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Medina McKeon JM, Hoch MC. The Ankle-Joint Complex: A Kinesiologic Approach to Lateral Ankle Sprains. *J Athl Train.* 2019;54:589-602.
2. Seixas A, Sanudo B, Sa-Caputo D, Taiar R, Bernardo-Filho M. Whole-Body Vibration for Individuals with Reconstructed Anterior Cruciate Ligament: A Systematic Review. *Biomed Res Int.* 2020:7362069.
3. Calatayud J, Martin F, Gargallo P, Garcia-Redondo J, Colado JC, Marin PJ. The validity and reliability of a new instrumented device for measuring ankle dorsiflexion range of motion. *Int J Sports Phys Ther*. 2015;10:197-202.
4. Howe LP, Bampouras TM, North JS, Waldron M. Improved ankle mobility after a 4-week training program affects landing mechanics: a randomized controlled trial. *J Strength Cond Res.* 2020.
5. Malloy P, Morgan A, Meinerz C, Geiser C, Kipp K. The association of dorsiflexion flexibility on knee kinematics and kinetics during a drop vertical jump in healthy female athletes. *Knee Surg Sports Traumatol Arthrosc.* 2015;23:3550-5.
6. Rabin A, Kozol ZVI. Utility of the overhead squat and forward arm squat in screening for limited ankle dorsiflexion. *J Strength Cond Res.* 2017;31:1251-8.
7. Rabin A, Kozol Z, Spitzer E, Finestone A. Ankle dorsiflexion among healthy men with different qualities of lower extremity movement. *J Athl Train*. 2014;49:617-23.
8. Macrum E, Bell DR, Boling M, Lewek M, Padua D. Effect of limiting ankle-dorsiflexion range of motion on lower extremity kinematics and muscle-activation patterns during a squat. *J Sport Rehabil.* 2012;21:144-50.
9. Denegar CR, Hertel J, Fonseca J. The effect of lateral ankle sprain on dorsiflexion range of motion, posterior talar glide, and joint laxity. *Orthop Sports Phys Ther*. 2002;32:166-73.
10. Denegar CR, Miller SJ, 3rd. Can chronic ankle instability be prevented? rethinking management of lateral ankle sprains. *J Athl Train.* 2002;37:430-5.
11. Bell DR, Padua DA, Clark MA. Muscle strength and flexibility characteristics of people displaying excessive medial knee displacement. *Arch Phys Med Rehabil.* 2008;89:1323-28.
12. Fong CM, Blackburn JT, Norcross MF, McGrath M, Padua DA. Ankle-dorsiflexion range of motion and landing biomechanics. *J Athl Train*. 2011;46:5-10.
13. Dill KE, Begalle RL, Frank BS, Zinder SM, Padua DA. Altered knee and ankle kinematics during squatting in those with limited weight-bearing-lunge ankle-dorsiflexion range of motion. *J Athl Train.* 2014;49:723-32.
14. Wilder RP, Sethi S. Overuse injuries: tendinopathies, stress fractures, compartment syndrome, and shin splints. *Clin Sports Med.* 2004;23:55-81, vi.
15. Riddle DL, Pulisic M, Pidcoe P, Johnson RE. Risk factors for Plantar fasciitis: a matched case-control study. *J Bone Joint Surg Am.* 2003;85-A:872-7.
16. Duthon VB, Lubbeke A, Duc SR, Stern R, Assal M. Noninsertional Achilles tendinopathy treated with gastrocnemius lengthening. *Foot Ankle Int.* 2011;32:375-9.
17. Backman LJ, Danielson P. Low range of ankle dorsiflexion predisposes for patellar tendinopathy in junior elite basketball players: a 1-year prospective study. *Am J Sports Med*. 2011;39:2626-33.
18. Mestelle Z, Kernozek T, Adkins KS, Miller J, Gheidi N. Effect of heel lifts on patellofemoral joint stress during running. *Int J Sports Phys Ther.* 2017;12:711-7.
19. Kaufman KR, Brodine SK, Shaffer RA, Johnson CW, Cullison TR. The effect of foot structure and range of motion on musculoskeletal overuse injuries. *Am J Sports Med.* 1999;27:585-93.
20. Martin RL, McPoil TG. Reliability of ankle goniometric measurements: a literature review. *J Am Podiatr Med Assoc.* 2005;95:564-72.
21. Konor MM, Morton S, Eckerson JM, Grindstaff TL. Reliability of three measures of ankle dorsiflexion range of motion. *Int J Sports Phys Ther.* 2012;7:279-87.
22. Robles-Palazon FJ, Ayala F, Cejudo A, De Ste Croix M, Sainz de Baranda P, Santonja F. Effects of age and maturation on lower extremity range of motion in male youth soccer players. *J Strength Cond Res.* 2020.

23. Madaleno FO, Verhagen E, Ferreira TV, Ribeiro T, Ocarino JM, Resende RA. Normative reference values for handgrip strength, shoulder and ankle range of motion and upper-limb and lower limb stability for 137 youth judokas of both sexes. *J Sci Med Sport.* 2021;24:41-5.
24. Rabin A, Kozol Z. Weightbearing and nonweightbearing ankle dorsiflexion range of motion: are we measuring the same thing? *J Am Podiatr Med Assoc.* 2012;102:406-11.
25. Chan O, Malhotra K, Buraimoh O, Cullen N, Welck M, Goldberg A, *et al*. Gastrocnemius tightness: A population based observational study. *Foot Ankle Surg.* 2018;25:517-22.
26. Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother.* 1998;44:175-80.
27. Munteanu SE, Strawhorn AB, Landorf KB, Bird AR, Murley GS. A weightbearing technique for the measurement of ankle joint dorsiflexion with the knee extended is reliable. *J Sci Med Sport.* 2009;12:54-9.
28. Williams CM, Caserta AJ, Haines TP. The TiltMeter app is a novel and accurate measurement tool for the weight bearing lunge test. *J Sci Med Sport.* 2013;16:392-5.
29. Balsalobre-Fernandez C, Romero-Franco N, Jimenez-Reyes P. Concurrent validity and reliability of an iPhone app for the measurement of ankle dorsiflexion and inter-limb asymmetries. *J Sports Sci*. 2018;37:249-53.
30. Romero Morales C, Calvo Lobo C, Rodriguez Sanz D, Sanz Corbalan I, Ruiz Ruiz B, Lopez Lopez D. The concurrent validity and reliability of the Leg Motion system for measuring ankle dorsiflexion range of motion in older adults. *PeerJ.* 2017;5:e2820.
31. Garcia-Gutierrez MT, Guillen-Rogel P, Cochrane DJ, Marin PJ. Cross transfer acute effects of foam rolling with vibration on ankle dorsiflexion range of motion. *J Musculoskelet Neuronal Interact*. 2018;18:262-7.
32. Powden CJ, Hoch JM, Hoch MC. Reliability and minimal detectable change of the weight-bearing lunge test: A systematic review. *Man Ther*. 2015;20:524-32.
33. Stanek J, Sullivan T, Davis S. Comparison of Compressive Myofascial Release and the Graston Technique for Improving Ankle-Dorsiflexion Range of Motion. *J Athl Train.* 2018;53:160-7.
34. Guillen-Rogel P, San Emeterio C, Marin PJ. Associations between ankle dorsiflexion range of motion and foot and ankle strength in young adults. *J Phys Ther Sci.* 2017;29:1363-7.
35. Baumbach S, Braunstein M, Seeliger F, Borgmann L, Böcker W, Polzer H, *et al.* Ankle dorsiflexion: what is normal? Development of a decision pathway for diagnosing impaired ankle dorsiflexion and M. gastrocnemius tightness. *Arch Orthop Trauma Surg.* 2016;136:1203-11.
36. Searle A, Spink MJ, Chuter VH. Weight bearing versus non-weight bearing ankle dorsiflexion measurement in people with diabetes: a cross sectional study. *BMC Musculoskelet Disord.* 2018;19:183-.
37. Hall EA, Docherty CL. Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. *J Sci Med Sport.* 2017;20:618-21.
38. Hoch MC, McKeon PO. The effectiveness of mobilization with movement at improving dorsiflexion after ankle sprain. *J Sport Rehabil.* 2010;19:226-32.
39. Hoch MC, Farwell KE, Gaven SL, Weinhandl JT. Weight-bearing dorsiflexion range of motion and landing biomechanics in individuals with chronic ankle instability. *J Athl Train.* 2015;50:833-9.
40. Powden CJ, Hoch JM, Hoch MC. Rehabilitation and Improvement of Health-Related Quality-of-Life Detriments in Individuals With Chronic Ankle Instability: A Meta-Analysis. *J Athl Train*. 2017;52:753-65.
41. Reid A, Birmingham TB, Alcock G. Efficacy of mobilization with movement for patients with limited dorsiflexion after ankle sprain: a crossover trial. *Physiother Can.* 2007;59:166-72.
42. Hirata K, Yamadera R, Akagi R. Associations between Range of Motion and Tissue Stiffness in Young and Older People. *Med Sci Sports Exerc.* 2020;52:2179-88.

Effects of repeated-sprint hypoxic training on physical fitness of active adults

Alba Camacho-Cardenosa, Marta Camacho-Cardenosa, Marta Marcos-Serrano, Ismael Martínez-Guardado, Rafael Timón, Guillermo Olcina

Faculty of Sport Sciences. University of Extremadura. Cáceres. Spain.

doi: 10.18176/archmeddeporte.00109

Recibido: 23/12/2020
Aceptado: 22/09/2021

Summary

Due to the time is, commonly, a barrier to exercise, the scientific community has paid attention to a new model of training. Repeated-sprint hypoxic training is now considered an effective time-efficient method for improving physical performance in different sport modalities. However, few researchers have studied the effect of this strategy in healthy untrained or moderately trained individuals. Depending of the prior fitness status, different findings may be obtained. Therefore, this study determined the effects of 4 weeks of repeated-sprint in hypoxia on cardiorespiratory fitness and anaerobic capacity in healthy men. Twenty-four physically active males (were randomly assigned to repeated-sprint in normoxia (n=8; 0.20 FiO_2), in hypoxia (n=8; 0.14 FiO_2) or a control group (n=8). Participants of both exercise groups developed eight training sessions consisted of 2 sets of 5 all-out cycling sprints of 10 s with a recovery of 20 s between sprints and 10 min between sets. Repeated sprint ability, vertical jump performance and estimated maximal oxygen consumption were tested at baseline, 7 days and 2 weeks after the last session. Seven days after the last sessions, significant differences ($p<0.05$) between normoxia (+7.8%; $p<0.001$; ES=1.66) and hypoxia groups (+9.9%; p=0.000; ES=1.42) compared with control group were found in estimated maximal oxygen consumption. In the hypoxia group, the number of sprints to exhaustion (7 days Post +55.6%; ES=1.40; 2 weeks Post +10.0%; ES=1.80) improved with a large effect size at 7 days and 2 weeks after the last sessions compared with baseline. Eight sessions of repeated-sprint training in hypoxia conditions could produce improvements and delayed effects on anaerobic capacity.

Key words:
Hypoxia. Sprint interval training. Physical conditioning. Cardiorespiratory fitness. Jump performance.

Efectos del entrenamiento de esprints repetidos en hipoxia sobre la condición física de adultos activos

Resumen

La comunidad científica ha prestado atención en los últimos años a un nuevo modelo de entrenamiento, debido a que la falta de tiempo es comúnmente la principal barrera para la práctica deportiva. En este contexto, el entrenamiento de esprint repetidos en hipoxia es considerado como una prometedora estrategia para mejorar el rendimiento físico en diferentes modalidades deportivas. Sin embargo, existen pocos estudios que investiguen los efectos sobre población moderadamente entrenada o sedentaria. Así, este estudio determina los efectos de un entrenamiento de esprint repetidos en hipoxia sobre la condición física de hombres sanos. Veinticuatro hombres fueron asignados aleatoriamente a un grupo normoxia (n=8; 0.20 FiO_2), hipoxia (n=8; 0.14 FiO_2) o control (n=8). Después de ocho sesiones de esprint repetido en cicloergómetros de 10 s, la habilidad de esprint repetido, el rendimiento en el salto vertical, así como el consumo de oxígeno fueron evaluados en la línea base y a los días y 2 semanas de la última sesión de entrenamiento. A los 7 días, se observaron diferencias significativas entre normoxia (+7,8%; $p<0.001$; ES=1,66) e hipoxia (+9,9%; p=0,000; ES=1,42) comparado con el grupo control en el consumo máximo de oxígeno estimado. En hipoxia, el número de esprint hasta la extenuación (7 días Post +55,6%; ES=1,40; 2 semanas Post +10,0%; ES=1,80) también mejoró con tamaño del efecto elevado a los 7 días y 2 semanas de la última sesión comparado con la línea base. El protocolo de 8 sesiones de esprines repetido en hipoxia podría producir mejoras y retrasar los efectos sobre el rendimiento anaeróbico de hombres sanos.

Palabras clave:
Hipoxia. Sprint repetido. Condición física. Resistencia cardiovascular. Salto vertical.

Correspondencia: Marta Camacho-Cardenosa
E-mail: mcamachocardenosa@unex.es

Introduction

In the clinical and sport context, improving or maintaining muscular strength, power, and endurance are goals commonly pursued by individuals practice physical training programs[1]. Over last decades, the scientific community has paid attention to high-intensity training such an effective time-efficient training method for improving physical performance in athletes[2]. Due to the most commonly cited barrier to physical activity is lack of time[3], there is today a surge of research interest focused on examining the effects of short sprints and all-out efforts[2]. In this sense, all-out repeated-sprint training has been shown as high-intensity training regimen capable to enhance exercise performance with a lower training volume[4].

Last decades, greater improvements in exercise performance of athletes of different sport modalities have been shown when high-intensity is carried out under hypoxic condition[5]. Innovative 'live low-train high' methods have emerged as 'repeated-sprint training in hypoxia' (RSH), based on maximal "all-out" efforts of short duration (<30 s) with incomplete recoveries[6,7]. Specific adaptations have been attributed to RSH, which differ from intermittent hypoxic training (IHT) adaptations. Maximal intensity accompanied with the drop in arterial oxygen content favour the usage of fast twitch fibers[8] and the compensatory vasodilation[9]. Increasing in muscle mitochondrial, capillary density[10] and stimulation of markers of mitochondrial metabolism and biogenesis[11] may enhance the anaerobic energy system contributing to greater improvements in anaerobic capacity and cardiorespiratory fitness[12].

Recently, it has been shown that RSH led to greater exercise performance than the same training in normoxia in athletes[5-8,13-18], as well as obesity population[19]. However, controversial results are shown and, no additional effect on performance outcomes were found in other reports[20].

On the other hand, the exercise program effectiveness is not only determined by short-term effects, unless the maintenance of the benefits achieved during the detraining period is essential[21]. After high-intensity programs, the beneficial training effects usually return to near resting values within only 2 weeks of detraining after programs[22]. In this sense, adding a hypoxic stimulus may allow for more systemic and muscular adaptations due to elevated hypoxic and oxidative stress in conjunction with pertinent neuromuscular and neuromechanical loading[23,24]. Lasting for at least three weeks post-intervention of RSH training, Yo-Yo performance and repeated-sprint ability of elite field team-sport kept increasing[25]. In obese women, RSH was an effective alternative for improving cardiovascular respiratory fitness when compared to the same normoxic training, even after of 4-weeks the cessation of the training program[19]. However, studies on the maintenance of exercise-induced performance benefits after cessation of training are rare.

Meanwhile RSH has been investigated in different modalities athletes[25], few researchers have investigated the effect of this strategy on performance in healthy untrained or moderately trained individuals. Depending of the prior fitness status, different findings may be found[26]. Therefore, the present study aimed at determining the effects of four weeks of RSH on cardiorespiratory fitness and anaerobic capacity in active adults. We hypothesized that RSH would lead to greater enhancement in aerobic as well as anaerobic parameters performance.

Material and method

Study design

The study was designed as a randomised blinded controlled trial. Participants were randomly assigned to one of the three groups of the study: control (CON; n=8) that completed only testing sessions, normoxic repeated-sprint training (RSN; n=8) or repeated-sprint training in hypoxia (RSH; n=8). One week prior to baseline measurements, participants visited the laboratory for familiarisation with experimental trials and fitness testing. A general questionnaire was completed to collect medical and personal data before entering the study. Subjects in both groups were instructed to maintain their usual physical activities during the study period. All participants were assessed at three time points: at baseline (Pre), in the 7 days after the last session (Post) and 2 weeks after the last session (Det). All time points for evaluations consisted of the same measurements.

Participants

Participants were recruited from the Sports Science Faculty of the University of Extremadura. Inclusion criteria, assessed during a screening visit, were: healthy men, physically active (per week: >75 min moderate-to-vigorous physical activity or 150 min moderate physical activity) and have not been acclimated or recently exposed to altitude (above 1,500 m for more than 6 hours per day (i.e., no overnight sleep at altitude), during the last 3 months). Exclusion criteria included contraindications to exercise and medication that may have affected on their daily activities.

Twenty-four physically active males (age: 23.1±3.6 years; body mass: 72.6±6.7 kg; BMI: 23.6±3.5 kg·m^{-2}) volunteered for this study. Compliance training was calculated as the number of sessions completed divided by the 8 possible sessions available per participant. All the participants should have to complete at least 80% of the sessions. Subjects were informed of the experimental protocol and after signing the informed consent became part of the study. This project was approved by the Bioethics Committee of the Council of Europe of the University of Extremadura and carried out according to the Declaration of Helsinki. Participant's characteristics are shown in Table 1.

Training sessions

Participants started the training protocol 1 week following baseline. During the 8-weeks study period, 8 training sessions were completed over 4 weeks, 2 days per week, supervised by an experienced member of the research group. Sessions were scheduled with at least 1 day of

Table 1. Participant's characteristics at baseline

	CON (n=8)	RSN (n=8)	RSH (n=8)
Age, years	22.8 ± 4.8	24.4 ± 3.5	22.1 ± 2.6
Weight, kg	70.2 ± 6.7	71.4 ± 5.8	69.3 ± 10.4
BMI, kg·m^{-2}	22.3 ± 0.5	23.1 ± 2.7	23.7 ± 2.5

Values are mean ± SEM. BMI: body mass index.

rest between for optimal recovery (Monday and Wednesday or Tuesday and Thursday) and participants were requested to train at the same time throughout the 8 sessions. Each session consisted of repeated-sprint during cycling in a hypoxic chamber (CAT 310, Louisville, Colorado, USA) built in our laboratory (459 m of altitude, 24ºC and 40% relative humidity). RSH group breathed an oxygen fraction (FiO_2) at 0.14 ± 0.003 (simulate an altitude of 3,400 m above sea level) controlled with an electronic device (HANDI+, Maxtec, Salt Lake City, Utah, USA). Oxygen content within the chamber could be reduced by insufflating nitrogen, which was produced from chamber air through a molecular sieve. Normoxic repeated-sprint training group exercised at FiO_2 of 0.20 corresponding to sea level in the laboratory. Blinding of the subjects, the system also ran for normoxic repeated-sprint training with normoxic airflow into the chamber.

Training sessions were performed in a cyclosimulator with an integrated potentiometer (Cycleops 410 pro, Cycleops, Madison, USA). Cycling provides a lower risk of leg muscle injury (by minimal eccentric contraction), which was the most important reason for selecting this exercise mode. After 10 min of warm-up at 60 watts (W), all training sessions consisted in 2 sets of 5 repeated 10 s all-out sprints with a recovery of 20 s between sprints and a recovery period of 10 min at 120W between sets, ending with a 5 min recovery at 120 W. The maximum power of each sprint was registered and monitored by the potentiometer in real time via the potentiometer data screen itself. Between training sessions there were at least 48 hours of rest for an optimal recovery.

Testing sessions

In all time points, assessments were carried out over 2 sessions. On the morning of the first day, body composition and jump performance were measured. Then, after 45 minutes, subjects performed a Yo-Yo Intermittent Recovery Test at level 1. On the second day, the subjects took a Repeated sprint ability (RSA) Test.

- *Body mass index:* height and weight were measured following standard procedures. Body mass index was derived from height and weight using the accepted method (BMI = weight/height^2, kg·m^{-2}).
- *Repeated sprint ability test:* The subjects conducted a repeated sprint test under normoxic conditions, comprising the largest number of 10 seconds all-out sprints (maximal pedalling) with a 20-sec active rest between sprints at 120 W[27]. Subjects were given very strong verbal encouragement and performed as many sprints as possible until exhaustion. A minimum of 70 rpm or less after 5 s of sprinting was set as the criterion to stop the test. The total number of sprints was registered.
- *Jump Performance:* to test the lower limb explosive strength performance an Optojump platform connected to a personal computer were used (OptojumpNext, Microgate, Bolzano, Italia). Jump height of the widely knows squat Jump (SJ) and Counter-movement Jump (CMJ) protocols were registered. Two trials were performed for each of the jumping tests (SJ and CMJ). A 10 s rest within and a 90 s rest between jumping tests were set. The best trial was retained for analysis and the jumping height was calculated from the flight time[28].
- *Yo-Yo Intermittent Recovery Level 1 Test:* participants performed twenty-meters shuttle runs with increase of the velocity until the exhaustion. Periods of 10 s of active recovery were developed between runs. Total distance covered (including the last incomplete shuttle) was registered and used to estimate maximal oxygen consumption (VO_{2max}) using the equation: VO_{2max} ml·kg^{-1} min^{-1} = [IR1 distance (m) * 0.0084] + 36.4[29].

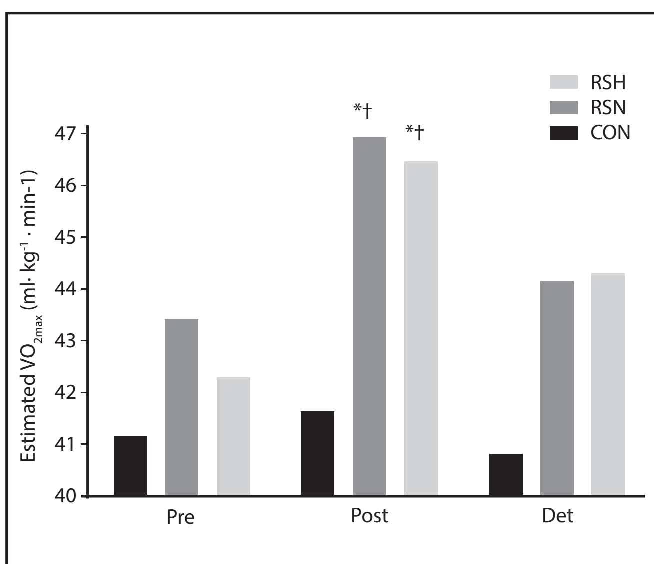
Statistical analyses

The statistical package SPSS v.20 for MAC (IBM, New York, USA) was used for statistical analysis. Before the analysis, the Kolmogorov–Smirnov test and Levene's test were calculated to identify data homogeneity. Then, two-way repeated measures analysis of variance (ANOVA) was used to compare responses in each variable. Bonferroni post hoc analysis was used to identify where changes occurred. To establish statistical significance, $p<0.05$ was used. The effect size was calculated for all variables between pre- and post-testing. The magnitude of the difference was considered as a small (0.2), moderate (0.5) or large (0.8) effect size (ES).

Results

Compliance with training prescription was 100% in the RSH group and 91.39% in the RSN group. Effects of training about estimated VO_{2max} obtained in the Yo-Yo Test are shown in Figure 1. After training, estimated VO_{2max} increased significantly in both RSN ($p=0.02$) and RSH ($p=0.04$) groups compared with control group. Statistically significant differences within groups with a large ES were found in the RSN group

Figure 1. Estimated VO_{2max} with Yo-Yo Test at baseline (Pre), in the 7 days after the last session (Post) and 2 weeks after the last session (Det).



Estimated VO_{2max}: maximal oxygen uptake; CON: Control Group, RSN: Repeated-Sprint Normoxia, RSH: Repeated Sprint Hypoxia. *Significant difference ($p < 0.05$) compared to Pre-. †Significant difference ($p < 0.05$) compared to CON.

Table 2. Repeated sprint and jump ability results before and after intervention.

		Pre (A)	Δ (% A-B)	Post (B)	Δ (% B-C)	Det (C)	d Cohen (A-B)	d Cohen (B-C)
Number of sprints, n	CON	5.5 ± 0.8	-2.7	5.3 ± 1.6	+17.0	6.2 ± 1.2	0.14	0.70
	RSN	5.0 ± 1.2	+24.0	6.2 ± 2.2	-9.7	5.6 ± 0.9	0.71	0.39
	RSH	4.5 ± 1.7	+55.6	7.0 ± 1.8	+10.0	7.7 ± 1.9	1.40	1.80
SJ Height, cm	CON	32.3 ± 6.8	-4.6	30.8 ± 7.1	-6.2	28.9 ± 6.0	0.23	0.28
	RSN	30.1 ± 5.0	+0.7	30.3 ± 6.2	+5.3	31.9 ± 5.6	0.04	0.26
	RSH	29.5 ± 3.0	+2.0	30.1 ± 3.6	+14.3	34.4 ± 5.4	0.19	0.95
CMJ Height, cm	CON	34.2 ± 3.9	+5.3	36.0 ± 4.7	-5.3	34.1 ± 4.6	0.41	0.40
	RSN	35.5 ± 7.6	+0.8	35.8 ± 5.7	-5.3	33.9 ± 5.4	0.03	0.34
	RSH	30.9 ± 4.2	+6.1	32.8 ± 3.8	+10.7	36.3 ± 4.4	0.98	0.88

Values are mean ± SEM. CON: Control Group; RSN: Repeated-Sprint Normoxia; RSH: Repeated-Sprint Hypoxia; Δ: absolute change; d Cohen: Effect size; SJ: squat jump; CMJ: countermovement Jump.

(+7.83%; p=0.001; ES=1.66) and RSH group (+9.95%; p=0.000; ES=1.42) between Pre and Post evaluation.

The training effects on RSA and jump performance are shown in Table 2. The number of sprints until exhaustion and jump performance did not show significant improvements compared with control group. In within group analysis, RSH showed a large ES between Pre and Post (+55.56%; ES=1.40) and Pre and Det (+10%; ES=1.80) in the number of sprints. Increases in SJ and CMJ height were also found in RSH group with a large ES between Pre and Post and between Pre and Det (SJ: +2.03% and +14.3%, ES=0.98 and ES=0.88, respectively; CMJ: +6.15% and +10.7%, ES=1.28 and ES=0.88, respectively).

Discussion

The present study aimed at determining the effects of four weeks of RSH on cardiorespiratory fitness and anaerobic capacity in active adults. The main finding was that the combination of repeated-sprint and hypoxic stimulus could not lead to an additional effect on cardiorespiratory fitness compared with the same protocol in normoxia conditions. After training, significant differences were found in estimated VO_{2max} in RSN group compared with control group, as well as RSH group with respect to the control group. However, the anaerobic capacity, showing through the number of sprints to exhaustion, may tend to increase under hypoxia conditions. The greater large effect sizes found in RSH group leads us to think that significant changes could be obtained from higher sampling. Besides, delayed effects on anaerobic capacity with a large effect size were shown after 2-weeks of cessation of the program. In any case, finding no significant differences, the results must be taken with caution.

Cardiorespiratory fitness

Hypoxic training has been commonly used to improve cardiorespiratory capacity over years. The stress of hypoxic exposure, in addition to the training stress, may increase the adaptations experienced with exercise alone and will lead to greater improvements in performance[30]. Whereas previous studies reported that RSH induced greater improvements on cardiorespiratory capacity in elite athletes[14,18,25] and obese people[19], the present study did not show additional effects of RSH on estimated VO_{2max} through Yo-Yo Intermittent Recovery tests. Despite aerobic field-based protocol may be preferred over laboratory-based protocols due to an increase in ecological validity for performance measurement in sport-field[18], the lack of additional benefits of RSH over RSN is the non-specificity of training relatively to the test implemented[31].

Anaerobic capacity

Based on previous studies, RSH, when compared with that under normoxia, may be more useful for enhancing anaerobic capacity[4], by increases the contribution of the anaerobic energy system during all-out sprint exercise[32]. The results observed in the present study are partially agreed with meta-analysis' aggregated findings[7] that indicated RSH vs. RSN improved in RSA. In contrast, other studies found that RSH equally improved RSA performance compared with RSN[14,18,20,25,33]. Many factors may be contributing to these controversial results[7] such as level of athlete and/or protocol design. Similarly to Hamlin *et al.* (2017) and Beard *et al.* (2019), improvements in RSA performance were reported when a multiple-set protocol of RSH was applied[7]. Although the mechanisms for the anaerobic capacity are still under debate, RSH may induce greater improvements of oxygen utilization by the fast-twitch fibers during 'all-out' maximal repeated sprints performed in hypoxia[8].

Surprisingly, in the present study, anaerobic capacity continued improving after two weeks of detraining in RSH group. These findings are especially relevant in a population where cessation of training is common for holidays[19]. As previous authors have reported, delayed effects on exercise performance could be achieved after RSH protocol[19,25]. Although speculative, this phenomenon could be attributed to higher variations of blood perfusion delaying fatigue in the RSA test and improvements in vascular conductance where fast-twitch fibers are better utilised[8]. In parallel, neural adaptations would increase motor unit synchronization and/or agonist muscle activation[34]. Conversely, skeletal muscle molecular beneficial may elicit higher short-term adaptations with a rapid decay and normalization of molecular adaptations after cessation of the training[7]. However, studies on the maintenance of exercise-induced exercise performance benefits after cessation of training are rare and more research is required.

There are some limitations to this study. We cannot ignore that the present study includes a low hypoxic dose with 8 RSH sessions, 800 s sprinting duration over 28 days (mean of the RSH studies was 9.4 ± 3.1 sessions, 1216 ± 527 s sprinting duration over a 27.3 ± 8.4 days period[7]). A factor of importance to the outcome of an altitude-training program is the exercise regimen undertaken during the intervention period[35]. The severity of altitude, time spent training at altitude or type of training represents important factors to consider when designing a training program at altitude. Thus, this lowest volume could partially explain why no significant changes were shown. The small sample size certainly is a weakness in this study. Despite this, there are significant indications that this type of training could have benefits for this population, as shown by the high effect sizes. Besides, the non-specificity of training relatively to the test implemented establishes another important limitation of the present study. Using a field test (Yo-Yo test) predicting VO_{2max} rather than measuring it with metabolic gas analysis have a considerable error for estimating VO_{2max} in adults. For these reasons, the findings of this study should be confirmed in further investigations.

Conclusions

In conclusion, eight RSH sessions performed over four weeks does not appear to have an additional effect on cardiorespiratory capacity in active adults compared with equivalent training in normoxia. However, it could produce improvements in RSA and lead delayed effects on anaerobic capacity. Further studies with protocols designed for double blind and large sample sizes are needed to support the effectiveness of RSH in this population.

Acknowledgments

This research was funded by the Government of Extremadura with funding from the European Regional Development Fund under Grant (Ref: GR18003) and by Cátedra Real Madrid: research project 2014/04RM.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Han TS, Lean ME. A clinical perspective of obesity, metabolic syndrome and cardiovascular disease. *JRSM Cardiovasc Dis.* 2016;5:204800401663337.
2. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. *Sport Med*. 2013;43:313–38.
3. Sharifi N, Mahdavi R, Ebrahimi-Mameghani M. Perceived barriers to weight loss programs for overweight or obese women. *Heal Promot Perspect.* 2013;3:11–22.
4. Kon M, Nakagaki K, Ebi Y. Effects of all-out sprint interval training under hyperoxia on exercise performance. *Physiol Rep*. 2019;7.
5. Beard A, Ashby J, Kilgallon M, Brocherie F, Millet GP. Upper-body repeated-sprint training in hypoxia in international rugby union players. *Eur J Sport Sci.* 2019;19:1175–83.
6. Girard O, Brocherie F, Millet GP. Effects of altitude/hypoxia on single- and multiple-sprint performance: a comprehensive review. *Sport Med.* 2017;47:1931–49.
7. Brocherie F, Girard O, Faiss R, Millet GP. Effects of repeated-sprint training in hypoxia on sea-level performance: a meta-analysis. *Sport Med*. 2017;47:1651–60.
8. Faiss R, Girard O, Millet GP. Advancing hypoxic training in team sports: From intermittent hypoxic training to repeated sprint training in hypoxia. *Br J Sports Med.* 2013;47.
9. Casey DP, Joyner MJ. Compensatory vasodilatation during hypoxic exercise: Mechanisms responsible for matching oxygen supply to demand. *J Physiol.* 2012;590:6321–6.
10. Vogt M, Puntschart A, Geiser J, Zuleger C, Billeter R, Hoppeler H. Molecular adaptations in human skeletal muscle to endurance training under simulated hypoxic conditions. *J Appl Physiol.* 2001;91:173–82.
11. Zoll J, Ponsot E, Dufour S, Doutreleau S, Ventura-Clapier R, Vogt M, *et al.* Exercise training in normobaric hypoxia in endurance runners. III. Muscular adjustments of selected gene transcripts. *J Appl Physiol.* 2006;100:1258–66.
12. Kasai N, Mizuno S, Ishimoto S, Sakamoto E, Maruta M, Goto K. Effect of training in hypoxia on repeated sprint performance in female athletes. *Springerplus*. 2015;4.
13. Brocherie F, Girard O, Faiss R, Millet GP. High-intensity intermittent training in hypoxia: A double-blinded, placebo-controlled field study in youth football players. *J Strength Cond Res.* 2015;29:226–37.
14. Cooke K, Galvin HM, Sumners DP, Mileva KN, Bowtell JL. Repeated sprint training in normobaric hypoxia. *Br J Sports Med*. 2013;47.
15. Hamlin MJ, Olsen PD, Marshall HC, Lizamore CA, Elliot CA. Hypoxic repeat sprint training improves rugby player's repeated sprint but not endurance performance. *Front Physiol.* 2017;8.
16. Millet GP, Faiss R, Brocherie F, Girard O. Hypoxic training and team sports: A challenge to traditional methods? *Br J Sports Med.* 2013;47.
17. Gatterer H, Menz V, Salazar-Martinez E, Sumbalova Z, Garcia-Souza LF, Velika B, *et al.* Exercise performance, muscle oxygen extraction and blood cell mitochondrial respiration after repeated-sprint and sprint interval training in hypoxia: A pilot study. *J Sport Sci Med*. 2018;17:339–47.
18. Brechbuhl C, Schmitt L, Millet GP, Brocherie F. Shock microcycle of repeated-sprint training in hypoxia and tennis performance: Case study in a rookie professional player. *Int J Sport Sci Coach*. 2018;13:723–8.
19. Camacho-Cardenosa A, Camacho-Cardenosa M, Brazo-Sayavera J, Timón R, González-Custodio A, Olcina G. Repeated sprint in hypoxia as a time-metabolic efficient strategy to improve physical fitness of obese women. *Eur J Appl Physiol.* 2020;120:1051–61.
20. Montero D, Lundby C. No improved performance with repeated-sprint training in hypoxia versus normoxia: A double-blind and crossover study. *Int J Sports Physiol Perform.* 2017;12:161–7.
21. Lobo A, Carvalho J, Santos P. Effects of training and detraining on physical fitness, physical activity patterns, cardiovascular variables, and hrqol after 3 health-promotion interventions in institutionalized elders. *Int J Family Med*. 2010;2010:1–10.
22. Bonsu B, Terblanche E. The training and detraining effect of high-intensity interval training on post-exercise hypotension in young overweight/obese women. *Eur J Appl Physiol.* 2016;116:77–84.
23. Morales-Alamo D, Ponce-González JG, Guadalupe-Grau A, Rodríguez-García L, Santana A, Cusso MR, *et al.* Increased oxidative stress and anaerobic energy release, but blunted Thr172-AMPKα phosphorylation, in response to sprint exercise in severe acute hypoxia in humans. *J Appl Physiol.* 2012;113:917–28.
24. McGinnis G, Kliszczewiscz B, Barberio M, Ballmann C, Peters B, Slivka D, *et al.* Acute hypoxia and exercise-induced blood oxidative stress. *Int J Sport Nutr Exerc Metab.* 2014;24:684–93.
25. Brocherie F, Millet GP, Hauser A, Steiner T, Rysman J, Wehrlin JP, *et al.* "live High-Train Low and High" Hypoxic training improves team-sport performance. *Med Sci Sports Exerc.* 2015;47:2140–9.
26. Edge J, Hill-Haas S, Goodman C, Bishop D. Effects of resistance training on H+ regulation, buffer capacity, and repeated sprints. *Med Sci Sports Exerc.* 2006;38:2004–11.
27. Faiss R, Léger B, Vesin JM, Fournier PE, Eggel Y, Dériaz O, *et al.* Significant molecular and systemic adaptations after repeated sprint training in hypoxia. *PLoS One.* 2013;
28. Bosco C, Luhtanen P, Komi P V. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol Occup Physiol.* 1983;50:273–82.
29. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sport Med.* 2008;38:37–51.
30. Czuba M, Zajac A, Maszczyk A, Roczniok R, Poprzecki S, Garbaciak W, *et al.* The effects of high intensity interval training in normobaric hypoxia on aerobic capacity in basketball players. *J Hum Kinet*. 2013;39:103–14.
31. Fornasier-Santos C, Millet GP, Woorons X. Repeated-sprint training in hypoxia induced by voluntary hypoventilation improves running repeated-sprint ability in rugby players. *Eur J Sport Sci.* 2018;18:504–12.

32. Ogura Y, Naito H, Kurosaka M, Sugiura T, Junichiro A, Katamoto S. Sprint-interval training induces heat shock protein 72 in rat skeletal muscles. *J Sports Sci Med*. 2006;5:194–201.

33. Goods PSR, Dawson B, Landers GJ, Gore CJ, Peeling P. No additional benefit of repeat-sprint training in hypoxia than in normoxia on sea-level repeat-sprint ability. *J Sport Sci Med.* 2015;14:681–8.

34. Manimmanakorn A, Manimmanakorn N, Taylor R, Draper N, Billaut F, Shearman JP, *et al.* Effects of resistance training combined with vascular occlusion or hypoxia on neuromuscular function in athletes. *Eur J Appl Physiol.* 2013;113:1767–74.

35. Girard O, Amann M, Aughey R, Billaut FÇ, Bishop DJ, Bourdon P, *et al.* Position statement-Altitude training for improving team-Sport players' performance: Current knowledge and unresolved issues. *Br J Sports Med*. 2013;47.

Effect of joint mobilization on chronic instability of the ankle: a systematic review with meta-analysis

Ítalo L. Sobreira[1,2], Francisco K.A. de Sousa[1], Maria C.P. Kuehner[1], Jáder Luis C.F. Mendes[3], Flavio S. Araujo[3], Rodrigo Gustavo S. Carvalho[2,3]

[1]University Center Christus. Fortaleza/CE. Brazil. [2]Postgraduate Program in Physical Education. Federal University of Vale do São Francisco –UNIVASF. Petrolina/PE. Brazil. [3]Postgraduate Program in Rehabilitation and Functional Performance, University of Pernambuco – UPE. Petrolina/PE. Brazil.

doi: 10.18176/archmeddeporte.00110

Recibido: 23/10/2021
Aceptado: 07/09/2022

Summary

The present work aims to analyze the effect of joint mobilization in patients with chronic ankle instability on the outcomes of pain and dorsiflexion range of motion of the ankle after systematic review study with meta-analysis. The period for developing the research and collection was from August 2022. The databases used for collection were CENTRAL, MEDLINE/PUBMED, EMBASE, CINAHL, PEDro and SPORTDiscus, and only randomized controlled trials were included. Studies that included the clinical question by PICO (P = chronic ankle instability; I = joint mobilization; C = placebo and minimal intervention; O = pain and range of motion). The analysis was performed using the Review Manager 5.4.1. The I^2 test was used for heterogeneity of the studies. A total of 6 studies were selected for the meta-analysis in which they measured the range of motion. The findings were statistically significant for range of motion of dorsiflexion (mean difference – MD = 0.86, 95%CI = 0.06;1.66, p = 0.04), however the findings became insignificant after the sensitivity analysis (MD = 0.58, 95%CI = -0.07;1.23, p = 0.08). There was not enough literature for the pain outcome. The study obtained a satisfactory result for joint mobilization when all studies in the literature were grouped, but the result did not obtain statistical significance using better quality studies. Therefore, there is a need for better quality of evidence for the joint mobilization technique, as well as studies with better methodological quality so that we can more accurately state the real effects of this technique. Systematic Review Registration: Prospectively registered with PROSPERO (CRD42020193292).

Key words:
Ankle Injuries. Ankle Joint. Pain. Range of Motion.

Efecto de la movilización articular sobre la inestabilidad crónica del tobillo: una revisión sistemática con metaanálisis

Resumen

El presente trabajo tiene como objetivo analizar el efecto de la movilización articular en pacientes con inestabilidad crónica del tobillo sobre los resultados del dolor y el rango de movimiento de dorsiflexión del tobillo después de un estudio de revisión sistemática con metaanálisis. El período para el desarrollo de la investigación y la colección fue de Agosto de 2022. Las bases de datos utilizadas para la recopilación fueron CENTRAL, MEDLINE / PUBMED, EMBASE, CINAHL, PEDro y SPORTDiscus, y solo se incluyeron ensayos controlados aleatorios. Estudios que incluyeron la pregunta clínica por PICO (P = inestabilidad crónica del tobillo; I = movilización articular; C = placebo e intervención mínima; O = dolor y rango de movimiento). El análisis se realizó utilizando Review Manager 5.4.1. Se utilizó la prueba de I^2 para determinar la heterogeneidad de los estudios. Se seleccionaron un total de 6 estudios para el metaanálisis en el que midieron el rango de movimiento. Los hallazgos fueron estadísticamente significativos para el rango de movimiento de la dorsiflexión (diferencia de medias - DM = 0,86, IC del 95% = 0,06; 1,66, p = 0,04), sin embargo, los resultados se volvieron insignificantes después del análisis de sensibilidad (DM = 0,58, IC del 95% = -0,07; 1,23, p = 0,08). No hubo suficiente literatura sobre el resultado del dolor. El estudio obtuvo un resultado satisfactorio para la movilización articular cuando se agruparon todos los estudios de la literatura, pero el resultado no obtuvo significación estadística utilizando estudios de mejor calidad. Por lo tanto, se necesita una mejor calidad de evidencia para la técnica de movilización articular, así como estudios con mejor calidad metodológica para que podamos enunciar con mayor precisión los efectos reales de esta técnica. Registro de revisión sistemática: PROSPERO (CRD42020193292).

Palabras clave:
Lesiones de Tobillo. Articulación del Tobillo. Dolor. Rango de Movimiento.

Correspondencia: Rodrigo Gustavo da Silva Carvalho
E-mail: rodrigo.carvalho@univasf.edu.br

Introduction

Ankle sprains are among the most recurrent injuries in emergency care levels. The loss of time and initial recovery from ankle ligament sprains is less threatening than that of internal knee disorders, for example, but the high frequency and recurrence rate establish it as one of the main clinical and health system concerns, which despite being common, can cause chronic problems and recurrent injuries[1,2].

According to Doherty *et al.*[3], ligament injury presents high social economic costs associated with diagnosis, treatment and loss of work productivity, depending on the severity of the injury, and covers several spheres of the individual. This calls attention to a faster recovery, avoiding the chronicity of the injury and consequently chronic instability. According to Braun[4], symptoms which limit functional capacity and lifestyle are common from 6 to 18 months after an ankle sprain, and if the individual does not seek help, the condition may evolve with constant sprains and become more and more serious.

Some risk factors are cited by Martin[5], such as low amplitude of dorsiflexion ankle, history of previous injuries, not warming up before physical activity or not participating in a preventive program aimed at balance and proprioception. A portion of individuals who suffer from an acute ankle sprain have significant disability due to pain, functional instability, mechanical instability or recurrent sprain after the recovery plateaus 1 to 5 years after the injury[6]. The lower limbs have great functionality, and their immobilization due to injuries presents biomechanical, occupational, and psychological reduction, and consequently compensatory mechanisms to supply the absence of the injured joints.

Bialosky *et al.*[7] states that manual therapy interventions are generally one of the first choices among healthcare professionals and patients; however, systematic reviews have found relatively small effects in relation to their popularity. Also highlights the neurophysiological effects of joint mobilization, in which the proposed model categorizes neurophysiological stimuli originating from a peripheral mechanism (manual therapy), in which there will be control of pain, inflammation and even temporal summation due to spinal cord responses after the technique[8]. Furthermore, gains in relation to the range of motion are achieved after mechanical stimuli directly in the joint, decreasing spasm and exciting pro-inflammatory mediators.

It is worth mentioning that measurement before and after medical or physiotherapeutic interventions is important to define the real loss and some gain in joint function in the future. In the study by Powden *et al.*[9], they observed that the Weight Bearing Lounge Test (WBLT) is a highly reliable test for measuring the dorsiflexion range of motion of the ankle (ROM), since it provides consistency and repeatability among the evaluators, thus making it a validated instrument for clinical practice. In addition, the Visual Analog Pain Scale is validated to assess the intensity of local pain and used worldwide in diversified assessment systems[10-12].

Wright, Lines and Caim[13] report that due to the high frequency of patients with chronic ankle instability and the problems associated with pathology, knowledge of prevention and treatment approaches are of paramount importance for professionals working in the area. Despite medical, physiotherapeutic and outpatient care, poor recovery can offer an opportunity for chronic instability, with an injury cycle occurring to the individual. There is a need to seek better conducts and scientifically based treatment alternatives in order to bring about greater standardization regarding joint mobilization, better recovery of the individual and less repercussions, to prevent disabilities and improve their functionality.

Therefore, the aim of this study is to analyze the effect of joint mobilization in patients with chronic ankle instability on the outcomes of pain and dorsiflexion range of motion of the ankle after reviewing the current literature.

Material and method

Type of research

This is a systematic review with meta-analysis and followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – PRISMA[14] and the Cochrane Handbook for Systematic Reviews of Interventions version 6.2[15]. The period for developing the research and collection was from August 2022. The databases used for collection were CENTRAL (Cochrane Central Register of Controlled Trials, The Cochrane Library), MEDLINE/PUBMED, EMBASE (ELSEVIER), CINAHL (Cumulative Index to Nursing and Allied Health Literature, EBSCO), PEDro (Physiotherapy Evidence Database) and SPORTDiscus (EBSCO), and only randomized controlled trials (RCT) were accepted; there were no language restrictions or publication date. The review was submitted a priori by the International Prospective Register of Systematic Reviews (PROSPERO) platform, with the following credential ID = CRD42020193292 in order to preserve the study data and avoid possible manipulation of study outcomes and/or results.

Inclusion criteria

Studies which included the clinical question by PICO for the purposes of inclusion criteria in the review followed: P = patients with chronic ankle instability; I = joint mobilization; C = placebo and minimal intervention; O = pain and range of motion. Studies were selected that included male or female individuals aged 18 years or older, who had chronic ankle instability and received isolated joint mobilization treatment compared to minimal or false treatment (placebo).

Exclusion criteria

Studies were excluded from the review if: it was clear in the summary that they did not meet the above criteria; if the selected criteria were not clear in the summary, the full article was read and it was then decided to include or exclude it. The reasons for excluding studies after reviewing the full text are detailed in the table "Characteristics of excluded studies" (Figure 4).

Measured outcomes

Pain outcomes were measured by VAS (Visual Analogue Scale) and ROM by Weight Bearing Lounge Test (WBLT).

Collection of studies

The relevant studies were found through a computer-aided search through the PUBMED and PEDro databases. The search terms used were: ankle sprain, ankle instability, chronic, joint mobilization, manual therapy, MWM, Maitland, Mulligan, Pain, range of motion, and dorsiflexion. The terms were searched alone and in combinations in the search, with a search filter for Randomized Controlled Trials. Two reviewers (IS and FS) independently selected studies with the research terms selected a priori and with PICOT. The data selection was not blinded to the authors.

Data extraction

Two reviewers (IS and FS) independently extracted data about the study design, participants, interventions and results. Data extraction was not blinded to the authors. Disagreements about the results of the data extraction were resolved by consensus among the team. If the disagreement persisted, a third reviewer (CK) was consulted.

Methodological analysis

Two reviewers who were not blinded to the work in question (IS, FS) independently assessed the methodological quality of each RCT. Disagreements were addressed by discussion and consensus in the review team (IS, FS AND MK). The 11 criteria recommended by the PEDro Scale were used to assess the methodological quality of randomized clinical trials, each criterion was scored as "Yes" or "No", according to the recommendation of the scale itself, which is from 0 to 10.

Data analysis

The Review Manager 5.4.1 software program (RevMan 5.4.1 – The Collaboration Cochrane) was used to perform the meta-analysis of this review, to calculate the average size of the combined effect of the mean differences (MD) for all group comparisons and the 95% confidence interval (95% CI). The significance value p = 0.05 and 95% CI was observed in all studies, with a value less than or equal to 0.05 indicating a statistically significant difference or correlation. The I2 test was performed to identify possible heterogeneity between studies. The Kappa index was performed to obtain reliability between the two reviewers independently, where the score by PEDro Scale given by the two reviewers of the included studies was compared in the SPSS (Version 22) in relation to the assertiveness between the reviewers; 70% of the times there was the same score, showing good reliability and homogeneity of the reviewers' methodological criteria.

Results

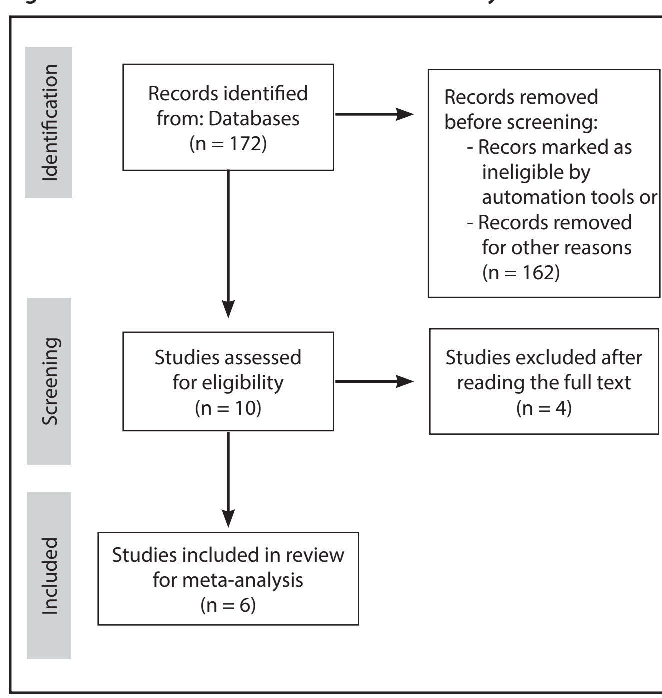
Of 172 study abstracts, 10 were selected for full reading. However, 4 studies were excluded with common reasons for exclusion including wrong intervention, wrong patient population and incorrect study design (Table 1). Thus, 6 studies were selected for the current meta-analysis, which analyzed the following outcomes: ROM and Pain in female or male patients aged 18 or over with chronic ankle instability. ROM was reported in the 6 selected studies, pain was measured in only 1 study, so only ROM was exposed in the meta analysis (Figure 1).

The reliability analysis showed a Kappa's quotient equal 0.714 and 95% CI was between 0.168;1.260 (p = 0.010), showing good agreement.

Table 1. Studies excluded and justification after reading the full text.

Author, Year	Title	Justification
Gilbreath *et al.* 2014[16]	The effects of mobilization with movement on dorsiflexion range of motion, dynamic balance and self-reported function in individuals with chronic ankle instability	There was no randomization of patients in the study.
Yeo *et al*. 2011[17]	Hypoalgesic effect of a passive accessory mobilization technique in patients with lateral ankle pain	There were sub-acute injuries in the study.
Wikistrom *et al*. 2017[18]	Predicting successful treatment with manual therapy in patients with chronic ankle instability: improving self-reported function	It was not compared to placebo or minimal intervention.
Ardèvol *et al*. 2002[19]	Treatment of complete rupture of the lateral ligaments of the ankle: a randomized clinical trial comparing plaster cast immobilization with functional treatment	The duration of the disease was not chronic

Figure 1. Selection of studies for the meta-analysis.



The 6 selected studies assessed ankle mobility before and after treatment, using the WBLT test with or without weight support and comparing minimal intervention or false treatment. The Table 2 shows data extraction from these studies.

All selected studies were methodologically evaluated by 2 non-blinded evaluators following the PEDro methodological quality scale (Figure 2).

The pooled data from four studies with 220 participants with chronic ankle instability were pooled to analyze the effects of joint mobilization on DFROM (MD = 0.86, 95% CI = 0.06;1.66, p = 0.03) and the analysis confirmed significant improvements immediately after treatments (Figure 3).

The results become statistically insignificant after the meta-regression by sensitivity analysis with at least or less studies 07 on the PEDro scale, with 121 patients for analysis of the effects of joint mobilization on DFROM (MD = 0.58, 95% CI = -0.07;1.23, p = 0.08) (Figure 4).

There was not enough data to elaborate the meta-analysis or make a conclusion on the efficacy for the pain outcome using the EVA scale. The certainties of the evidence and the results presented were analyzed as low-quality evidence (downgraded due to imprecision and inconsistency), for is analyzed was performed the recommendations of the The Grading of Recommendations Assessment, Development and Evaluation - GRADE[26] (Table 3).

Figure 2. Risk of bias - PEDro Scale: review authors' judgements about each risk of bias item for each included study.

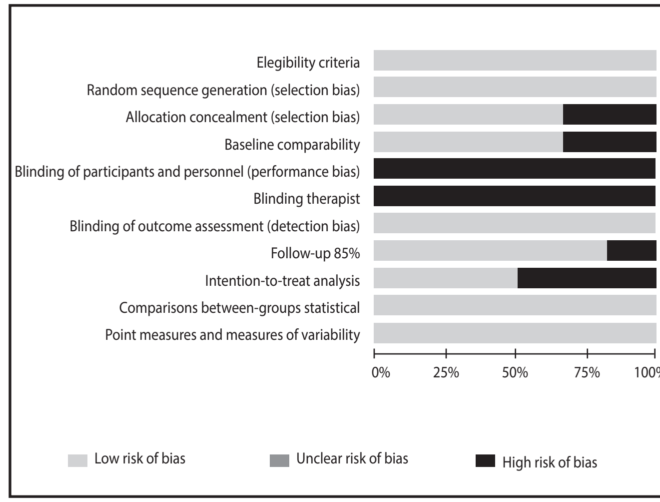


Table 2. Characteristics of the selected studies.

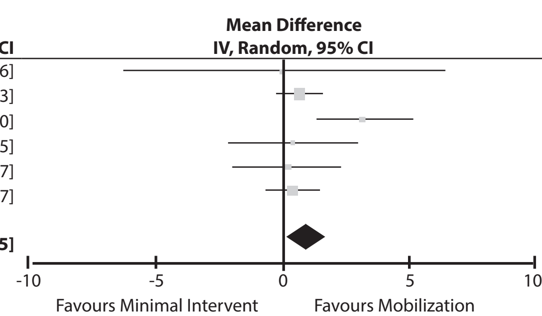
Author, Year	Subjects	Experimental Group	Control Group	Results
Cruz-Díaz *et al.* 2015[20]	n = 57	Ankle joint mobilization	Sham Mobilization	WB and DFROM Statistically significant improvements (p < 0.01)
Vincenzino *et al.* 2006[21]	n = 16	Ankle joint mobilization	No intervention	WB and DFROM Statistically significant improvements (p = 0.02)
Reid *et al*. 2007[22]	n = 23	Ankle joint mobilization	Simulated intervention	WB and DFROM Statistically significant improvements (p = 0.02)
Beazell *et al.* 2012[23]	n = 43	Manipulation of the proximal and distal tibiofibular	No intervention	WB and DFROM No significant differences were observed over time, however, there was a significant increase (p < 0.001) after intervention.
Hoch *et al*. 2010[24]	n = 20	Maitland Grade III of the ankle joint mobilization	Rest	WB and DFROM The results indicated that the treatment of joint mobilization was associated with significantly higher ROM (p = 0.01).
Marrón-Gomez *et al.* 2015[25]	n = 52	Ankle joint mobilization	Sham Intervention	WB and DFROM Statistically significant improvements compared to placebo (p < 0.05).

DFROM: Dorsiflexion Range of Motion; WBLT: Weight Bearing Lounge Test.

Figure 3. Forest Plot contemplating the studies included in the meta-analysis of the immediate effect of joint mobilization on the range of motion of dorsiflexion with weight support, gathering data from six studies (n = 220).

	Joint Mobilization			Minimal Intervention				Mean Difference
Study or subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Beazell 2012	3.9	7.1	13	3.9	10	15	1.5%	0.00 [-6.36, 6.36]
Cruz-Díaz 2015	6	1.6	30	5.3	1.7	31	36.8%	0.70 [-0.12, 1.53]
Gómez 2015	11.5	3.8	18	8.31	1.5	15	13.4%	3.19 [1.28, 5.10]
Hock 2010	12.6	2.7	10	12.2	3.1	10	8.4%	0.40 [-2.15, 2.95]
Reid 2007	10.5	3.7	23	10.3	3.8	23	11.0%	0.20 [-1,97, 2.37]
Vicenzino 2006	4.8	1.5	16	4.4	1.6	16	28.9%	0.40 [-0.67, 1.47]
Total (95% CI)			**110**			**110**	**100.0%**	**0.86 [0.06, 1.65]**

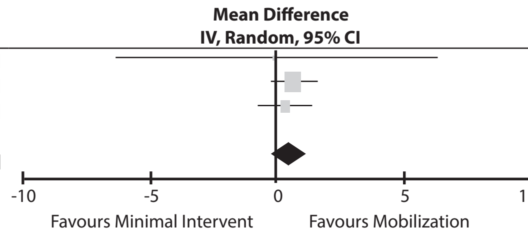
Heterogeneity: Tau² = 0.27; Chi² = 7.03, df = 5 (P = 0.22); I² = 29%
Test for overall effect: Z = 2.12 (P = 0.03)



95% CI: 95% confidence interval; SD: standard deviation; MD: mean difference.

Figure 4. Forest Plot contemplating the studies included in the meta-analysis of the immediate effect of joint mobilization on the range of motion of dorsiflexion with weight support gathering data from three studies with at least 07 on the PEDro scale (n = 121).

	Joint Mobilization			Minimal Intervention				Mean Difference
Study or subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Beazell 2012	3.9	7.1	13	3.9	10	15	1.5%	0.00 [-6.36, 6.36]
Cruz-Díaz 2015	6	1.6	30	5.3	1.7	31	62.1%	0.70 [-0.12, 1.53]
Vicenzino 2006	4.8	1.5	16	4.4	1.6	16	36.9%	0.40 [-0.67, 1.47]
Total (95% CI)			**59**			**62**	**100.0%**	**0.58 [-0.07, 1.23]**



Heterogeneity: Tau² = 0.00; Chi² = 0.22, df = 2 (P = 0.90); I² = 0%
Test for overall effect: Z = 1.75 (P = 0.08)

Table 3. Explanations of downgrade.

Range of motion (follow up: median 1 week; assessed with: cm)

Nº of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations
6	Randomised trials	Not serious	Serious[a]	Not serious	Serious[b]	None
Nº of patients		**Effect**		**Certainty**		
Joint movilization	**Anyother Intervention**	**Relative (95% CI)**	**Absolute (95% CI)**	⊕⊕◯◯ Low		
110	110	--	MD 0.86 more (0.06 more to 1.66 more)			

CI: 95% confidence interval; SD: standard deviation; MD: mean difference.
a. All studies have inconsistency in the confidence intervals, where there is no overlap between them, proving statistical inconsistency. b. Optimal information size was not met because the number of study participants was low (n < 400).

Discussion

The present study hypothesizes the improvement in DFROM and pain in patients with chronic ankle instability after the intervention suggested from a systematic review and meta-analysis. The results revealed that the data are statistically significant and that there was a clinically relevant improvement for DFROM when all studies were evaluated, without a methodological quality filter. However, the result was statistically insignificant after the meta-regression by sensitivity analysis (n = 03).

It was observed that all 6 studies failed to blind patients and therapists and may contain bias in the data measurement results and in the perception of treatments by patients. Nevertheless, it is known that blinding a therapist is something rare, especially with manual procedures, making it difficult for the authors to obtain the maximum grade. Only two[21,25] failed in the Hidden Allocation item, while two[22,23] failed in the Baseline Comparison. Only one study[24] failed in evaluator blinding, three failed to analyze by intention-to-treat[22,24,25], where patients who did not complete the treatment needed to be followed-up and have all their data collected, even without completing the treatment. All scored in the items Follow-up, appropriate, difference between groups and estimated point and variability.

Only Hock and McKeon[24] did not use Mulligan in his study; in contrast he used the Maitland technique, in which joint mobilization is performed through speed and range of motion degrees.

Low quality evidence observed an increase in ROM between mobilization and control, however, we noticed a deviation in results. We performed a downgrade and lowered the evidence to a high risk level of inconsistency, although the I^2 was low, there was little overlap in the confidence intervals showing different results between studies, and we lowered a level in inaccuracy due to the low number of subjects when grouping all studies.

A systematic review of the quality of clinical practice guidelines for treating ankle sprains carried out by Green[27] shows disparities in relation to graduated joint mobilizations or mobilization with movement, where they are not recommended by Dutch clinical practice guidelines, but are recommended by the American guidelines, and points out that the interpretation of the evidence between the two groups for developing the guidelines is not consistent. More research and robust studies are needed on joint mobilization recommendations for outcomes. Also concludes that most of the guidelines related to ankle sprain treatment are bad or outdated, and the absence of good methodologies is one of the main barriers to implementation.

Doherty *et al*[28] disclosed in his review on the treatment of recurrent ankle sprains that there was moderate evidence of neuromuscular training for patients with chronic instability, while manual therapy had moderate evidence for acute injuries, acting to control inflammation and pain.

Following the review by Weerasekara *et al.*[29], the current literature lacks standardization regarding joint mobilization as well as its real effects, considering that the DFROM can be modified by external factors which are not only the studied technique, but by simply applying the WBLT test (for example).

Based on the concept, joint mobilization mainly has its effects on range of motion blocks and joint pain or immediate periods[30]. From the results of the present study, mobilization does not seem to be effective for DFROM in chronic ankle instabilities, however due to the number of studies and their quality, future studies will help to more accurately express the confidence interval and the size of the studied technique's effect. Studies are also needed for other outcomes and with higher methodological quality so that there is no deviation from the real effects caused by low quality studies.

Pain measures have not been properly evaluated, thus suggesting that other resources with proven efficacy should be applied for local pain relief, taking into account the low quality of available evidence of the effectiveness of joint mobilization on pain.

Our review provides healthcare professionals with guidance on the technique of joint mobilization in patients with chronic ankle instability, emphasizing that decision-making is by the professional in conjunction with the patient and with their professional expertise.

Study limitations

The limitations of the review were the non-blinding of the reviewers, as well as the search only being conducted in two databases, although it is acceptable, it is possible that more studies from other databases could be included using the review filtering. The study samples are small, the short-term results varied between days and months, and it was not assessed whether the results were clinically relevant, only statistically significant, expanding the margin of clinical relevance depending on the professional. We planned to make a funnel plot to evaluate the publication bias if there were at least 10 studies in the meta-analysis. As we did not reach the desired quantity, the interpretation of the graph could have been biased due to the small number of studies.

Conclusion

This study was able to summarize the current efficacy of joint mobilization and pain in patients with chronic ankle instability, as well as its statistical significance and clinical relevance in the best- and worst-case scenarios.

Low-quality evidence suggests that joint mobilization may improve clinical ROM for patients with chronic ankle instability compared with placebo or non-treatment. Thus, there is a need for better quality of evidence for the joint mobilization technique, as well as studies with better methodological quality so that the real effects of the technique can be stated with greater precision.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Agel J, Evans TA, Dick R, Putukian M, Marshall SW. Descriptive epidemiology of collegiate men's soccer injuries: national collegiate athletic association injury surveillance system, 1988–1989 through 2002–2003. *J Athl Train*. 2007;42:270-7.
2. Malliaropoulos N, Ghrairi M, Zerguini Y, Padhiar N. Soft tissue injuries are still a challenge in musculoskeletal sports and exercise medicine. *Br J Sports Med*. 2016;50:1487.
3. Doherty C, Bleakley C, Delahunt E, Holden S. Treatment and prevention of acute and recurrent ankle sprain: an overview of systematic reviews with meta-analysis. *Br J Sports Med*. 2017;51:113-25.
4. Braun BL. Effects of ankle sprain in a general clinic population 6 to 18 months after medical evaluation. *Arch Fam Med*. 1999;8:143-8.
5. Martin RL, Davenport TE, Paulseth S, Wukich DK, Godges JJ, Altman RD, *et al.* Ankle stability and movement coordination impairments: ankle ligament sprains: clinical practice guidelines linked to the international classification of functioning, disability and health from the orthopaedic section of the American Physical Therapy Association. *J Orthop Sports Phys Ther.* 2013;43:A1-40.
6. Thompson JY, Byrne C, Williams MA, Keene DJ, Schlussel MM, Lamb SE. Prognostic factors for recovery following acute lateral ankle ligament sprain: a systematic review. *BMC Musculoskelet Disord.* 2017;18:421.
7. Bialosky JE, Beneciuk JM, Bishop MD, Coronado RA, Penza CW, Simon CB, *et al.* Unraveling the mechanisms of manual therapy: modeling an approach. *J Orthop Sports Phys Ther.* 2018;48:8-18.
8. Bialosky JE, Bishop MD, Price DD, Robinson ME, George SZ. The mechanisms of manual therapy in the treatment of musculoskeletal pain: a comprehensive model. *Man Ther.* 2009;14:531-8.
9. Powden CJ, Hoch JM, Hoch MC. Reliability and minimal detectable change of the weight-bearing lunge test: a systematic review. *Man Ther*. 2015;20:524-32.
10. Couper MP, Tourangeau R, Conrad FG, Singer E. Evaluating the effectiveness of visual analog scales: a web experiment. *Soc Sci Comput Rev*. 2006;24:227-45.
11. Delgado DA, Lambert BS, Boutris N, McCulloch PC, Robbins AB, Moreno MR, *et al.* Validation of digital visual analog scale pain scoring with a traditional paper-based visual analog scale in adults. *J Am Acad Orthop Surg Glob Res Rev.* 2018;2:e088.
12. Kelly AM. Does the clinically significant difference in visual analog scale pain scores vary with gender, age, or cause of pain? *Acad Emerg Med*. 1998;5:1086-90.
13. Wright CJ, Linens SW, Cain MS. A randomized controlled trial comparing rehabilitation efficacy in chronic ankle instability. *J Sport Rehabil.* 2017;26:238-49.
14. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement. *J Clin Epidemiol.* 2021;134:103-12.
15. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, *et al*. *Cochrane handbook for systematic reviews of interventions*. 2nd Edition. Chichester (UK): John Wiley & Sons; 2019.
16. Gilbreath JP, Gaven SL, Van Lunen BL, Hoch MC. The effects of mobilization with movement on dorsiflexion range of motion, dynamic balance, and self-reported function in individuals with chronic ankle instability. *Man Ther.* 2014;19:152-7.
17. Yeo HK, Wright A. Hypoalgesic effect of a passive accessory mobilisation technique in patients with lateral ankle pain. *Man Ther.* 2011;16:373-7.
18. Wikstrom EA, McKeon PO. Predicting manual therapy treatment success in patients with chronic ankle instability: improving self-reported function. *J Athl Train.* 2017;52:325-31.
19. Ardèvol J, Bolíbar I, Belda V, Argilaga S. Treatment of complete rupture of the lateral ligaments of the ankle: a randomized clinical trial comparing cast immobilization with functional treatment. *Knee Surg Sports Traumatol Arthrosc.* 2002;10:371-7.
20. Cruz-Díaz D, Lomas Vega R, Osuna-Pérez MC, Hita-Contreras F, Martínez-Amat A. Effects of joint mobilization on chronic ankle instability: a randomized controlled trial. *Disabil Rehabil.* 2015;37:601-10.
21. Vicenzino B, Branjerdporn M, Teys P, Jordan K. Initial changes in posterior talar glide and dorsiflexion of the ankle after mobilization with movement in individuals with recurrent ankle sprain. *J Orthop Sports Phys Ther.* 2006;36:464-71.

22. Reid A, Birmingham TB, Alcock G. Efficacy of mobilization with movement for patients with limited dorsiflexion after ankle sprain: a crossover trial. *Physiother Can.* 2007;59:166-72.

23. Beazell JR, Grindstaff TL, Sauer LD, Magrum EM, Ingersoll CD, Hertel J. Effects of a proximal or distal tibiofibular joint manipulation on ankle range of motion and functional outcomes in individuals with chronic ankle instability. *J Orthop Sports Phys Ther.* 2012;42:125-34.

24. Hoch MC, McKeon PO. Joint mobilization improves spatiotemporal postural control and range of motion in those with chronic ankle instability. *J Orthop Res*. 2011;29:326-32.

25. Marrón-Gómez D, Rodríguez-Fernández ÁL, Martín-Urrialde JA. The effect of two mobilization techniques on dorsiflexion in people with chronic ankle instability. *Phys Ther Sport*. 2015;16:10-5.

26. Piggott T, Morgan RL, Cuello-Garcia CA, Santesso N, Mustafa RA, Meerpohl JJ, *et al*. Grading of recommendations assessment, development, and evaluations (GRADE) notes: extremely serious, GRADE's terminology for rating down by three levels. *J Clin Epidemiol.* 2020;120:116-20.

27. Green T, Willson G, Martin D, Fallon K. What is the quality of clinical practice guidelines for the treatment of acute lateral ankle ligament sprains in adults? A systematic review. *BMC Musculoskelet Disord.* 2019;20:1-13.

28. Doherty C, Delahunt E, Caulfield B, Hertel J, Ryan J, Bleakley C. The incidence and prevalence of ankle sprain injury: a systematic review and meta-analysis of prospective epidemiological studies. *Sports Med.* 2014;44:123-40.

29. Weerasekara I, Deam H, Bamborough N, Brown S, Donnelly J, Thorp N, *et al.* Effect of mobilisation with movement (MWM) on clinical outcomes in lateral ankle sprains: a systematic review and meta-analysis. *Foot (Edinb)*. 2020;43:101657.

30. Mulligan BR. Mobilisations with movement (MWM'S). *J Man Manip Ther*. 1993;1:154-6.

The influence of contextual variables on physical and physiological match demands in soccer referees

Eñaut Ozaeta[1], Javier Yanci[2], Javier Raya-González[3], Uxue Fernández[2], Daniel Castillo[4]

[1]Faculty of Education and Sport. University of the Basque Country. UPV/EHU. Vitoria-Gasteiz. [2]Society, Sports and Physical Exercise Research Group (GIKAFIT). Physical Education and Sport Department, Faculty of Physical Activity and Sports Science. University of the Basque Country. UPV/EHU. Vitoria-Gasteiz. [3]Faculty of Health Sciences. University Isabel I. Burgos. [4]Valoración del Rendimiento Deportivo, Actividad Física y Salud, y Lesiones Deportivas (REDAFLED). Universidad de Valladolid. Soria.

doi: 10.18176/archmeddeporte.00111

Recibido: 11/02/2022
Aceptado: 13/09/2022

Summary

The aim of this paper was to examine how contextual factors affect match demands in amateur referees. Twenty-three field referees participated in this study. Match physical and physiological demands were monitored. Results showed that referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.05$) and $Cadence_{mean}$ ($p<0.05$) on natural fields compared to artificial turf fields. Greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.01$), $Cadence_{mean}$ ($p < 0.05$) and $Stiffness_{mean}$ ($p < 0.05$) were recorded in above-standard fields in comparison to below-standard fields. Referees recorded greater total distance ($p < 0.05$), $Power_{mean}$ ($p < 0.05$) and $Speed_{mean}$ ($p < 0.05$) during matches played with an environmental temperature of over 20º compared to those matches played at temperatures below 10º. Referees' covered more total distance in second-round matches compared to first round matches. Results suggest that the physical demands supported by soccer referees during official matches are influenced by the type of surface, pitch size, environmental temperature and period of the season, however, physiological demands do not seem to be conditioned by contextual factors

Key words:
Field referees. Season period. Field size. Turf. Temperature

La influencia de las variables contextuales en las cargas físicas y fisiológicas de los árbitros de fútbol

Resumen

El objetivo principal de este trabajo fue examinar cómo los factores contextuales afectan a la carga de partido de los árbitros amateur. Veintitrés árbitros de campo de la División de Honor española participaron en este estudio. Para ello se registraron la carga física y fisiológica de partido. Los resultados mostraron que los árbitros registraron una mayor distancia total ($p < 0,01$), potencia media ($p < 0,01$), velocidad media ($p < 0,05$) y cadencia media ($p < 0,05$) en los campos naturales en comparación con los campos de césped artificial. Se registró una mayor distancia total ($p < 0,01$), potencia media ($p < 0,01$), velocidad media ($p < 0,01$), cadencia media ($p < 0,05$) y media de stiffness medio ($p < 0,05$) en los campos más grandes que la media en comparación con los campos por debajo de la media. Los árbitros cubrieron más distancia total ($p < 0,05$), potencia media ($p < 0,05$) y velocidad media ($p < 0,05$) durante los partidos jugados con una temperatura ambiental superior a 20º en comparación con los partidos jugados con temperaturas inferiores a 10º. Los árbitros recorrieron más distancia total en los partidos de la vuelta en comparación con los partidos jugados en la ida ($p < 0,05$). Los resultados sugieren que la carga física de los árbitros de fútbol durante los partidos oficiales, están influenciadas por el tipo de superficie, el tamaño del campo, la temperatura ambiental y el período de la temporada, en cambio la carga fisiológica no parece estar condicionada por los factores contextuales.

Palabras clave:
Árbitros de campo. Periodo de temporada. Tamaño del campo. Césped. Temperatura.

Correspondencia: Javier Yanci
E-mail: javier.yanci@ehu.eus

Introduction

Thousands of amateur soccer matches are played weekly around the world, officiated by field referees and their two assistants from the national level upwards, and with only field referees officiating the majority of matches at grassroots and lower senior competitive levels. From a physical and physiological perspective, refereeing is an intermittent activity that mainly requires the implication of the aerobic system, although it is interspersed with periods of high-intensity requiring the anaerobic system[1,2]. In terms of total distance covered and distance covered at different speeds, amateur referees cover around 10-11 km per match, of which almost 3 km are covered at high intensity (over 13 $km{\cdot}h^{-1}$) and approximately 800 m at high speed (over 18 $km{\cdot}h^{-1}$)[3,4]. In addition, the accelerations and decelerations of referees have also been investigated. In this respect soccer referees cover around 1.5 km accelerating and around 400 m decelerating[3,5,6]. In addition, recent studies have validated the Stryd Power Meter as a suitable device to record the physical demands of referees during official matches[4,7]. Moreover, these studies have reported that the mean power registered by soccer referees during a match is around 120.72 ± 11.75 W. It has also been reported that the mean vertical oscillation presented by referees is 8.00 ± 0.54 cm, the mean ground contact time is 541.21 ± 57.73 $m{\cdot}s^{-1}$ and the mean stiffness is 9.28 ± 0.56 $KN{\cdot}m^{-1}$[(4)].

Moreover, referees present a mean heart rate (HR_{mean}) above 85% of their maximum HR ($\%HR_{peak}$)[3,8] during matches, while according to the match load recorded using Edward's training impulse (TRIMP), this population recorded 390 ± 34 AU during match-play[9]. Therefore, possessing an adequate capacity to respond to these demands during match play can help them to face matches with sufficient ability to follow the pace of the match and be close to the actions in order to make correct decisions[10,11].

Contextual variables has been previously analyzed in soccer players showing that several of them could influence their physical and physiological demands during match-play, highlighting the level of the opposing teams[12], the match outcome[13], the type of surface[14,15], the environmental temperature[16–18] and/or the period of the season[19], among other factors. Considering the strong association observed between the activity performed by outfield players and field referees[20–22], it could be assumed that such contextual variables could also influence referees' match demands. However, few studies have analyzed the influence of contextual variables such as age, experience and competitive level on the physical and physiological demands encountered by soccer referees during competition[23,24], and only one study has analyzed the influence of the level of the opposing teams on the referees' running activity[25]. In this respect, a gap has been identified in the literature on how contextual factors such as field dimensions or type of field could influence the referees' match demands. This aspect could be important to analyze since official matches at the amateur level are played on fields of different characteristics in terms of type and dimensions. Likewise, there is a lack of studies considering the influence of environmental temperature and the period of the season on the referees' match demands, although Taylor *et al.*[26] observed that warm and cold environments do not influence decision-making ability.

Previous studies have analyzed the evolution of referees' demands as the match progresses showing a decrease in total distance or distance covered at high intensity (>13 $km{\cdot}h^{-1}$) during the second half of matches compared to the first half[7,27–29]. Similarly, it was found that amateur referees showed higher values regarding physiological indicators such as HR, lactate concentration and tympanic temperature at the end of the matches and immediately after completion[30]. In addition, neuromuscular fatigue (i.e., distance decrease in horizontal jump performance) after finishing the matches has been previously reported[1]. Other studies have gone further and have analyzed referees' match demands during shorter periods (i.e., 15 min) showing that professional referees' match demands are higher in the initial periods of the match[5,31,32]. However, Ozaeta *et al.*[7] showed that the match demands increased in the last 15 min of the match in amateur soccer referees, so it would be interesting to investigate whether contextual factors may be the reason for the increased match demands.

Attending to the aforementioned information, and to understand the physical and physiological demands in soccer referees as well as to optimize the training process, the aim of this study was twofold: 1) to assess the differences in the physical and physiological responses encountered by soccer referees regarding each contextual variable (i.e., type of turf, pitch size, period of season, and environmental temperature) during official matches, and 2) to analyze the physical and physiological variations during 15 min periods according to each contextual variable (i.e. type of turf, pitch size, period of season, and environmental temperature). We hypothesized that contextual variables could influence the referees' physical and physiological responses during match play.

Material and method

Design

An observational (i.e., descriptive-comparative) design was used to analyze the physical and physiological demands encountered by field soccer referees according to contextual variables (i.e., type of turf, pitch size, period of season, and environmental temperature). A total of 23 official matches were analyzed during the in-season period (i.e., from November to March) of the 2019-2020 season. The data included measures of physical [total distance covered, power, speed, cadence, vertical oscillation, ground contact time (GCT) and stiffness] and physiological [HR_{mean}, $\%HR_{peak}$, HR zones (from zone 1 to zone 5) and TRIMP] match demands.

Subjects

Twenty-three male field referees (age: 25.65 ± 3.30 years; height: 173.4 ± 3.8 cm; body mass: 64.86 ± 5.82 kg; body mass index, BMI: 21.56 ± 1.67 $kg{\cdot}m^{-2}$) who officiated soccer matches in the División de Honor de Vizcaya (Spain), participated in the present study. The referees had an experience in the category at least 3 years. All the participants trained at least twice a week and officiated matches in the category twice a month. Participants were informed of the procedures, methods, benefits, and possible risks involved in the study before signing their written consent. This investigation was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of The University of the Basque Country (Code: M10/2018/289).

Procedures

Before the beginning of the match all the officials performed a 10 min warm-up consisting of running, stretching, short sprints and progressive sprints. The 15 min half-time data were excluded from the external and internal match load analysis. All the matches were played between 11 am and 5 pm.

Type of turf. The soccer matches were played on natural grass and artificial surfaces as propose by Stone *et al.* (2016)[14].

Pitch size. According to the rules of the game approved by the International Football Association Board (IFAB) for international matches, the touch line must have a minimum length of 100 m and the goal line a minimum length of 64 m[33]. In this regard, we opted to differentiate fields with a size of over 100 x 64 m (above-standard) versus fields with a size below 100 x 64 m (below-standard).

Period of the season. Two rounds (first and second) were determined as previously used by Mohr *et al.* (2003) with soccer referees.

Environmental temperature. Matches played at below 10º and above 20º were selected because previous studies have mainly focused on matches played at high temperatures (>20º Celsius)[16,17] and this study tried to see if there were differences between matches played at high and low temperatures.

Physical demands. Referees' physical demands were monitored using a Stryd Power Meter (Stryd, Inc., Boulder, Colorado, USA), which was placed over the right soccer boot with a plastic clip regardless of lower limb dominance[34]. The Stryd Power Meter has been shown to be a valid device for measuring external demands in soccer referees[4]. The Stryd was activated following the manufacturer's recommendations for offline use. It records total match data for the following variables: total distance covered (km), mean power (W), mean speed ($km{\cdot}h^{-1}$), mean cadence ($steps{\cdot}min^{-1}$), mean vertical oscillation (cm), mean GCT ($m{\cdot}s^{-1}$) and mean stiffness ($KN{\cdot}m^{-1}$).

Physiological demands. Referees' HR was monitored during matches with a Polar Team 2 device (Polar Team System™, Kempele, Finland) at 1s intervals. HR_{mean} and $\%HR_{peak}$ were considered for this study, and TRIMP was also calculated. According to the study by Edwards (1993)[35], intensity was represented by the time spent in 5 arbitrary HR zones (Zone 1, 50-60% of HR_{peak}; Zone 2, 60-70% of HR_{peak}; Zone 3, 70-80% of HR_{peak}; Zone 4, 80-90% of HR_{peak}; and Zone 5, 90-100% of HR_{peak}) multiplied by the number of each zone (1, 2, 3, 4, and 5). The sum of values obtained for each zone represented TRIMP, measured by arbitrary units (AU).

Statistical analyses

Data are presented as mean ± standard deviations (SD). Normality of data distribution and homogeneity of variances were tested using the Shapiro–Wilk and Levene tests, respectively. A two–way analysis of variance (ANOVA) was applied in order to test for differences in variables recorded during 15 min in-game periods, with contextual variables (i.e., type of turf, pitch size, period of season and environmental temperature) introduced as between-subject factors, and 15 min periods as a within-subject factor. Data sphericity was evaluated using Mauchly's test, and Greenhouse-Geiser or Huynh-Feldt corrections were applied for non-spherical distributions. The Bonferroni corrections was applied for post-hoc comparisons. Practical significance for pair wise comparisons was assessed by calculating Cohen's d effect size[36]. Effect sizes (d) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2 and lower than 0.2 were considered as large, moderate, small, and trivial, respectively[37]. Further, ANOVA effect sizes were calculated using partial eta squared (η_p^2), and <0.25, 0.26–0.63 and >0.63 were considered small, medium and large effect sizes respectively[38,39]. All statistical tests were performed using the IBM SPSS Statistics for Mac (IBM Corp., version 20.0, Armonk, NY, USA). Statistical significance was set at $p \leq 0.05$.

Results

Referees' physical demands according to the type of turf during official matches are shown in Table 1. Referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.05$) and $Cadence_{mean}$ ($p < 0.05$) on natural fields compared to artificial turf fields. However, no significant differences were found in Vertical oscillation-mean, GCT_{mean} and $Stiffness_{mean}$. Neither were differences found in any physiological variable according to the type of turf (Table 2).

Referees' physical demands according to the pitch size during official matches are shown in Table 3. Referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.01$), $Cadence_{mean}$ ($p < 0.05$) and $Stiffness_{mean}$ ($p < 0.05$) in above-standard in comparison to below-standard fields. However, no significant differences ($p > 0.05$) were found in Vertical $oscillation_{mean}$ and GCT_{mean}. Regarding physiological demands, referees spent more time in Zone 5 in above-standard fields, but no differences were found in any other HR zones, HR_{mean}, $\%HR_{peak}$ or TRIMP (Table 4).

According to the period of the season, during the second round, referees covered more total distance in the matches compared to the matches played in the first round ($p < 0.05$) (Table 5). However, no differences were found in most of the physical ($Power_{mean}$, $Speed_{mean}$, $Cadence_{mean}$, Vertical $oscillation_{mean}$, GCT_{mean} and $Stiffness_{mean}$) or physiological demands (Table 6).

Referees' physical demands according to the environmental temperature during official matches are shown in Table 7. Referees recorded greater total distance ($p < 0.05$), $Power_{mean}$ ($p < 0.05$) and $Speed_{mean}$ ($p < 0.05$) during matches played with a higher environmental temperature (more than 20º) compared to those matches played in temperatures below 10º. However, no significant differences were found in other physical ($Cadence_{mean}$, Vertical $oscillation_{mean}$ GCT_{mean} or $Stiffness_{mean}$) or physiological demands (Table 8).

No significant interaction ($p > 0.05$) was observed in physical and physiological demands within 15 min periods according to type of turf, field, size, period of season or environmental temperature.

Discussion

The main aim of this study was to analyze how contextual variables (i.e., type of turf, pitch size, period of season, and environmental

Table 1. Physical demands registered by soccer referees according to type of turf (i.e., natural and artificial) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Type of turf	Type of turf x period
Total distance (km)	Natural	1.57±0.17	1.48±0.10	1.54±0.13	1.46±0.19	1.37±0.17	1.77±0.27	9.18±0.62#	$F_{1, 21}$= 10.076	$F_{5.00, 105.00}$= 0.922
	Artificial	1.37±0.21	1.40±0.14	1.31±0.31	1.31±0.16	1.29±0.14	1.57±0.19	8.25±0.75	**p = 0.005**	p = 0.470
									η_p^2= 0.324	η_p^2= 0.042
$Power_{mean}$(W)	Natural	136.21±11.51	129.18±14.23	125.88±10.19	127.35±14.08	125.08±18.53	126.75±14.55	128.36±11.48#	$F_{1, 21}$= 11.373	$F_{5.00, 105.00}$= 0.637
	Artificial	120.04±15.55	120.02±16.34	109.67±7.63	117.14±8.89	110.87±9.54	110.80±11.24	114.84±7.68	**p = 0.003**	p = 0.672
									η_p^2= 0.351	η_p^2=0.029
$Speed_{mean}$ ($km \cdot h^{-1}$)	Natural	7.87±0.58	7.57±0.56	7.27±0.54	7.52±0.82	7.27±0.78	7.37±0.71	7.48±0.55#	$F_{1, 21}$ = 7.256	$F_{5.00, 105.00}$ = 0.417
	Artificial	7.08±0.79	7.04±0.78	6.66±0.56	6.96±0.57	6.66±0.59	6.60±0.75	6.83±0.56	**p = 0.014**	p = 0.836
									η_p^2= 0.257	η_p^2= 0.019
$Cadence_{mean}$ (steps per min)	Natural	65.80±2.92	63.81±1.77	63.99±2.01	63.88±3.26	62.77±3.27	62.61±2.64	63.80±1.69#	$F_{1, 21}$ = 6.855	$F_{5.00, 105.00}$= 1.274
	Artificial	63.42±2.24	62.79±2.93	60.45±3.49	63.33±1.62	61.36±2.47	60.94±1.90	62.07±1.43	**p = 0.016**	p = 0.281
									η_p^2= 0.246	η_p^2= 0.057
Vertical $oscillation_{mean}$(cm)	Natural	8.20±0.95	8.04±0.43	8.06±0.66	8.06±0.58	8.08±0.82	7.82±0.66	8.04±0.61	$F_{1, 21}$ = 0.161	$F_{5.00, 105.00}$= 0.412
	Artificial	8.07±0.58	8.00±0.58	7.86±0.63	7.84±0.44	8.08±0.73	7.88±0.65	7.96±0.47	p = 0.692	p = 0.839
									η_p^2= 0.008	η_p^2= 0.019
GCT_{mean}($m \cdot s^{-1}$)	Natural	504.44±69.91	538.74±68.03	546.58±81.73	527.77±78.40	524.30±76.12	525.33±56.44	527.75±59.67	$F_{1, 21}$ = 0.881	$F_{3.820, 80.221}$ = 0.835
	Artificial	528.40±80.86	563.78±66.95	542.36±118.13	532.24±80.60	572.37±50.22	568.23±66.00	551.56±58.73	p = 0.359	p = 0.502
									η_p^2= 0.040	η_p^2= 0.038
$Stiffness_{mean}$($KN \cdot m^{-1}$)	Natural	9.24±0.56	9.24±0.53	9.30±0.52	8.82±0.43	9.07±0.59	9.02±0.52	9.12±0.36	$F_{1, 21}$ = 1.480	$F_{5.00, 105.00}$= 1.116
	Artificial	9.59±1.05	9.52±0.92	9.31±0.67	9.46±0.76	9.33±0.70	9.12±0.68	9.41±0.66	p = 0.237	p = 0.356
									η_p^2=0.066	η_p^2= 0.050

GCT: ground contact time; #Significantly different (p < 0.05) from artificial turf.

Table 2. Physiological demands registered by soccer referees according to type of turf (i.e., natural and artificial) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Type of turf	Type of turf x period
HR_{mean} (bpm)	Natural	156.60±10.80	159.86±11.89	158.59±12.58	154.69±14.84	155.12±12.51	157.84±13.27	157.17±12.16	$F_{1, 21}$ = 0.311	$F_{2.659, 55.836}$= 0.934
	Artificial	163.00±16.46	163.90±12.79	159.56±16.18	157.53±11.35	158.44±10.98	157.37±13.42	159.83±12.23	p = 0.583	p = 0.421
									η_p^2=0.015	η_p^2= 0.043
$\%HR_{peak}$	Natural	87.83±2.98	88.09±3.13	88.08±2.15	88.04±2.07	86.80±2.33	88.20±2.14	85.56±2.50	$F_{1, 21}$ = 0.406	$F_{2.853, 59.919}$ = 1.774
	Artificial	85.13±6.43	87.67±5.15	87.91±5.24	87.98±2.10	88.83±2.32	85.60±4.10	82.28±6.04	p = 0.531	p = 0.164
									η_p^2= 0.019	η_p^2=0.078
Zone 1 (min)	Natural	0.194±0.32	0.00±0.00	0.00±0.00	0.02±0.05	0.03±0.10	0.00±0.01	0.25±0.34	$F_{1, 21}$ = 2.167	$F_{1.946, 40.869}$ = 0.246
	Artificial	0.80±2.30	0.18±0.63	0.55±1.89	0.32±1.07	0.15±0.55	0.22±0.74	2.22±4.21	p = 0.156	p = 0.777
									η_p^2= 0,094	η_p^2= 0.012
Zone 2 (min)	Natural	0.29±0.40	0.25±0.47	0.16±0.22	0.47±0.77	0.61±0.92	0.33±0.62	2.12±2,47	$F_{1, 21}$ = 1.012	$F_{1.709, 35.895}$ = 1.550
	Artificial	0.51±0.62	0.45±1.15	1.14±2.90	1.16±2.35	1.14±2.91	1.95±3.53	6.34±13.04	p =0.326	p = 0.227
									η_p^2= 0.046	η_p^2=0.069
Zone 3 (min)	Natural	2.65±1.70	2.18±1.62	3.20±2.22	3.53±2.05	3.01±1.73	3.30±1.90	17.88±8,02	$F_{1, 21}$ = 1.044	$F_{5.00, 105.00}$= 1.260
	Artificial	3.38±2.87	2.96±3.35	3.81±3.51	4.39±3.57	4.27±3.81	5.89±4.50	24.70±19.82	p = 0.318	p = 0.287
									η_p^2= 0.047	η_p^2= 0.057
Zone 4 (min)	Natural	6.90±1.65	6.50±1.28	6.35±1.27	7.10±1.62	7.40±1.85	9.00±1.45	43.25±5.04	$F_{1, 21}$ = 0.302	$F_{5.00, 105.00}$ = 1.060
	Artificial	5.49±1.96	7.02±2.42	6.79±2.98	6.53±3.04	6.90±3.47	7.74±4.73	40.48±15.23	p = 0.589	p = 0.387
									η_p^2= 0.014	η_p^2= 0.048
Zone 5 (min)	Natural	4.55±2.11	5.63±2.38	5.84±2.69	3.50±3.00	3.55±1.80	5.96±3.44	29.04±11.94	$F_{1, 21}$ = 2.132	$F_{5.00, 105.00}$= 1.203
	Artificial	4.49±3.23	4.25±3.69	3.81±3.47	2.50±2.04	2.47±2.18	3.24±3.37	20.76±14.54	p = 0.159	p = 0.313
									η_p^2= 0.092	η_p^2= 0.054
TRIMP (AU)	Natural	59.07±3.82	61.25±4.99	64.52±7.06	57.45±6.00	57.63±5.20	76.40±8.92	376.32±28.53	$F_{1, 21}$ = 1.343	$F_{2.603, 54.666}$ = 0.644
	Artificial	56.37±11.44	59.29±8.12	60.48±12.80	54.42±9.88	55.19±9.66	68.96±12.51	354.72±53.16	p = 0.260	p = 0.569
									η_p^2=0.060	η_p^2= 0.030

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

Table 3. Physical demands registered by soccer referees according to pitch size (i.e., over standard and below standard) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Pitch size	Pitch size x period
Total distance (km)	Over standard	1.57±0.17	1.48±0.11	1.51±0.12#	1.41±0.19	1.37±0.15	1.74±0.25	9.08±0.59##	$F_{1,21}$= 22.682	$F_{5.00,105.00}$= 1.449
	Below standard	1.25±0.12	1.34±0.10	1.23±0.37	1.30±0.14	1.23±0.13	1.50±0.12	7.85±0.58	**p = 0.000**	p = 0.213
									η_p^2= 0.519	η_p^2= 0.065
$Power_{mean}$ (W)	Over standard	135.67±11.00	129.93±13.95	121.28±11.22	125.50±12.54	122.57±15.74	123.10±14.00	126.21±10.03##	$F_{1,21}$= 17.836	$F_{5.00,105.00}$= 1.290
	Below standard	110.95±9.92	112.88±13.42	108.15±8.06	114.22±8.04	106.70±8.78	107.67±11.16	110.41±5.56	**p = 0.000**	p = 0.274
									η_p^2= 0.459	η_p^2=0.058
$Speed_{mean}$ ($km{\cdot}h^{-1}$)	Over standard	7.83±0.6	7.61±0.61#	7.18±0.50	7.48±0.76	7.20±0.69	7.24±0.74	7.42±0.53##	$F_{1,21}$ = 17.432	$F_{5.00,105.00}$ = 0.817
	Below standard	6.67±0.52	6.64±0.48	6.44±0.55	6.68±0.23	6.42±0.52	6.35±0.64	6.54±0.37	**p = 0.000**	p = 0.540
									η_p^2= 0.454	η_p^2= 0.037
$Cadence_{mean}$ (steps per min)	Over standard	65.50±2.42	63.76±2.25	63.16±2.54	63.75±2.82	62.36±2.90	62.03±2.49	63.39±1.74#	$F_{1,21}$ = 6.128	$F_{5.00,105.00}$= 1.362
	Below standard	62.51±2.40	62.26±2.79	59.80±3.85	63.22±1.52	61.24±2.84	60.97±2.03	61.77±1.26	**p = 0.022**	p = 0.245
									η_p^2= 0.226	η_p^2= 0.061
Vertical $oscillation_{mean}$ (cm)	Over standard	8.23±0.88	8.12±0.48	8.08±0.69	8.05±0.57	8.20±0.78	7.88±0.71	8.10±0.61	$F_{1,21}$ = 1.764	$F_{5.00,105.00}$= 0.320
	Below standard	7.94±0.35	7.81±0.54	7.69±0.47	7.72±0.25	7.85±0.71	7.79±0.52	7.81±0.24	p = 0.198	p = 0.900
									η_p^2= 0.077	η_p^2= 0.015
GCT_{mean}($m{\cdot}s^{-1}$)	Over standard	511.08±66.17	537.64±60.62	550.3±66.70	518.50±83.16	541.41±68.67	541.33±52.93	533.68±51.47	$F_{1,21}$ = 0.721	$F_{3.852,80.882}$ = 0.821
	Below standard	530.92±94.38	581.49±73.19	532.64±152.95	552.41±66.07	570.34±59.86	565.04±83.83	555.33±72.81	p = 0.406	p = 0.511
									η_p^2= 0.033	η_p^2= 0.038
$Stiffness_{mean}$ ($KN{\cdot}m^{-1}$)	Over standard	9.20±0.58	9.16±0.60	9.22±0.58	8.96±0.57	8.97±0.56	8.90±0.56	9.07±0.43#	$F_{1,21}$ = 7.862	$F_{5.00,105.00}$= 0.626
	Below standard	9.88±1.17	9.84±0.91	9.47±0.64	9.60±0.78	9.67±0.60	9.41±0.57	9.68±0.57	**p = 0.011**	p = 0.680
									η_p^2=0.272	η_p^2= 0.029

GCT: ground contact time; #Significantly different (#p < 0.05, ##p < 0.01) from below standard fields.

Table 4. Physiological demands registered by soccer referees according to pitch size (i.e., over standard and below standard) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Pitch size	Pitch size x period
HR_{mean} (bpm)	Over standard	159.50±12.83	162.64±12.84	159.05±16.30	156.38±13.39	157.45±11.58	158.22±14.44	158.84±12.89	$F_{1,21}$ = 0.006	$F_{2.633,55.288}$= 0.308
	Below standard	161.58±17.75	161.21±12.00	159.30±11.02	156.13±12.34	156.15±12.15	156.38±10.77	158.36±10.96	p = 0.939	p = 0.794
									η_p^2=2.847	η_p^2= 0.014
$\%HR_{peak}$	Over standard	88.06±2.63	88.40±2.80	87.45±4.93	87.65±2.06	87.10±2.05	86.90±3.79	85.41±2.66	$F_{1,21}$ = 0.110	$F_{3.985,83.682\,0}$= 4.200
	Below standard	83.04±7.45	86.82±6.37	88.99±1.62	88.67±1.94	89.53±2.60	86.40±3.36	80.51±6.86	p = 0.744	**p = 0.004**
									η_p^2= 0.005	η_p^2=0.167
Zone 1 (min)	Over standard	0.13±0.27	0.00±0.00	0.46±1.76	0.03±0.07	0.02±0.08	0.01±0.04	0.65±1.77	$F_{1,21}$ = 2.157	$F_{1.989,41.770}$ = 1.467
	Below standard	1.30±2.90	0.29±0.80	0.05±0.13	0.48±1.37	0.25±0.70	0.33±0.94	2.70±4.92	p = 0.157	p = 0.242
									η_p^2= 0,093	η_p^2= 0.065
Zone 2 (min)	Over standard	0.30±0.35	0.17±0.40	0.23±0.43	0.49±0.70	0.47±0.77	0.64±1.58	2.30±2.82	$F_{1,21}$ = 2.223	$F_{1.709,35.895}$ = 1.353
	Below standard	0.64±0.75	0.74±1.43	1.62±3.66	1.54±2.97	1.73±3.67	2.38±4.09	8.65±16.37	p =0.151	p = 0.269
									η_p^2= 0.096	η_p^2=0.061
Zone 3 (min)	Over standard	2.69±1.83	1.83±1.52	2.97±2.32	3.52±1.89	2.99±1.52	3.74±2.07	17.75±7.57	$F_{1,21}$ = 2.946	$F_{5.00,105.00}$= 0.931
	Below standard	3.76±3.28	4.11±3.82	4.61±3.88	4.93±4.39	5.10±4.69	6.68±5.46	29.19±24.11	p = 0.101	p = 0.464
									η_p^2= 0.123	η_p^2= 0.042
Zone 4 (min)	Over standard	6.55±1.50	6.80±1.80	6.33±1.56	7.19±1.60	7.53±1.64	8.72±2.31	43.12±5.22	$F_{1,21}$ = 0.629	$F_{5.00,105.00}$ = 1.112
	Below standard	5.26±2.44	6.80±2.42	7.10±3.49	6.00±3.66	6.34±4.33	7.48±5.52	38.99±19.21	p = 0.437	p = 0.359
									η_p^2= 0.029	η_p^2= 0.050
Zone 5 (min)	Over standard	4.97±2.41	5.82±2.62	5.67±3.03	3.43±2.51	3.66±1.72	5.45±3.70	29.00±11.15#	$F_{1,21}$ = 5.958	$F_{5.00,105.00}$= 0.701
	Below standard	3.66±3.27	3.04±3.56	2.86±2.99	2.02±2.34	1.58±2.04	2.49±2.62	15.65±14.81	**p = 0.023**	p = 0.624
									η_p^2= 0.221	η_p^2= 0.032
TRIMP (AU)	Over standard	59.87±4.93	62.10±4.82	63.52±9.05	57.47±5.30	58.37±4.49	74.68±9.62	376.01±29.10	$F_{1,21}$ = 3.400	$F_{2.606,54.732}$ = 0.244
	Below standard	53.19±12.94	56.47±8.83	59.82±13.59	52.49±12.10	52.28±11.46	67.53±13.85	341.78±60.83	p = 0.079	p = 0.854
									η_p^2=0.139	η_p^2= 0.011

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse. #Significantly different (p < 0.05) from below standard fields.

Table 5. Physical demands registered by soccer referees according to period of season (i.e., first and second round) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Round	Round x period
Total distance (km)	First round	1.39±0.19	1.44±0.13	1.34±0.33	1.30±0.15	1.30±0.16	1.57±0.19	8.33±0.75#	$F_{1, 21}$= 5.452	$F_{5.00, 105.00}$= 1.538
	Second round	1.54±0.24	1.42±0.12	1.51±0.11	1.47±0.18	1.35±0.16	1.78±0.26	9.07±0.77	**p = 0.030**	p = 0.184
									η_p^2= 0.206	η_p^2= 0.068
$Power_{mean}$ (W)	First round	121.19±14.41	123.07±14.79	113.12±11.07	116.82±11.07	114.22±11.13	115.54±11.75	117.50±7.98	$F_{1, 21}$= 2.572	$F_{5.00, 105.00}$= 1.084
	Second round	134.72±15.07	125.21±17.79	121.39±11.83	127.76±11.42	120.73±20.00	120.58±18.43	124.89±14.35	p = 0.117	p = 0.373
									η_p^2= 0.113	η_p^2=0.049
$Speed_{mean}$ ($km{\cdot}h^{-1}$)	First round	7.18±0.75	7.20±0.75	6.78±0.67	6.97±0.67	6.81±0.69	6.76±0.66	6.95±0.55	$F_{1, 21}$ = 2.023	$F_{5.00, 105.00}$ = 0.814
	Second round	7.75±0.79	7.37±0.73	7.11±0.52	7.50±0.73	7.07±0.80	7.16±0.97	7.32±0.71	p = 0.170	p = 0.542
									η_p^2= 0.088	η_p^2= 0.037
$Cadence_{mean}$ (steps per min)	First round	63.78±2.67	63.78±2.80	62.06±4.03	63.18±2.53	61.62±3.15	61.70±2.02	62.76±1.72	$F_{1, 21}$ = 0.139	$F_{5.00, 105.00}$= 1.086
	Second round	65.33±2.79	62.54±1.95	61.89±2.53	64.06±2.80	62.42±2.53	61.61±2.84	62.92±1.87	p = 0.713	p = 0.373
									η_p^2= 0.007	η_p^2= 0.049
Vertical $oscillation_{mean}$ (cm)	First round	7.98±0.75	7.95±0.49	7.70±0.54	7.77±0.45	8.13±0.79	7.74±0.66	7.88±0.49	$F_{1, 21}$ = 1.452	$F_{5.00, 105.00}$= 1.916
	Second round	8.32±0.74	8.09±0.55	8.27±0.63	8.15±0.52	8.01±0.75	7.99±0.61	8.15±0.55	p = 0.242	p = 0.098
									η_p^2= 0.065	η_p^2= 0.084
GCT_{mean} ($m{\cdot}s^{-1}$)	First round	524.62±85.08	555.32±76.66	536.85±129.37	530.09±80.48	548.82±67.82	541.01±63.85	539.19±66.16	$F_{1, 21}$ = 0.021	$F_{3.154, 66.232}$ = 0.345
	Second round	509.36±64.58	549.73±56.08	553.75±52.94	530.09±78.64	554.91±66.73	560.71±66.86	543.83v51.62	p = 0.885	p = 0.803
									η_p^2= 0.001	η_p^2= 0.016
$Stiffness_{mean}$ ($KN{\cdot}m^{-1}$)	First round	9.33±0.76	9.36±0.73	9.26±0.40	9.24±0.81	9.24±0.73	9.03±0.52	9.27±0.48	$F_{1, 21}$ = 0.057	$F_{5.00, 105.00}$ = 0.420
	Second round	9.57±1.03	9.45±0.88	9.37±0.80	9.10±0.58	9.18±0.57	9.13±0.72	9.30±0.67	p = 0.814	p = 0.834
									η_p^2=0.003	η_p^2= 0.020

GCT: ground contact time; #Significantly different ($p < 0.05$) from second round matches.

Table 6. Physiological demands registered by soccer referees according to period of season (i.e., first and second round) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Round	Round x period
HR_{mean} (bpm)	First round	160.84±14.09	162.97±13.56	158.12±17.29	153.63±14.02	156.22±13.54	155.04±13.61	157.66±13.27	$F_{1, 21}$ = 0.173	$F_{2.628, 55.184}$ = 1.993
	Second round	159.42±15.42	161.07±13.56	160.46±10.27	159.76±10.56	158.00±8.83	160.87±12.17	159.99±10.66	p = 0.682	p = 0.133
									η_p^2=0.008	η_p^2= 0.087
$\%HR_{peak}$	First round	88.15±3.08	87.87±5.30	87.61±5.14	87.18±1.77	88.19±2.92	86.07±3.96	83.87±5.22	$F_{1, 21}$ = 0.008	$F_{3.086, 64.796}$= 2.931
	Second round	83.91±6.69	87.82±2.80	88.47±2.34	89.08±1.91	87.62±1.92	87.58±2.98	83.50±5.01	p = 0.927	**p = 0.039**
									η_p^2= 4.038	η_p^2=0.122
Zone 1 (min)	First round	0.18±0.41	0.18±0.63	0.55±1.89	0.31±1.07	0.18±0.55	0.22±0.74	1.61±3.79	$F_{1, 21}$ = 0.165	$F_{2.003, 42.056}$ = 1.395
	Second round	1.01±2.60	0.00±0.02	0.00±0.00	0.03±0.08	0.00±0.00	0.00±0.00	1.04±2.61	p = 0.688	p = 0.259
									η_p^2= 0,008	η_p^2= 0.062
Zone 2 (min)	First round	0.34±0.63	0.37±1.16	1.06±2.92	1.23±2.37	1.16±2.99	1.64±3.55	5.80±13.24	$F_{1, 21}$ = 0.492	$F_{1.713, 35.977}$ = 1.139
	Second round	0.51±0.38	0.36±0.49	0.26±0.35	0.37±0.54	0.58±0.46	0.74±1.14	2.82±2.20	p =0.491	p = 0.324
									η_p^2= 0.023	η_p^2=0.051
Zone 3 (min)	First round	3.12±2.03	1.82±2.08	2.31±2.01	3.81±1.90	2.81±1.92	4.28±2.19	18.16±9.786	$F_{1, 21}$ = 1.548	$F_{5.00, 105.00}$ = 2.962
	Second round	2.98±2.96	3.66±3.17	5.14±3.34	4.27±4.09	4.91±3.95	5.40±5.26	26.38±21.16	p = 0.227	**p = 0.015**
									η_p^2= 0.069	η_p^2= 0.124
Zone 4 (min)	First roundd	6.28±2.21	6.72±2.14	6.72±2.67	6.83±2.67	7.59±2.92	8.85±3.92	43.00±13.50	$F_{1, 21}$ = 0.363	$F_{5.00, 105.00}$ = 0.509
	Second round	5.87±1.56	6.90±1.87	6.44±2.01	6.71±2.38	6.50±2.73	7.56±3.37	39.98±9.53	p = 0.553	p = 0.769
									η_p^2= 0.017	η_p^2= 0.024
Zone 5 (min)	First round	4.80±2.53	5.62±3.39	4.86±3.31	2.55±2.31	3.02±2.11	3.60±2.36	24.46±11.85	$F_{1, 21}$ = 0.002	$F_{5.00, 105.00}$ = 2.503
	Second round	4.14±3.08	3.84±2.78	4.47±3.35	3.45±2.75	2.83±2.09	5.50±4.69	24.22±16.74	p = 0.968	**p = 0.035**
									η_p^2= 0.891	η_p^2= 0.106
TRIMP (AU)	First round	59.39±5.39	61.39±7.58	60.83±12.75	54.26±9.42	56.43±9.43	69.73±11.29	362.02±49.94	$F_{1, 21}$ = 0.062	$F_{2.807, 58.945}$ = 2.689
	Second round	55.15±11.99	58.52±5.78	64.06±7.44	57.66±6.80	56.02±6.02	75.41±11.52	366.82±39.18	p = 0.805	p = 0.058
									η_p^2=0.003	η_p^2= 0.114

HR_{mean}: mean heart rate; $\%H_{Rpeak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

Table 7. Physical demands registered by soccer referees according to environmental temperature (i.e., below 10º and over 20º) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Temperature	Temperature x period
Total distance (km)	Below 10º Over 20º	1.40±0.23 1.56±0.22	1.42±0.12 1.48±0.11	1.31±0.35 1.53±0.13	1.31±0.16 1.43±0.17	1.26±0.16 1.41±0.08	1.53±0.19 1.82±0.24	8.23±0.74# 9.23±0.65	$F_{1,21}$= 5.024 **p = 0.017** η_p^2= 0.334	$F_{5.00, 105.00}$= 0.757 p = 0.669 η_p^2= 0.070
$Power_{mean}$ (W)	Below 10º Over 20º	120.72±15.64 137.35±13.37	123.69±16.13 128.89±15.63	112.42±11.15 122.00±11.66	113.91±7.64 131.08±9.83	110.44±7.76 127.69±16.44	112.21±9.30 125.72±16.90	115.79±6.51# 128.50±11.98	$F_{1,21}$= 4.775 **p = 0.020** η_p^2= 0.323	$F_{5.00, 105.00}$= 0.981 p = 0.465 η_p^2=0.089
$Speed_{mean}$ ($km \cdot h^{-1}$)	Below 10º Over 20º	7.14±0.76 7.92±0.71	7.15±0.78 7.59±0.62	6.72±0.66 7.21±0.44	6.80±0.42 7.71±0.68	6.64±0.60 7.41±0.56	6.63±0.57 7.45±0.84	6.85±0.46# 7.54±0.57	$F_{1,21}$ = 4.421 **p = 0.026** η_p^2= 0.307	$F_{7.128, 71.276}$ = 0.793 p = 0.598 η_p^2= 0.073
$Cadence_{mean}$ (steps per min)	Below 10º Over 20º	63.83±2.90 65.12±2.64	63.62±3.19 63.30±1.82	62.46±4.39 62.15±2.41	63.03±2.28 63.48±2.47	61.60±3.48 62.71±2.27	61.26±1.98 62.19±2.41	62.73±1.76 63.10±1.69	$F_{1,21}$ = 0.256 p = 0.776 η_p^2= 0.025	$F_{5.00, 105.00}$= 0.779 p = 0.649 η_p^2= 0.072
Vertical $oscillation_{mean}$ (cm)	Below 10º Over 20º	7.95±0.57 8.46±0.97	7.94±0.54 8.13±0.54	7.67±0.56 8.17±0.70	7.74±0.51 8.24±0.47	7.95±0.60 8.43±0.91	7.77±0.63 8.03±0.76	7.85±0.41 8.24±0.67	$F_{1,21}$ = 1.924 p = 0.172 η_p^2= 0.161	$F_{5.00, 105.00}$= 0.919 p = 0.519 η_p^2= 0.084
GCT_{mean} ($m \cdot s^{-1}$)	Below 10º Over 20º	533.76±81.10 552.78±76.70	556.15±83.81 549.32±47.29	543.81±147.05 555.39±31.28	547.28±62.07 502.89±91.31	553.54±64.80 537.76±71.44	543.04±67.74 543.09±55.96	545.75±68.52 531.64±40.38	$F_{1,21}$ = 0.202 p = 0.819 η_p^2= 0.020	$F_{7.892, 78.920}$ = 0.714 p = 0.676 η_p^2= 0.067
$Stiffness_{mean}$ ($KN \cdot m^{-1}$)	Below 10º Over 20º	9.42±0.83 9.37±1.11	9.41±0.65 9.23±0.88	9.36±0.48 9.08±0.76	9.33±0.90 8.99±0.57	9.38±0.76 9.10±0.60	9.05±0.52 8.87±0.58	9.35±0.49 9.12±0.69	$F_{1,21}$ = 0.734 p = 0.492 η_p^2=0.068	$F_{5.00, 105.00}$= 0.643 p = 0.774 η_p^2= 0.060

GCT: ground contact time; #Significantly different ($p < 0.05$) from over 20º matches.

Table 8. Physiological demands registered by soccer referees according to environmental temperature (i.e., below 10º and over 20º) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Temperature	Temperature x period
HR_{mean} (bpm)	Below 10º Over 20º	165.50±15.10 158.13±11.34	165.98±15.63 160.52±9.01	163.45±16.50 155.70±14.91	156.00±18.18 156.77±8.47	157.38±16.34 158.32±6.32	158.73±15.85 157.99±13.13	161.09±15.41 157.86±10.08	$F_{1,21}$ = 0.460 p = 0.638 η_p^2=0.044	$F_{5.271, 52.706}$ = 1.757 p = 0.135 η_p^2= 0.149
$\%HR_{peak}$	Below 10º Over 20º	88.48±3.48 86.46±3.60	87.73±6.20 88.57±1.52	89.30±2.07 86.37±6.00	87.48±2.04 87.75±1.98	87.84±3.19 88.19±1.91	86.52±3.03 87.48±4.63	83.70±5.81 84.52±3.95	$F_{1,21}$ = 0.522 p = 0.601 η_p^2= 0.050	$F_{6.134, 61.336}$= 2.456 **p = 0.033** η_p^2=0.197
Zone 1 (min)	Below 10º Over 20º	0.17±0.43 0.11±0.23	0.23±0.72 0.00±0.00	0.04±0.12 0.76±2.28	0.40±1.22 0.03±0.08	0.23±0.62 0.00±0.00	0.27±0.84 0.02±0.05	1.34±3.94 0.91±2.29	$F_{1,21}$ = 0.284 p = 0.756 η_p^2= 0,208	$F_{4.059, 42.593}$ = 2.565 p = 0.052 η_p^2= 0.204
Zone 2 (min)	Below 10º Over 20º	0.39±0.71 0.31±0.25	0.48±1.31 0.18±0.47	1.18±3.33 0.32±0.54	1.51±2.67 0.44±0.56	1.57±3.34 0.30±0.44	1.54±3.74 1.12±2.10	6.68±14.96 2.66±3.20	$F_{1,21}$ = 0.398 p =0.677 η_p^2= 0.038	$F_{3.218, 32.177}$ = 0.769 p = 0.528 η_p^2=0.071
Zone 3 (min)	Below 10º Over 20º	2.70±1.89 3.89±2.91	1.89±2.32 2.64±2.79	2.29±2.32 4.57±3.46	3.80±2.32 4.00±2.98	3.26±1.96 3.58±3.47	4.37±2.46 4.22±4.24	18.30±11.06 22.91±18.33	$F_{1,21}$ = 0.511 p = 0.607 η_p^2= 0.049	$F_{5.00, 105.00}$= 2.177 **p = 0.025** η_p^2= 0.179
Zone 4 (min)	Below 10º Over 20º	6.44±2.30 5.93±1.66	6.66±2.38 7.30±1.67	6.71±2.73 5.77±1.79	6.85±2.93 6.72±1.94	7.41±3.25 6.89±2.60	9.05±4.40 7.27±3.27	43.11±15.23 39.89±9.04	$F_{1,21}$ = 0.167 p = 0.847 η_p^2= 0.016	$F_{5.00, 105.00}$ = 0.896 p = 0.540 η_p^2= 0.082
Zone 5 (min)	Below 10º Over 20º	5.16±2.10 4.26±3.04	5.54±3.68 4.52±2.39	5.24±3.87 4.50±2.97	2.33±2.80 3.38±2.26	2.41±2.00 3.86±1.83	3.66±3.53 5.87±3.89	24.34±14.74 26.40±13.02	$F_{1,21}$ = 0.295 p = 0.748 η_p^2= 0.029	$F_{5.00, 105.00}$= 1.491 p = 0.154 η_p^2= 0.130
TRIMP (AU)	Below 10º Over 20º	60.61±4.81 57.44±6.00	61.18±8.46 60.07±4.83	62.29±13.19 60.72±9.13	53.84±11.23 56.71±4.88	54.85±10.28 58.23±5.29	70.98±13.82 73.36±11.86	363.74±57.43 366.54±35.62	$F_{1,21}$ = 0.031 p = 0.969 η_p^2=0.003	$F_{5.480, 54.901}$ = 1.661 p = 0.154 η_p^2= 0.142

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

temperature) affect referees' physical and physiological demands during official matches. This is the first study to analyze this topic, opening up a new line of research that may allow referees' strength and conditioning specialists to be more precise in prescribing training sessions and planning post-match recovery. This study showed that playing on natural grass meant that referees had to cover more distance, using higher power, speed and cadence than on artificial grass. Also, in above-standard fields more distance, power, speed, cadence and stiffness and more time in zone 5 were recorded than in below-standard fields. Also, referees covered more total distance during matches played in the second round in comparison to the first. Finally, more distance, power and speed were recorded in matches with environmental temperatures over 20º than below 10º. No differences were found within 15 min periods according to type of turf, pitch size, season period or environmental temperature in physical and physiological variables.

Knowing whether contextual variables influence the demands of official matches in soccer referees may be of great interest to strength and conditioning specialists in order to plan training sessions and to establish more appropriate recovery strategies. Previous studies carried out with soccer players have observed that contextual factors affect match demands[12–14,16,19,26,40], so it is of interest to analyze whether these factors also affect referees. In this vein, in our study it has been shown that matches played on natural grass imply greater total distance, power, speed and cadence for amateur soccer referees compared to matches played on artificial grass. Although other research has not found significant differences in physical demands between matches played on artificial turf and natural grass[14,15], the artificial turf standards in the aforementioned studies were higher than in the present study. These differences may be due to the fact that first-generation artificial grass (old-aged) decreases ball and game velocity and thus the physical demands on the referee. Likewise, refereeing on above-standard pitches meant greater total distance, power, speed, cadence and stiffness, and time spent in zone 5 than on below-standard pitches. In small sided soccer games it has been demonstrated that bigger soccer fields are related to higher physical demands[41], so this study would confirm the same pattern during official matches.

On the other hand, the fact of covering more total distance during matches played in the second round in comparison to the first could be associated with the pressure involved in playing the last matches of the season when the referees have to be prepared to keep up with the pace of play in matches with high physical and physiological demands. Also, playing with an environmental temperature above 20ºC is associated with more total distance, power and speed than in matches played with an ambient temperature below 10ºC. However, other studies have found that lower temperatures are associated with higher physical demands in professional soccer players[17,18], so the disparity of results found on this aspect may be due to the fact that in amateur leagues cold temperatures below 10ºC can lead to a lower body temperature and therefore to a lower intensity, reducing the physical demands on the referees. These results suggest the need to consider contextual variables during training periodization for this population. However, in general, no differences were found in vertical oscillation, GCT and stiffness, nor in the majority of physiological responses in any of the variables studied. However, this is the first study to analyze the influence of contextual variables on these parameters, so it would be interesting to perform further studies that address the analysis of these variables.

When isolated 15 min periods were analyzed, we did not observe significant differences between contextual variables and referees' match performance in physical and physiological variables, except a significant interaction ($p < 0.05$) between season periods and $\%HR_{peak}$, time spent in zone 3 and time spent in zone 5, but post hoc analysis did not reveal significant differences ($p > 0.05$). These results show that contextual variables do not influence the demands of the match in 15 min periods, although as demonstrated above, these variables influence the demands encountered during the entire match. The scientific literature has shown disparate results according to how physical and physiological demands evolve in referees over the course of matches. While some studies observed that physical demands decrease and physiological demands are maintained as the match progresses[31], other studies have shown that physiological demands also diminish as the match progresses[5], and other studies have shown that physiological demands increase as the match progresses[42]. The responses of the referees in each 15 min period can be associated with the requirements of the game (e.g., score, pace of the match imposed by the players due to their physical and technical capabilities, tactical and strategic decisions, etc.). Hence, there is no clear trend in the evolution of physical and physiological responses during each 15 min period, and in our case, the contextual variables analyzed did not appear to influence this evolution. To conclude, referees may need to be prepared for highly variable demands during a match and be able to respond to them at any time of the match whatever the contextual factors.

Although this study shows that contextual variables have an impact on the knowledge about the physical and physiological demands in amateur referees, it is not without limitations, so we see the need to extend the sample to other categories of grassroots soccer and to professional referees. Considering that there are studies that have proved the validity of subjective quantification methods[43] and more specifically in soccer referees[9,44], including these quantification methods could have provided valuable information to complement the results obtained. Finally, the contextual factors analyzed in this study are limited, which opens up a line of research to take into account other contextual factors such as the style of play of the teams, effective playing time, the referee's physical fitness level, etc.

Conclusions

The results of this study show that the type of surface, pitch size, the environmental temperature and season period influence the physical demands of soccer referees during official matches. Therefore, it is suggested that strength and conditioning specialists should consider the influence of contextual variables on the match demands involved in refereeing activities, in order to prescribe more appropriate training and recovery strategies to face the matches with greater guarantees. Furthermore, the fact that no differences were found within 15 min periods throughout the match according to the contextual variables studied could indicate that it is not possible to determine a specific period in which the contextual variables play a determining role, but rather that the entire match should be taken into account.

Acknowledgements

The authors gratefully acknowledge the support of a Spanish government subproject mixed method approach on performance analysis (in training and competition) in elite and academy sport (PGC2018-098742-B-C33] (2019–2021) from the Ministry of Science, Innovation and Universities (MCIU), the State Research Agency (AEI) and the European Regional Development Fund (ERDF), that is part of the coordinated project New Approach of Research in Physical Activity and Sport from Mixed Methods Perspective (NARPAS_MM) [SPGC201800X098742CV0].

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Castillo D, Cámara J, Sedano S, Yanci J. Impact of official matches on soccer referees' horizontal-jump performance. *Sci Med Footb.* 2017;1:145–50.
2. Castillo D, Camara J, Yanci J. Análisis de las respuestas físicas y fisiológicas de árbitros y asistentes de fútbol durante partidos oficiales. *RICYDE Rev Int Ciencias del Deport.* 2016;45:250–61.
3. Castillo D, Cámara J, Lozano D, Berzosa C, Yanci J. The association between physical performance and match-play activities of field and assistants soccer referees. *Res Sport Med.* 2019;27:283–97.
4. Ozaeta E, Yanci J, Castagna C, Romaratezabala E, Castillo D. Associations between well-being state and match external and internal load in amateur referees. *Int J Environ Res Public Health.* 2021;18:1–9.
5. Barbero-Álvarez JC, Boullosa DA, Nakamura FY, Andrín G, Castagna C. Physical and physiological demands of field and assistant soccer referees during America's Cup. *J Strength Cond Res.* 2012;26:1383–8.
6. Barbero-Álvarez JC, Boullosa DA, Nakamura FY, Andrín G, Weston M. Repeated acceleration ability (RAA): A new concept with reference to top-level field and assistant soccer referees. *Asian J Sports Med*. 2014;5:63–6.
7. Ozaeta E, Fernandez U, Martinez-Aldama I, Cayero R, Castillo D. Match physical and physiological response of amateur soccer referees: a comparison between halves and match periods. *Int J Environ Res Public Health*. 2022;19:1–14.
8. Lima e Silva L, Godoy ES, Neves EB, Vale RGS, Hall Lopez JA, Moreira Nunes R de A. Frecuencia cardíaca y la distancia recorrida por los árbitros de fútbol durante los partidos: una revisión sistemática. *Arch Med del Deport.* 2019;36:36–42.
9. Castillo D, Weston M, McLaren SJ, Cámara J, Yanci J. Relationships between internal and external match-load indicators in soccer match officials. *Int J Sports Physiol Perform.* 2017;12:922–7.
10. Mallo J, Gonzalez Frutos P, Juárez D, Navarro E. Effect of positioning on the accuracy of decision making of association football top-class referees and assistant referees during competitive matches. *J Sports Sci.* 2012;30:1437–45.
11. Reilly T, Gregson W. Special populations: The referee and assistant referee. *J Sports Sci.* 2006;24:795–801.
12. Misjuk M, Hurt N, Rannam I. Soccer players training load during Estonian Premium League matches: comparison of high and low ranking teams. *J Hum Sport Exerc.* 2015;10:521–5.
13. Oliva-Lozano JM, Rojas-Valverde D, Gómez-Carmona CD, Fortes V, Pino-Ortega J. Impact of contextual variables on the representative external load profile of Spanish professional soccer match-play: A full season study. *Eur J Sport Sci.* 2020;21:497–506.
14. Stone KJ, Hughes MG, Stembridge MR, Meyers RW, Newcombe DJ, Oliver JL. The influence of playing surface on physiological and performance responses during and after soccer simulation. *Eur J Sport Sci.* 2016;16:42–9.
15. Hughes MG, Birdsey L, Meyers R, Newcombe D, Oliver JL, Smith PM, *et al.* Effects of playing surface on physiological responses and performance variables in a controlled football simulation. *J Sports Sci.* 2013;31:878–86.
16. Özgünen KT, Kurdak SS, Maughan RJ, Zeren Ç, Korkmaz S, Yazc Z, *et al.* Effect of hot environmental conditions on physical activity patterns and temperature response of football players. *Scand J Med Sci Sport.* 2010;20:140–7.
17. Konefal M, Chmura P, Andrzejewski M, Chmura J. Analysis of motor performance of professional soccer players in different environmental conditions. *Trends Sport Sci.* 2014;4:221–7.
18. Link D, Weber H. Effect of ambient temperature on pacing in soccer depends on skill level. *J Strength Cond Res*. 2017;31:1766–70.
19. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci.* 2003;21:519–28.
20. Weston M, Drust B, Gregson W. Intensities of exercise during match-play in FA Premier League referees and players. *J Sports Sci.* 2011;29:527–32.
21. Weston M, Castagna C, Impellizzeri FM, Rampinini E, Abt G. Analysis of physical match performance in English Premier League soccer referees with particular reference to first half and player work rates. *J Sci Med Sport*. 2007;10:390–7.
22. Weston M, Batterham AM, Castagna C, Portas MD, Barnes C, Harley J, *et al.* Reduction in physical match performance at the start of the second half in elite soccer. *Int J Sports Physiol Perform.* 2011;6:174–82.
23. Weston M, Castagna C, Impellizzeri FM, Rampinini E, Breivik S. Ageing and physical match performance in English Premier League soccer referees. *J Sci Med Sport*. 2010;13:96–100.
24. Di Salvo V, Carmont MR, Maffulli N. Football officials activities during matches: a comparison of activity of referees and linesmen in European, Premiership and Championship matches. *Muscles Ligaments Tendons J.* 2011;1:106–11.
25. Castillo D, Castagna C, Camara J, Iturricastillo A, Yanci J. Influence of team's rank on soccer referees' external and internal match loads during official matches. *J Strength Cond Res.* 2018;32:1715–22.
26. Taylor L, Fitch N, Castle P, Watkins S, Aldous J, Sculthorpe N, *et al.* Exposure to hot and cold environmental conditions does not affect the decision making ability of soccer referees following an intermittent sprint protocol. *Front Physiol.* 2014;5:1–9.
27. Costa EC, Vieira CMA, Moreira A, Ugrinowitsch C, Castagna C, Aoki MS. Monitoring external and internal loads of brazilian soccer referees during official matches. *J Sport Sci Med.* 2013;12:559–64.
28. D'Ottavio S, Castagna C. Analysis of match play activities in elite soccer referees during actual match play. *J Strength Cond Res*. 2001;15:167–71.
29. Lima e Silva L, Neves E, Silva J, Alonso L, Vale R, Nunes R. The haemodynamic demand and the attributes related to the displacement of the soccer referees in the moments of decision / intervention during the matches. *Int J Perform Anal Sport.* 2020;20:219–30.
30. Castillo D, Yanci J, Cámara J, Weston M. The influence of soccer match play on physiological and physical performance measures in soccer referees and assistant referees. *J Sports Sci.* 2016;34:557–63.
31. Krustrup P, Helsen W, Randers MB, Christensen JF, Macdonald C, Rebelo AN, *et al.* Activity profile and physical demands of football referees and assistant referees in international games. *J Sports Sci.* 2009;27:1167–76.
32. Krustrup P, Mohr M, Bangsbo J. Activity profile and physiological demands of top-class soccer assistant refereeing in relation to training status. *J Sports Sci.* 2002;20:861–71.
33. IFAB. Laws of the game. 2021.
34. Navalta JW, Montes J, Bodell NG, Aguilar CD, Radzak K, Manning JW, *et al.* Reliability of trail walking and running tasks using the stryd power meter. *Int J Sports Med.* 2019;40:498–502.
35. Edwards S. *The heart rate monitor book.* New York: Polar electro Oy; 1993. 170 p.
36. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol.* 2013;
37. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. N. L. E. Associates, editor. Hillsdale; 1998. 579 p.
38. Ferguson CJ. An Effect Size Primer: A guide for clinicians and researchers. *Prof Psychol Res Pract.* 2009;40:532.
39. Richardson JTE. Eta squared and partial eta squared as measures of effect size in educational research. *Educ Res Rev*. 2011;6:135–47.
40. Butler RJ, Southers C, Gorman PP, Kiesel KB, Plisky PJ. Differences in soccer players' dynamic balance across levels of competition. *J Athl Train*. 2012;47:616–20.
41. Casamichana D, Castellano J. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J Sports Sci.* 2010;28:1615–23.
42. Krustrup P, Bangsbo J. Physiological demands of top-class soccer refereeing in relation to physical capacity: Effect of intense intermittent exercise training. *J Sports Sci.* 2001;19:881–91.
43. Borg G, Hassmén P, Lagerström M. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *Eur J Appl Physiol Occup Physiol*. 1987;56:679–85.
44. Weston M, Bird S, Helsen W, Nevill AM, Castagna C. The effect of match standard and referee experience upon the objective and subjective match workload of English Premier League referees. *J Sci Med Sport*. 2006;9:256–62.

Epidemiología lesional en la liga española de hockey patines masculina y femenina: un estudio descriptivo

Bernat de Pablo[1,2,3], Guillem Trabal[4], Javier Yanguas[2], David Dominguez[5], Gil Rodas[2,5], Martí Casals[6,7]

[1]Hospital Universitari Mutua Terrassa. Terrassa. Barcelona. [2]Servicios Médicos F.C. Barcelona. Barcelona. [3]Escuela de Doctorado. Universitat de Vic – Universitat Central de Catalunya. Vic. Barcelona. [4]Facultat d'Educació, Traducció, Esports i Psicologia. Universitat de Vic. Universitat Central de Catalunya. Vic. Barcelona. [5]Unitat de Medicina de l'Esport. Hospital de Barcelona / Hospital Sant Joan de Déu. Barcelona / Hospital Clínic de Barcelona. [6]Centre d'Estudis de l'Esport i l'Activitat Física (CEEAF). Facultat de Medicina. Universitat de Vic. – Universitat Central de Catalunya. Vic. Barcelona. [7]Institut Nacional d'Educació Física de Catalunya (INEFC). Universitat de Barcelona. Barcelona.

doi: 10.18176/archmeddeporte.00112

Recibido: 26/04/2022
Aceptado: 13/09/2022

Resumen

El propósito del presente estudio es describir los patrones lesionales durante una temporada de los deportistas de la máxima competición masculina y femenina de Hockey Patines en España.
Se realizó un estudio descriptivo de las lesiones con baja deportiva (el/la deportista no puede participar como mínimo en un entrenamiento o partido debido a la lesión) recogidas por los equipos biomédicos de cada equipo. Se estudiaron 137 deportistas (98 hombres, con una media de edad de 26,7 ± 5,9 años y 39 mujeres con una media de edad de 23,3 ± 4,6 años)
Se recogieron un total de 94 lesiones con baja deportiva, siendo las más frecuentes las lesiones musculares (38 episodios, 40,4% de las lesiones totales), en especial del músculo aductor largo (23 episodios, 60,5% de las lesiones musculares). La mayoría de lesiones registradas fueron leves (1-7 días de baja deportiva) aunque el tiempo medio de baja fue de 19,4 ± 29,6 días. Se recogieron 8 episodios de relesión (8,5% de las lesiones totales) y 2 lesiones que precisaron tratamiento quirúrgico (2,1% de las lesiones totales).
Al estudiar a las deportistas femeninas destaca que presentaron un mayor número de lesiones ligamentosas de extremidades inferiores en comparaciones con los varones y no se describió ningún episodio de tendinopatía.
Al estudiar las lesiones específicas de los porteros/as se evidenció que las lesiones que causaban más baja deportiva eran las lesiones de rodilla.
El presente estudio es el primero en describir las lesiones en jugadores/as de primer nivel de hockey patines y debe marcar un punto de partida para el estudio y prevención de las lesiones en este deporte.

Palabras clave:
Lesiones. Epidemiología. Vigilancia de lesiones.

Injury epidemiology among male and female Spanish rink hockey players: a cross-sectional study

Summary

The purpose of the present study is to describe the injury patterns among male and female athletes of the Spanish Rink hockey league.
A cross-sectional study was performed, concerning the time-loss injuries (the athlete is prevented to participate in a training session / game because of the injury registered by the medical staff of every team. 137 athletes were included (98 male, age 26.7 ± 5.9 years; 39 female, age 23.3 ± 4.6 years).
Ninety-four time-loss injuries were recorded, being the most frequent the muscle injury (38 episodes, 40.4%), especially the ones affecting the adductor longus muscle (23 episodes, 60,5% of the muscle injuries). The majority of the registered injuries were classified as mild (1-7 days of time-loss) but the and the median return-to-play was 19.4 ± 29.6 days. Eight episodes of reinjury were described (8.5% of total injuries) and 2 injuries required surgical treatment (2.1% of total injuries).
Concerning female athletes, we can highlight a increased number of ligament injuries in the lower limbs compared with male athletes and the absence of tendinopathies causing time-loss.
The knee injuries were the injuries with a higher return-to-play in goalkeepers.
The present study is the first to describe the injury patterns among rink hockey elite athletes and must set a starting point to study and prevent injuries in this sport.

Key words:
Time-loss injuries. Roller hockey. Epidemiology. Injury surveillance.

Correspondencia: Bernat de Pablo Marquez
E-mail: bernatdepablo@gmail.com

Introducción

El hockey patines (HP) es un deporte con gran tradición en España, principalmente en las regiones de Cataluña, Galicia, Asturias y Madrid. La máxima división nacional (OK Liga masculina y femenina) concentra a muchos de los mejores deportistas mundiales, ya que el hockey patines español es el deporte más laureado a nivel internacional, con 17 mundiales masculinos y 7 mundiales femeninos[1].

Se trata de un deporte colectivo, dinámico y complejo donde se enfrentan dos equipos de cinco jugadores (cuatro jugadores de pista y un portero). Los jugadores se deslizan sobre patines clásicos (dos pares de ruedas paralelas) y utilizan un stick para propulsar una bola sólida y redonda con el fin de anotar gol[1]. El HP se considera un deporte de contacto debido a la fácil interacción entre los elementos dinámicos (pelota y stick) y estáticos (vallas y portería) del juego, que aumentan el riesgo de contacto entre participantes[2-4]. Existen factores que diferencian el HP de otros deportes indoor: (i) la velocidad que alcanzan los deportistas es muy alta (hasta 30 km/h) en comparación con otros deportes[2], (ii) el uso de ruedas paralelas causa diferentes mecanismos de giro y frenado, en comparación con otros deportes de patinaje como el hockey en línea o el hockey hielo[3] , (iii) la velocidad de la bola, que puede alcanzar los 115 km/h[4,5]. Se debe tener en cuenta también que la figura del portero presenta unas características diferentes al jugador de pista, ya sea por postura, movilidad y por el hecho de tener como objetivo defender una bola que se desplaza a grandes velocidades[6,7]. Considerando estos factores, se puede considerar que el HP es un deporte con un elevado riesgo de lesión musculoesquelética[8,9], lo que puede influir en el rendimiento de los deportistas y en su recuperación.

Pese que existen pocos estudios relacionados con la epidemiología lesional del hockey patines, la literatura científica disponible apunta a un elevado riesgo de lesiones, principalmente secundarias a traumatismos[8,10,11]. De todos modos, los estudios existentes hasta el momento son estudios descriptivos basados en muestras muy pequeñas y heterogéneas.

Las lesiones deportivas con baja deportiva (*time-loss injuries,* TLI) pueden influir en el rendimiento deportivo y la salud del deportista, así como en los resultados colectivos de los equipos[12]. Los programas de vigilancia de lesiones permiten analizar los patrones lesionales de un deporte, establecer la magnitud del problema, definir un primer paso para la creación de programas de prevención de lesiones y conocer nuevos problemas para conocer más en profundidad el patrón lesional de los atletas[12,13].

El objetivo del presente estudio es describir los patrones de lesión con baja deportiva (time loss injuries) en los participantes en la máxima división española (OK Liga) masculina y femenina de HP durante toda una temporada.

Material y método

Diseño del estudio

Estudio descriptivo usando un muestreo no probabilístico intencional de 14 equipos de la OK Liga masculina y femenina, máxima categoría senior española de HP (10 equipos de la primera división sénior masculina [SM] y cuatro equipos de la primera división sénior femenina [SF]). La OK Liga masculina y femenina en la temporada 2020/21 estaban constituidas por 16 equipos cada una.

Se estudiaron 137 deportistas. 98 SM (71,5% de la muestra), con una media de edad de 26,7 ± 5,9 años (rango: 18,1 – 45,2) y 39 SF (28,5%), con una media de edad de 23,3 ± 4,6 años (rango: 15,9 – 35,2). Del total de 98 SM, 78 (79,6%) eran jugadores de pista y 20 (20,4%) eran porteros y de las 39 SF, 32 (82%) eran jugadoras de pista y 7 (18%) porteras.

Para que los deportistas fueran incluidos en el estudio debían cumplir los siguientes criterios: el deportista debía jugar en el equipo senior y formar parte de la plantilla original del mismo. Los deportistas de categorías inferiores que sólo participaran ocasionalmente en los entrenamientos/partidos fueron excluidos.

Todos los deportistas dieron su consentimiento para la recolección de los datos lesionales. El estudio se diseñó de acuerdo con la Declaración de Helsinki[14] y fue aceptado por el Comité de Ética (código 014/CEICGC/2021).

Datos

El registro de los datos de los deportistas y las características lesionales fueron reportados por el equipo médico de cada equipo durante toda la temporada 2020/21, iniciándose la recogida el primer día de pretemporada y finalizándose en el último partido de la temporada. El número de partidos oficiales de la temporada osciló entre 35 y 45 en función de los resultados deportivos.

La información clínica referente al tipo de lesión, mecanismo de lesión y días de baja deportiva fueron registrados en una plantilla común previamente diseñada.

Las lesiones no relacionadas con el HP y las ausencias relacionadas con enfermedades médicas u otros motivos no fueron registradas.

Definiciones, categorías y cálculo de incidencia lesional

Las lesiones fueron clasificadas siguiendo la *Orchard Sports Injury Classification Systen* (OSICS) versión 10[15]. El tipo de lesión, localización y aparición fueron recogidos siguiendo el Consenso del Comité Olímpico Internacional[13]. Los conceptos de lesión con baja deportiva (*time-loss injury*) y regreso a la actividad deportiva (*return-to-play,* RTP) fueron recogidos basándose en las definiciones sugeridas por la *Union of European Football Associations* (UEFA)[16,17].

Las definiciones utilizadas en el estudio se muestran en la Tabla 1.

Análisis estadístico

Se llevó a cabo un análisis descriptivo de las lesiones *time-loss* calculando la frecuencia absoluta y frecuencia relativa en relación al número total de lesiones en cada categoría de interés para las variables cualitativas.

En el caso de las variables cuantitativas, se calcularon medidas resumen de tendencia central (media) y de dispersión estadística (desviación estándar y rango).

Calculamos las medidas resumen de las incidencias *time-loss* según la fórmula $i=n/e$, donde n es el número de lesiones durante el período de estudio y es el número respectivo de atletas expuestos (AE) o participantes), con proporciones de incidencia presentadas como lesiones por 100 jugadores por temporada. Además, se calculó la razón de incidencia acumulada (*Cumulative incidence ratio* (CIR)) para comparar las proporciones de incidencia lesional entre ambos sexos. Para el cálculo de incidencias y medida de asociación CIR se ha utilizado la función *pois.exact* de la librería *epitools* y la función *'epi.2by2'* de la librería epiR en R, respectivamente. En estos cálculos se estima la incidencia e intervalos de confianza al 95% mediante una distribución de Poisson. Todos los análisis se realizaron utilizando SPSS v21 y el paquete estadístico R (The R Foundation for Statistical Computing, Viena, Austria), versión 3.4.

Resultados

Lesiones totales (*time-loss injuries*)

Se registraron un total de 94 lesiones con baja deportiva (*time-loss injuries,* TLI), 61 (64,9%) en SM y 33 (35,1%) en SF.

La media de TLI por deportista y temporada fue de 0,7 ± 0,9 (0,6 ± 0,8 en SM y 0,9 ± 1 en SF). Una SF padeció 4 TLI durante la temporada, 6 deportistas sufrieron 3 TLI (4 SM y 2 SF), 14 deportistas sufrieron 2 TLI (9 SM y 5 SF), 44 deportistas sufrieron 1 TLI (31 SM y 13 SF). 51 deportistas (37,2% del total) no padecieron ninguna lesión durante la temporada 2020/21. En jugadores de pista la media de lesiones fue de 0.7 ± 0.9 y en porteros de 0,4 ± 0.7.

Se recogieron una media de 6,7 ± 3,22 (rango 3-13) TLI por equipo y temporada. La media en los equipos masculinos fue de 6,1 ± 3 (rango 3-11) y en equipos femeninos 8,2 ± 3,6 (rango 5-13).

Frecuencias relativas

Las TLI más frecuentes fueron las lesiones musculares, con 38 (40,4%) episodios. Las lesiones musculares afectaron principalmente al muslo, con 30 (31,9%) episodios de lesión muscular en esta localización, de las cuáles 23 afectaron al músculo aductor largo, 4 al recto anterior, 2 al músculo grácil y 1 al músculo semitendinoso. Se cuantificaron 11 (11,7%) lesiones tendinosas, siendo todas ellas diagnosticadas en varones (Tabla 1).

La mayoría de las lesiones afectaron a las extremidades inferiores (68,1%), seguido por la extremidad superior (15,9%), cabeza y cuello (11,7%) y tronco (6,4%). En la extremidad inferior la localización más frecuente fue el muslo, con 34 lesiones (36,2%), seguido por la rodilla con 13 (13,8%) y el tobillo con 8 (8,5%).

Se registraron un total de 53 (56,4%) TLI durante los entrenamientos y 41 (43,6%) durante los partidos. Diferenciando por género, de las 61 TLI registradas en la liga masculina 37 (60,6%) acontecieron durante entrenamientos y 24 (39,4%) durante partidos. En la liga femenina se constataron más lesiones durante partidos (n=17, 51,5%) que durante entrenamientos (n=16, 48,5%) De las lesiones sin contacto la mayoría se produjeron durante los entrenamientos (n=40, 64,5%). De las lesiones por contacto, en cambio, la mayoría se produjeron durante los partidos (n=22 68,7%) (Tabla 2).

La localización de las lesiones catalogadas por posición de juego y género se muestran en la Figura 1.

Se produjeron 8 episodios de relesión, 2 de ellos en un mismo jugador. El índice de relesión fue del 9,3% de las lesiones. Tres relesiones se dieron por episodios de osteopatía dinámica de pubis y 3 episodios por reaparición de lesiones musculares en el músculo aductor largo.

Proporción de incidencia

La Tabla 3 muestra la proporción de incidencia de las TLI descritas en el estudio.

La proporción de incidencia lesional total fue de 68,6 (IC 95% 61,2-76,8) lesiones/100 deportistas/temporada, siendo mayor en jugadoras de pista mujeres, 90,6 (IC 95% 81,1-101,3), que en jugadores de pista hombres 67,9 (IC 95% 58,3-79,1). La razón de proporciones de incidencias (CIR) entre jugadores de pista de ambos sexos de lesionarse para todo el período de estudio fue de 1,33 (IC 95%, 1,10-1,61), lo que indica que las jugadoras tenían 1,33 veces más probabilidades de lesionarse que los jugadores de pista masculino.

La incidencia de lesión muscular fue de 32,8 (IC 95% 25,2-42,5), siendo 26,4 (IC 95% 27,1-48,9) en varones y 25,6 (IC 95% 15-43,8) en mujeres.

Tabla 1. Definiciones utilizadas en el estudio.

Concepto	Definición
Time-loss injury	Cualquier dolencia física manifestada por el deportista que apareciera durante un entrenamiento o partido que obligara al deportista a ausentarse del siguiente entrenamiento o partido[16,17].
Return-to-play	Tiempo de ausencia (en días) desde el día de la lesión hasta que el deportista puede participar de nuevo en un partido o sesión de entrenamiento completa[16,17].
Re-lesión	Cualquier lesión del mismo tipo y en el mismo sitio anatómico que una lesión del mismo individuo los dos meses posteriores al RTP[17].
Incidencia lesional	Calculado acorde a la fórmula i=n/e donde n es el número de lesiones durante el período de estudio y e era el número de Atletas Expuestos (AE) con una proporción de incidencia presentada en lesiones por 100 deportistas por temporada[18].
Severidad	La severidad de las lesiones fue clasificada según el RTP en leve (1 a 7 días), moderada (8 a 28 días) o severa (>28 días) siguiendo la clasificación de Van Mechelen *et al.*[12].
Aparición	Clasificándose en Aparición aguda o progresiva[15].
Mecanismo causal	Clasificándose en sobreuso o traumatismo directo (con un rival o con un objeto del juego)[15].

Adaptado de Tuominen *et al.* 2015[19].

Figura 1. Localizaciones más frecuentes de TLI en jugadores de pista (izquierda) y porteros (derecha).

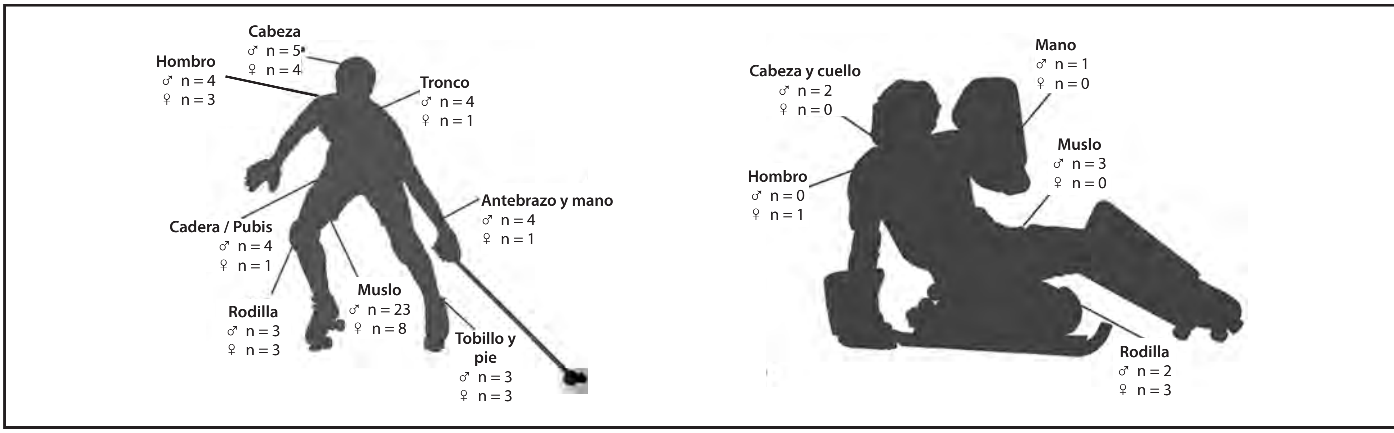


Tabla 2. Características de las lesiones.

	Total N (%)	SM N (%)	SF N (%)
Total lesiones	94	61	33
Momento			
Entrenamiento	53 (56,4%)	37 (60,6%)	16 (48,5%)
Partido	41 (43,6%)	24 (39,3%)	17 (51,5%)
Tipo de lesión			
Muscular	38 (40,4%)	28 (45,9%)	10 (30,3%)
Contusión/herida	16 (17%)	7 (11,5%)	9 (27,3%)
Ligamentosa	12 (12,8%)	5 (8,2%)	7 (21,2%)
Tendinosa	15 (15,9%)	11 (18%)	-
Fractura	7 (7,4%)	5 (8,2%)	2 (6%)
Artritis	6 (6,4%)	2 (3,3%)	4 (12,1%)
Luxación	4 (4,2%)	4 (6,5%)	-
Onset			
Sobreuso aparición aguda	28 (29,7%)	16 (26,3%)	12 (35,2%)
Sobreuso aparición progresiva	34 (36,2%)	26 (42,6%)	8 (23,5%)
Traumatismo	32 (34,1%)	19 (31,1%)	13 (38,3%)
Mecanismo			
Sin contacto	62 (66%)	43 (70,5%)	19 (57,6%)
Contacto con deportista	10 (10,6%)	5 (8,2%)	5 (15,1%)
Contacto con objeto	22 (23,4%)	13 (21,3%)	9 (27,3%)
Severidad			
Leves (1-7 días)	46 (48,9%)	25 (41%)	21 (63,6%)
Moderadas (8 a 28 días)	28 (29,8%)	20 (32,8%)	8 (24,2%)
Graves (>28 días)	20 (21,3%)	16 (26,2%)	4 (12,1%)

La incidencia de lesión tendinosa fue de 9,5 (IC 95% 5,4-16,6). De las 11 lesiones tendinosas, 7 afectaron a los músculos aductores del muslo.

La incidencia lesional en porteros fue 44,4 (IC 95% 29,1-67,7). 40 en SM (IC 95% 23,4-68,4) 57,1 en SF (IC 95% 30,1-108,5). La incidencia lesional en jugadores de pista fue 74,5 (IC 95% 66,8-83,1).

Return-to-play y severidad

El RTP de las lesiones descritas fue de 19,4 ± 29,6 (rango 1-185, moda 2), siendo de 23,5 ± 34,6 (rango 1-185, moda 2) en SM y de 11,7 ±14,3 (rango 1-60, moda 2) en SF.

Figura 2. Posiciones iniciales utilizadas por el portero. A la izquierda, rodilla en el suelo, a la derecha, en posición de media pantalla (fuente propia).

Clasificando por severidad, 46 lesiones fueron consideradas leves (1-7 días de RTP), 28 fueron consideradas moderadas (7-28 días de RTP) y 20 fueron consideradas graves (>28 días de RTP) (Tabla 2).

Las lesiones musculares presentaron un RTP promedio de 18,6 ± 25,2 (rango 1-90, moda 2), siendo 15 moderadas, 14 leves y 9 graves.

Dentro de la severidad de la lesión, diferenciamos de manera especial aquellas que requirieron de una operación quirúrgica. Estas representaron un 2,1% de las lesiones registradas (n=2), con una incidencia de 1,72 (IC 95% 4,4-68,1). Las dos lesiones quirúrgicas registradas en nuestro estudio fueron dos luxaciones glenohumerales, con un tiempo de RTP de 105 y 185 días respectivamente.

En porteros, las lesiones con un RTP más prolongado fueron las que afectaron a la rodilla, con un RTP promedio de 28,6 días ± 37,8 (rango 4-95).

Discusión

El objetivo del presente estudio es describir los patrones de lesión en los participantes en la primera división española (OK Liga) masculina y femenina de HP durante toda una temporada.

En primer lugar, debemos destacar que existen estudios previos sobre epidemiología lesional en deportistas masculinos de HP, pero no existe ningún estudio previo con deportistas femeninas. Así, los

Tabla 3. Proporciones de incidencia de las TLI según las características de la lesión y las características del/la deportista.

		Total	Senior masculino				Senior femenino			
			Jugadores de pista		Porteros		Jugadoras de pista		Porteras	
		N	N	Incidencia (95% IC)	N	Incidencia (95% IC)	N	Incidencia (95% IC)	N	Incidencia (95% IC)
Lesiones totales		94	53	67,9 (58,3-79,1)	8	40 (23,4-68,4)	29	90,6 (81,1-101,3)	4	57,1 (30,1-108,5)
Momento	Entrenamiento	54	36	46,1 (36,3-58,7)	3	15 (5,2-42,6)	12	37,5 (23,9-58,6)	3	42,8 (18,2-100,8)
	Partido	40	18	23,1 (15,4-34,6)	5	25 (11,7-53,4)	16	50 (35,4-70,7)	1	14,2 (2,3-87,6)
Aparición	Sobreuso agudo	29	14	17,9 (11,2-28,8)	3	15 (5,3-42,6)	10	31,2 (18,7-52,2)	2	28,6 (8,8-92,2)
	Sobreuso progresivo	34	25	32 (23,2-44,3)	1	5 (0,7-33,8)	7	21,8 (11,4-42,1)	1	14,3 (2,3-87,6)
	Trauma	31	13	16,7 (10,1-27,4)	4	2 (0,8-48)	12	37,5 (23,9-58,6)	2	28,6 (8,8-92,2)
Mecanismo	Sin contacto	62	40	51,2 (41,3-63,7)	3	15 (5,3-42,6)	16	50 (35,3-70,7)	3	42,8 (18,2-100)
	Contacto con atleta	14	6	7,7 (3,5-16,7)	0	-	8	25 (13,7-45,6)	0	-
	Contacto con objeto	18	8	10,2 (5,3-19,7)	4	20 (8,3-48)	5	15,6 (7-34,9)	1	14,3 (2,3-87,7)
Severidad	Leve	47	21	26,9 (18,7-38,8)	4	20 (8,3-48)	19	59,4 (44,6-79,1)	3	42,8 (12,82-100,8)
	Moderado	28	19	24,3 (16,5-36)	1	5 (0,7-33,8)	7	21,9 (11,4-42,1)	1	14,2 (2,3-87,6)
	Severo	20	13	16,7 (10,1-27,3)	3	15 (5,3-42,6)	4	12,5 (4,9-31,3)	0	-
Tipo de lesión	Muscular	38	25	32 (23,2-44,3)	2	10 (2,7-37,2)	10	31-2 (18,7-52,2)	0	-
	Aductor longus	23	17	21,8 (14,3-33,2)	0	-	5	15,6 (7-34,9)	0	-
	Rectus femoris	4	1	1,2 (0,1-8,9)	0	-	3	9,8 (3,2-27,5)	0	-
	Contusión / herida	16	3	3,8 (1,3-11,6)	3	15 (5,2-42,6)	9	28,1 (16,1-48,9)	1	14,3 (2,3-87,7)
	Esguince	13	3	3,8 (1,3-11,6)	2	10 (2,7-37,2)	6	18,7 (9,1-38,5)	2	28,6 (8,8-92,2)
	Tendinopatía	11	11	14,1 (8,1-24,4)	0	-	0	-	0	-
	Fractura	6	4	5,1 (1,9-13,3)	1	5 (0,7-33,8)	1	3,1 (0,5-21,5)	0	-
	Artritis	5	2	2,6 (0,6-10)	0	-	2	6,2 (1,6-23,9)	1	14,3 (2,3-87,7)
	Luxación	5	4	5,1 (1,9-13,3)	0	-	1	3,1 (0,5-21,5)	0	-

resultados obtenidos en deportistas masculinos serán comparados con los resultados publicados hasta el momento y los resultados obtenidos en deportistas femeninas serán utilizados para definir un punto de partida para el estudio de lesiones en dicha población de deportistas. En segundo lugar, en ninguno de los estudios publicados previamente sobre lesiones en HP se incluían deportistas de diferentes equipos de la misma liga, permitiendo ampliar la muestra y evitar sesgos.

En cuanto al número de TLI por temporada, los dos únicos estudios publicados hasta el momento en el ámbito de la primera división española (en equipos masculinos) mostraron una media superior de lesiones por jugador y temporada (dos TLI por jugador y temporada en el estudio de Reverter[8] y 1,1 TLI por jugador y temporada en el estudio de Egocheaga[10].

Los dos equipos que se proclamaron campeones de liga fueron los que sufrieron más lesiones (11 en la liga masculina y 13 en la liga femenina), ello se podría explicar por el mayor número de partidos, al ser los dos equipos que llegaron a las finales fueron los que más partidos oficiales disputaron. Aún así, al no disponer de los datos de horas de entrenamientos no se puede determinar una causalidad con la mayor exposición.

Respecto a la localización anatómica más frecuente, los resultados obtenidos confirman la tendencia de estudios previos, donde la extremidad inferior era la zona más frecuentemente afectada, seguida de la extremidad superior y la cabeza y cuello[8,10].

La lesión muscular fue la más frecuentemente descrita en el estudio, concordando con dos publicaciones previas en deportistas españoles[8,10]. En ninguno de dichos estudios se definieron los músculos afectos ni la severidad de las lesiones. Los resultados presentados permiten concluir que el músculo más afectado en los jugadores de HP es el aductor largo, con 23 de las 38 lesiones musculares descritas y una incidencia de 19,8 (IC 95% 13,7-28-6). Se describieron también 11 lesiones tendinosas, para una incidencia de 9,5 (IC 95% 5,4-16,6) y los músculos más frecuentemente afectados fueron los aductores del muslo. En el estudio de Florit[26] donde se estudió la incidencia de tendinopatía en un equipo profesional de HP durante 8 temporadas la incidencia de tendinopatías que acarrearan time-loss fue de 10,7 (IC 95% 9,5-12), por lo que los resultados fueron similares. En dicho estudio la zona más frecuentemente afectada fue también la zona aductora del muslo.

Con los resultados obtenidos podemos concluir que la región del pubis es la más susceptible a lesiones musculares y tendinosas en HP.

Dichos resultados concuerdan con estudios publicados en hockey hielo, deporte de patinaje extensamente estudiado, donde dicha zona concentra la mayoría de las lesiones por sobreuso[19].

Mecanismo

La mayoría de las lesiones registradas se han producido sin contacto, dichos resultados coinciden con el estudio de Reverter[8], realizado en un solo equipo de OK Lliga, con una proporción similar. Estudios publicados en deportes biomecanicamente similares, como el hockey línea[20] o el hockey hielo[19] constataron que la mayoría de lesiones descritas se daban por contacto directo. La normativa del HP, que castiga de forma severa el contacto en comparación las otras disciplinas del patinaje, puede favorecer dichas diferencias.

Al analizar el mecanismo causal de las lesiones constatamos que las lesiones sin contacto se produjeron en mayor medida en entrenamientos, mientras que en competición ocurrió lo contrario, siendo más frecuentes las lesiones por contacto. Ello se explica por la propia naturaleza de la actividad, teniendo la competición un mayor contacto y exigencia que el entrenamiento. Dicha tendencia se ha visto en otros deportes como el fútbol[21] pero no se había estudiado previamente en HP y permite llegar a la conclusión que no se entrena como se juega.

Lesiones craneales

En el mundo del HP ha crecido en los últimos años la preocupación por las lesiones craneales y las consecuencias que ellas puedan tener en los deportistas. Dicha preocupación ha llevado a algunas federaciones nacionales a promover el uso de casco protector en categorías inferiores[22]. Estudios previos[9,23] han demostrado que las lesiones craneofaciales son frecuentes en el HP, aunque no especificaron si se realizaban estudios entre los deportistas de primer nivel. En el estudio de Reverter[8] se registraron dos episodios de conmoción cerebral y 14 contusiones y heridas en región craneofacial durante dos temporadas en 23 deportistas, con una incidencia de 39,1 (IC 95% 31,5-48,5).

Los resultados obtenidos detectaron nueve TLI que afectaran la cabeza, con una incidencia de 7,7 (IC 4,1-14,5), menor que en el estudio de Reverter, con un solo episodio de conmoción cerebral. Las diferencias con el estudio de Pelaez[9] que incluía deportistas amateurs y de categorías inferiores y presentaba una elevada tasa de conmoción cerebral se podría explicar con la mayor habilidad del deportista profesional tanto a nivel de patinaje como a nivel del manejo de la bola y el stick: en otros deportes como el patinaje en línea se ha demostrado que una mayor inexperiencia en el patinaje aumenta el riesgo de lesiones[20, 25].

Pese que la concienciación sobre las lesiones craneales está creciendo mucho en el mundo del deporte, existe un riesgo de infradiagnóstico, tanto por parte de los deportistas como de los equipos médicos[24]. Es importante que las federaciones faciliten información a los atletas, cuerpos técnicos, equipos médicos e incluso familias, con el fin de mantener una actitud vigilante sobre los traumatismos craneales y las potenciales consecuencias de los mismos a largo plazo[25].

Lesiones en deportistas femeninas

Las tendencias mencionadas anteriormente, como la localización más frecuente y el mecanismo causal, se asemejan a los deportistas masculinos. Pese a ello, las jugadoras de pista presentaron 1,33 veces más riesgo de lesionarse que los jugadores de pista.

De los resultados obtenidos, cabe destacar que en las deportistas femeninas se evidenciaron más lesiones en partidos que en entrenamientos. Dicho resultado puede ser debido a que, pese que los equipos femeninos compiten a máximo nivel, no son profesionales y el volumen de entrenamiento no es el mismo que en equipos profesionales masculinos. Dicha afirmación se debería ver confirmada con un estudio de las horas de exposición tanto a entrenamiento como a partidos de equipos masculinos y femeninos.

Cabe destacar también que se han registrado una proporción más elevada de lesiones ligamentosas en extremidades inferiores, principalmente de rodilla y tobillo, en comparación con el sexo masculino.

Por ultimo, no se han evidenciado tendinopatías por sobreuso. Dicho hallazgo no se ha visto en otros deportes de patinaje y debería ser estudiado con más profundidad.

Lesiones en porteros/as

La posición de portero/a en HP, además de ser clave para el desarrollo del deporte[26], tiene una serie de particularidades que obligan a estudiarla de forma diferencial respecto a los jugadores de campo. La posición que adoptan los porteros, alternando una posición recostada en el suelo con una posición de rodilla al suelo (Figura 2) provoca un mayor stress sobre la zona de las rodillas siendo más frecuentes las lesiones en dicha localización en comparación con los jugadores de campo.

Dado que los porteros utilizan protecciones, las lesiones por contusión directa han sido menos frecuentes que en jugadores de pista. Ello rompe el estereotipo expuesto por Trabal[6] que el rol de portero es más peligroso que la del jugador de campo.

Así pues, se deberían crear estrategias de prevención para evitar lesiones de rodilla en los porteros de HP. Igualmente, se deberían buscar herramientas de mejora para la protección de la región cervical en estos deportistas.

Limitaciones

El estudio se realizó durante la temporada 2020/21, marcada por la pandemia mundial de COVID-19. Los casos COVID-19 y los confinamientos preventivos presentados durante la temporada pudieron interrumpir los entrenamientos y partidos de los equipos, con una potencial afectación de su rendimiento

Se desconoce hasta el momento los efectos que pueda tener la infección por SARS-COV2 en el rendimiento de los deportistas. No se correlacionaron los resultados obtenidos con la infección por SARS-COV2.

La variabilidad en la configuración de los equipos médicos de cada club pudo hacer variar los procesos diagnósticos y terapéuticos de las lesiones.

No se dispone de las horas de exposición en entrenamientos y partidos por lo que no se permite un cálculo óptimo de la incidencia lesional (tasa de incidencia lesional). Aunque el objetivo de nuestro estudio es solamente descriptivo (no comparativo) además de contener poca muestra, en este trabajo se ha evaluado una medida de asociación CIR para calcular la razón de proporción de incidencias entre jugadores y jugadoras de pista. El riesgo de lesionarse entre las jugadoras vs jugadores parece ser relevante. Aun así, en futuros estudios sería recomendable poder disponer de información de tasas de incidencia con horas de exposición y así poder calcular tanto medidas de frecuencia como de asociación para ser más rigurosos con estos hallazgos.

Aplicaciones prácticas

En equipos de la máxima división de hockey patines en España la lesión muscular es la más frecuente, destacando las lesiones del músculo aductor largo. Dichas lesiones tienen incidencia sobre la disponibilidad para entrenar/jugar de los deportistas, por lo que sería adecuado diseñar protocolos de prevención para este tipo de lesiones.

Las lesiones traumáticas son especialmente frecuentes en el deporte, debido a su propia naturaleza. Las lesiones traumáticas en la cabeza son un motivo de preocupación y es importante realizar una monitorización de las estrategias de prevención (casco de protección) pendientes de implantación por parte de los estamentos reguladores del hockey patines.

Por primera vez se definen las lesiones más frecuentes en las jugadoras de hockey patines. Los resultados deben ser un punto de partida para ampliar los estudios en esta población de deportistas.

Agradecimientos

A Marc Bosqué, Marc Godayol, Vicenç Rizo, Jordi Boada, Pedro Abal, Aleix Rovira, Roger Sotelino, Marc Pi, Adrià Gimenez, Pol Parareda, Ramón Fernández por su ayuda en la recolección de datos.

Conflicto de interés

Los autores no declaran conflicto de interés alguno.

Bibliografía

1. Moreno D. *Anàlisi dels gols en hoquei patins a les lligues espanyola, italiana i portuguesa*. Tesis doctoral. Universitat de Barcelona, Barcelona, 2019.
2. Fernández D, Varo F, Carmona G, Reche X. Quantification of external load of elite rink hockey players in official matches. *J Sports Med Phys Fitness.* 2020;60:1520-5.
3. Vitale JA, Castellini G, Gianola S, Stucovitz E, Banfi G. Analysis of the christiania stop in professional roller hockey players with and without previous groin pain: a prospective case series study. *Sport Sci Health.* 2019;15:641–6.
4. Vaz M, Ramos N, Abrantes J, Queiros de Melo F, Conceiçao F. Biomechanics of the penalty stroke in roller hockey. *Rev Port Cienc Desporto.* 2011;2:129–32.
5. Ballestero E. *El hockey sobre Patines: Variables del rendimiento en el disparo a portería*. Tesis doctoral. Universitat de Lleida, Lleida. 2017.
6. Trabal Tañá G. Estudi etnogràfic del porter d'hoquei sobre patins: una vida entre paradoxes. *Apunts Sport Med*. 2016;126:23–9.
7. Trabal G, Riera J. Goalkeeper effectiveness in the direct free hit of rink Hockey. *Apunts Sport Med.* 2020;139:56–64.
8. Reverter J, de Vega M, Hernandez V. Occupational injury in spanish professional roller hockey during two seasons: a comparative study. *J Phys Educ Sport.* 2018;18:1767–72.
9. Pelaez EG, Dascenzi PF, Savastano LE, Cremaschi FE. Lesiones craneofaciales producidas en hockey sobre patines. *Rev Arget Neurocir.* 2008;22:181–5.
10. Egocheaga J, Yague P, Mones L. Características de la patología lesiva en dos deportes de patinaje. *Med Rehab.* 2004;17:12–6.
11. Husen M, Burgsmüller L, Burggraf M, Jäger M, Dudda M, Kauther M. Injuries and overuse syndromes in rink hockey players. *Int J Sports Med.* 2021;42:132-7.
12. Van Mechelen W, Hlobil H, Kemper HCG. Incidence, severity, aetiology and prevention of sports injuries. *Sports Med.* 1992;14:82-99.
13. Bahr R, Clarsen B, Derman W, Dvorak J, Emery CA, Finch CF, *et al.* International olympic committee consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (Including the STROBE extension for sports injury and illness surveillance (STROBE-SIIS)). *Orthop J Sports Med.* 2020;8:2325967120902908.
14. World medical association declaration of Helsinki. *JAMA*. 2013;310:2191-4.
15. Orchard J. Revision, uptake and coding issues related to the open access Orchard Sports Injury Classification System (OSICS) versions 8, 9 and 10.1. *Open Access J Sports Med.* 2010;1:207-14.
16. Hagglund M. Methods for epidemiological study of injuries to professional football players: developing the UEFA model. *Br J Sports Med*. 2005;39:340-6.
17. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med.* 2011;45:553-8.
18. Florit D, Pedret D, Casals M, Malliaras P, Sugimoto D, Rodas G. Incidence of tendinopathy in team sports in a multidisciplinary sports club over 8 seasons. *J Sports Sci Med.* 2019;18:780–8.
19. Tuominen M, Stuart MJ, Aubry M, Kannus P, Parkkari J. Injuries in men's international ice hockey: a 7-year study of the international ice hockey federation adult world championship tournaments and olympic winter games. *Br J Sports Med*. 2015;49:30-6.
20. Moreno-Alcaraz VJ, Cejudo A, Sainz de Baranda P. Injury types and frequency in spanish inline hockey players. *Phys Ther Sport.* 2020;42:91-9.
21. Noya J, Sillero M. Epidemiología de las lesiones en el fútbol profesional español en la temporada 2008-2009. *Arch Med Deporte.* 2012;29:750–66.
22. Real Federación Española de Patinaje. www.fep.es. Consultado 1 de febrero 2022.
23. Lopes L, Santos M. Mouthguard and orofacial traumatismo in young roller hockey practicers. *Global J Med Res.* 2013;19:5-11.
24. Meehan WP, Mannix RC, O'Brien MJ, Collins MW. The prevalence of undiagnosed concussions in athletes. *Clin J Sport Med.* 2013;23:339–42.
25. Schmidt JD, Welch D, ML Weber, Bierema L, Miller LS, Courson R, *et al.* Coach, sports medicine, and parent influence on concussion care seeking intentions and behaviors in collegiate student-athletes. *J Clin Transl Res*. 2020;5:215–26.
26. Trabal G, Daza G, Arboix J. Influencia de las variables contextuales en la intervención del portero de hockey patines en la falta directa. *Cuad Psicol Deporte.* 2020;20:139–51.

POSTGRADOS OFICIALES:

SALUD Y DEPORTE

UCAM UNIVERSIDAD CATÓLICA DE MURCIA

Miguel Ángel López
Campeón del Mundo en 20 km. marcha (Pekín, 2015)
Estudiante y deportista de la UCAM

- **Actividad Física Terapéutica** (2)
- **Alto Rendimiento Deportivo: Fuerza y Acondicionamiento Físico** (2)
- **Performance Sport: Strength and Conditioning** (1)
- **Audiología** (2)
- **Balneoterapia e Hidroterapia** (1)
- **Desarrollos Avanzados de Oncología Personalizada Multidisciplinar** (1)
- **Enfermería de Salud Laboral** (2)
- **Enfermería de Urgencias, Emergencias y Cuidados Especiales** (1)
- **Fisioterapia en el Deporte** (1)
- **Geriatría y Gerontología: Atención a la dependencia** (2)
- **Gestión y Planificación de Servicios Sanitarios** (2)
- **Gestión Integral del Riesgo Cardiovascular** (2)
- **Ingeniería Biomédica** (1)
- **Investigación en Ciencias Sociosanitarias** (2)
- **Investigación en Educación Física y Salud** (2)
- **Neuro-Rehabilitación** (1)
- **Nutrición Clínica** (1)
- **Nutrición y Seguridad Alimentaria** (2)
- **Nutrición en la Actividad Física y Deporte** (1)
- **Osteopatía y Terapia Manual** (2)
- **Patología Molecular Humana** (2)
- **Psicología General Sanitaria** (1)

(1) *Presencial* (2) *Semipresencial*

MÁS INFORMACIÓN: **968 27 88 01** · **ucam.edu**

Effects of physical exercise on aerobic capacity and quality of life in patients diagnosed with asthma: A systematic review and meta-analysis

Daniel Gallardo Gómez, Francisco Álvarez Barbosa

Departamento de Educación Física y Deporte. Universidad de Sevilla. Sevilla. Departamento de Actividad Física y Deporte. Epidemiology of Physical Activity and Fitness Across the Lifespan Research Group EPAFit.

doi: 10.18176/archmeddeporte.00113

Recibido: 14/07/2021
Aceptado: 08/09/2021

Summary

Introduction: Nowadays, asthma is a disabling disease with no cure, and the development of effective non-pharmacological treatments which can alleviate side effects of drugs and pathological symptoms is urgent. Some studies have shown that physical exercise may have beneficial effects in patients with asthma, but results were controversial and inconsistent. More evidence is needed to ensure exercise as possible effective treatment in people with asthma.
Objectives: To examine the effects of physical exercise on aerobic capacity and quality of life in patients with asthma. Also, we analyze the possible moderation effects of the selected covariates. As a final aim, we verified if a correlation exists between benefits on aerobic capacity and those obtained on quality of life.
Material and method: We followed the PRISMA statement to search for randomized controlled trials that used physical exercise as intervention to improve aerobic capacity or quality of life in patients diagnosed with asthma. After data extraction, we conducted a random-effects meta-analysis model with moderation analysis. Then, we inspected the correlation between both outcomes through a multivariate approach. Finally, we performed some additional analyses: methodological quality analysis through the PEDro scale, publication bias analysis through funnel asymmetry tests and funnel plot visualization, and sensitivity analyses by outliers and influential cases detection.
Results: Physical exercise had positive effects on aerobic capacity and quality of life. None of the covariates showed a significant moderation effect. We found a positive correlation between the effects of exercise on aerobic capacity and those caused on their quality of life.
Conclusions: Our meta-analysis reports information that supports the use of physical exercise as part of the management and treatment of asthma. However, more specific studies are needed to find optimal type and dose of physical activity for those patients.

Key words:
Physical exercise. Aerobic capacity. Quality of life. Asthma. Meta-analysis.

Efectos del ejercicio físico en la capacidad aeróbica y la calidad de vida en pacientes diagnosticados con asma: revisión sistemática y meta-análisis

Resumen

Introducción: Actualmente, el asma es una enfermedad incapacitante sin cura, y urge el desarrollo de tratamientos no farmacológicos eficaces que puedan aliviar los efectos secundarios de los fármacos y los síntomas patológicos. Algunos estudios han demostrado que el ejercicio físico puede tener efectos beneficiosos en pacientes con asma, pero los resultados fueron controvertidos e inconsistentes. Se necesita más evidencia para garantizar que el ejercicio sea un posible tratamiento eficaz en personas con asma.
Objetivos: Examinar los efectos del ejercicio físico sobre la capacidad aeróbica y la calidad de vida en pacientes con asma. Además, analizamos los posibles efectos de moderación de las covariables seleccionadas. Como objetivo final, verificamos si existe una correlación entre los beneficios en la capacidad aeróbica y los obtenidos sobre la calidad de vida.
Material y método: Seguimos la declaración PRISMA para buscar ensayos controlados aleatorios que utilizaran el ejercicio físico como intervención para mejorar la capacidad aeróbica o la calidad de vida en pacientes con diagnóstico de asma. Después de la extracción de datos, realizamos un modelo de meta-análisis de efectos aleatorios con análisis de moderación. Luego, inspeccionamos la correlación entre ambos resultados a través de un enfoque multivariado. Finalmente, realizamos algunos análisis adicionales: análisis de calidad metodológica a través de la escala PEDro, análisis de sesgos de publicación a través de pruebas de asimetría de embudo y visualización de gráficos de embudo, y análisis de sensibilidad mediante la detección de 'outliers' y de casos influyentes.
Resultados: El ejercicio físico tuvo efectos beneficiosos en la capacidad aeróbica y en la calidad de vida. Ninguna de las covariables presentó un efecto moderador significativo. Encontramos una correlación positiva entre los efectos del ejercicio sobre la capacidad aeróbica y los provocados en la calidad de vida.
Conclusiones: Nuestro meta-análisis presenta información que respalda el uso del ejercicio físico como parte del manejo y tratamiento del asma. Sin embargo, se necesitan estudios más específicos para encontrar qué tipo y qué dosis de actividad física son los óptimos para estos pacientes.

Palabras clave:
Ejercicio físico. Capacidad aeróbica. Calidad de vida. Asma. Meta-análisis.

Premio SEMED a la Investigación 2021

Correspondencia: Daniel Gallardo-Gómez
E-mail: dggomez@us.es

Introduction

Asthma is a major non-communicable disease whose symptoms (i.e., any combination of cough, wheeze, shortness of breath and chest tightness) affect an estimated 300 million people[1], causing approximately 500,000 deaths[1]. Also, asthma is the most common chronic disease among children[1], which increases a) the global impact of this disease on vital outcomes (e.g., aerobic capacity, quality of life, or activities of daily-living)[2] and b) the urgency to discover new possible treatments and refine those that currently exist[3].

Although there is no definitive treatment for asthma[3], existing evidence shows that the most effective pharmacological treatments against the symptoms of the disease seem to be strategies with combined inhaled corticosteroids and long-acting β agonists[4]. Nonetheless, drug treatment has associated side effects such as weight gain or stress[5], which is detrimental to the quality of life of these patients. Scientific literature shows that physical exercise could be an effective non-pharmacological intervention to reduce these side effects and cope the symptoms of the disease[6], such as the inflammation of the small airways[7]. Several meta-analyses[6,8–10] showed a possible preventive effect of exercise on asthma development[6], and positive effects on asthma control[8,9], aerobic capacity[10], lung function[9], and quality of life[10].

However, the current evidence is scarce, low-quality, and imprecise[11]. A point we must consider is that most of the meta-analyses that have inspected the effects of exercise in asthmatic patients only focused on aerobic exercises (e.g., swimming, walking, leisure biking and hiking)[6,9], being a knowledge gap the potential effects on quality of life and asthma control of other types of physical exercise such as multicomponent or strength. We also found discrepancy on the results (e.g., positive effects[10] vs. null[12] on quality of life), which combined with some methodological concerns (e.g., unexplained high levels of heterogeneity, differences in the age groups studied, or a clear definition of the analyzed variable), makes the information about physical exercise effects on asthmatic patients inconsistent[11]. Everything points that this lack of robustness may hamper the application of physical exercise as an effective non-pharmacological treatment to manage asthma symptoms. Therefore, we analyzed the effects of physical exercise on aerobic capacity (i.e., the maximum oxygen consumption during physical activity) and quality of life, both clinically important outcomes in patients suffering from asthma. We also examined the possible interactions between covariates selected for their evidence in the literature[6] and the effects on the study outcomes. Finally, we inspected the correlation between aerobic capacity and quality of life to detect potential associations between the effects caused in this target population.

Material and method

This systematic review with meta-analysis was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[13].

Search strategy

Guided by the PICOS framework, we performed a systematic search in the databases PubMed (MEDLINE), Scopus, Web of Science and SportDiscus from inception to April 2021. The search strategy was based on combining all terms related to the same cluster (e.g., participants or interventions) with OR and finally to combine all clusters with AND. Terms related to the search were "asthma patients", "exercise", "physical therapy", "aerobic capacity", "quality of life" and "randomized controlled trial".

Study selection

We searched for and included: (1) Randomized controlled trials in which (2) aerobic capacity or quality of life were studied in (3) patients who were five years old or older diagnosed with asthma[14] (4) that received an intervention based on aerobic or multicomponent physical exercises as the main element of the intervention (5) compared with non-exercise treatments or another exercise intervention.

As an exclusion criterion, we determined that interventions that consisted in physical exercise plus another healthy lifestyle intervention (e.g., diet) and patients diagnosed with an obstructive pulmonary disease other than asthma were excluded.

Data extraction

All data corresponding to trial patients' characteristics (e.g., sample size, age, sex), descriptive statistics (i.e., pre- and post-sample size, means, standard deviations of experimental and control groups) and outcome description were extracted into a self-made data extraction spreadsheet in Excel. If information was missing, the corresponding author was requested to supply the information or data for inclusion in the analyses.

Data synthesis

As we anticipated considerable between-study heterogeneity, a random-effects meta-analysis model was used to pool effect sizes, which were calculated as standardized mean differences (SMD; Hedges' g[15]). The restricted maximum likelihood estimator[16] was used to calculate the heterogeneity variance tau^2. We used Knapp-Hartung adjustments[17] to calculate the confidence interval (CI) around the pooled effect. We also estimated the prediction intervals (PI) as accurate measures. Then, we conducted a moderation analysis to find possible interaction effects between the pooled effects and the selected covariates (i.e., age, type of exercise, and duration of the intervention) identified by existing evidence[6]. Lastly, assuming a moderate correlation coefficient of 0.41[18], we estimated the correlation between pooled effects using a multivariate approach to find potential associations between aerobic capacity and quality of life in these patients.

All analyses were performed in R statistical software (version 4.0.3)[19]. We used the 'esc' package[20] to calculate the effect sizes (Hedges' g), the *'dmetar'* package[21] contains utility functions to facilitate the conduction of a random-effects meta-analysis model, and the 'meta' package[22] to evaluate biases in meta-analysis (i.e., outliers detection, influential cases analysis, and publication bias).

Additional analyses

Methodological quality

The score extracted from the Physiotherapy Evidence Database was used to evaluate the methodological quality of each trial and avoid the risk of bias[23]. When the score of an article was not shown in the PEDro website, reviewers agreed on a rating of this study following the criteria stipulated by the PEDro scale. Total PEDro scores of 0–3 are considered 'poor', 4–5 'fair', 6–8 'good', and 9-10 'excellent'. However, for trials evaluating complex interventions (e.g., exercise) a total PEDro score of 8/10 is optimal[24].

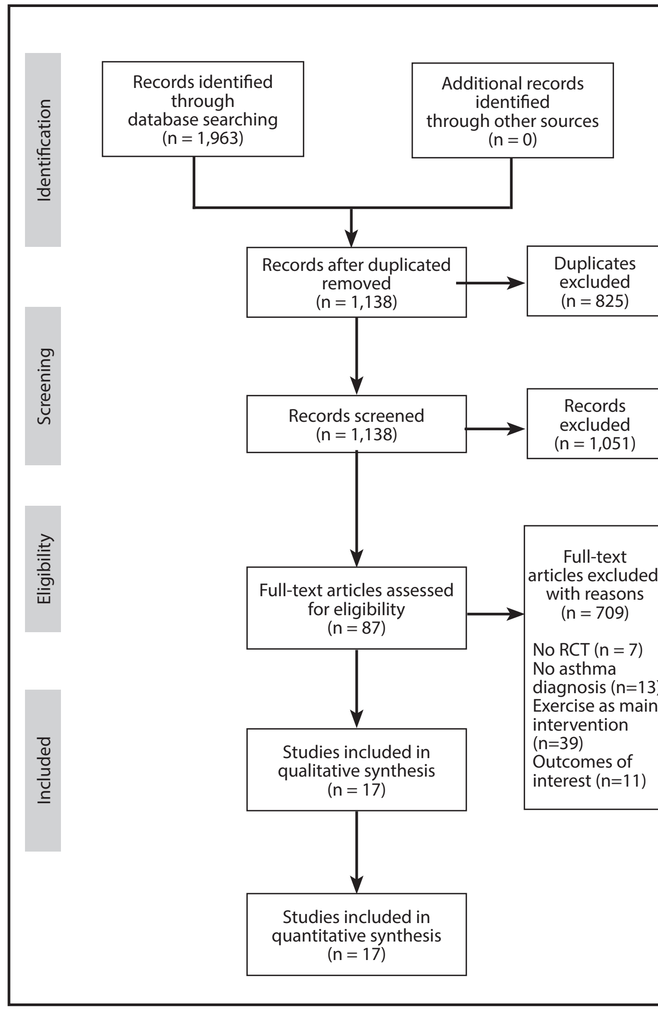
Publication bias

We used the visualization of the standard errors corresponding to each study and its effect size through a funnel plot per outcome. To quantify this possible asymmetry, we used the significance of the Eggers' test[25]. To support these results, we conducted the same analysis under Pustejovsky-Rodges approach[26], an option to conduct Eggers' test with the corrected standard error formula recommended for studies that used SMD as effect size[26].

Sensitivity analyses

To analyze the between-study heterogeneity, we inspected the studies with an extreme effect size (i.e., outliers) and those which heavily pushed the pooled effect of our analysis into one direction (i.e., influential cases). Furthermore, to support the influential cases analysis, we conducted a leave-one-out meta-analysis model[27], which reported the individual contribution to the pooled effect of a specific outcome and to heterogeneity levels (i.e., I^2). After removing the studies detected as outliers or influential cases, we conducted new meta-analytical models and plotted their corresponding forest plots to visualize models' comparison.

Figure 1. PRISMA flowchart of study selection.



Results

Included studies

We identified 1,963 registers through the initial searches. After screening citations by title and abstract, we considered 87 possible eligible studies for inclusion. After removing duplicates and applying the selection criteria, 17 studies[8,28-43] (1,329 patients; 29 effect sizes) were selected for inclusion in this meta-analysis (Figure 1).

The year of publication ranged from 2001 to 2020. A total of 627 (47.18%) of patients were women. The average age was 25.58±18.34 years old (range of 10 - 68.2). The average body mass index (BMI) was 23.11±3.54. The interventions had an average duration of 10.64±3.92 weeks. The interventions used in the included studies were aerobic exercises (n = 16) and multicomponent exercises (n = 13). All studies' characteristics referring to the intervention and control groups details, evaluation tools and main results are presented in Table 1.

Meta-analysis

Our results showed that exercise had positive effects on aerobic capacity in patients diagnosed with asthma (k = 15; Hedges' g = 0.73; 95% CI [0.16, 1.28]; p = 0.01). Also, significant effects were found for exercise on the quality of life of these patients (k = 14; Hedges' g = 0.69; 95% CI [0.26, 1.11]; p < 0.01). Forest plots are illustrated in Figure 2. None of the analyzed covariates showed a significant moderation effect.

For aerobic capacity, the between-study heterogeneity variance was estimated at $tau^2 = 0.78$ (95% CI: 0.37 - 2.43), with an I^2 value of 84% (95% CI: 75 - 90%). For quality of life, the between-study heterogeneity variance was estimated at $tau^2 = 0.28$ (95% CI: 0.11 - 1.51), with an I^2 value of 69% (95% CI: 45 - 82%). The prediction intervals ranged from g = –1.25 to 2.71 in aerobic capacity, and from g = –0.56 to 1.93 in quality of life, indicating that negative intervention effects cannot be ruled out for future studies.

Correlation between aerobic capacity and quality of life

We found a positive moderate correlation (r = 0.59) between aerobic capacity and quality of life, indicating that positive effects on aerobic capacity may cause positive effects on quality of life. The pooled effects and the association between outcomes are illustrated in Figure 3.

Table 1. Characteristics of the included studies.

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Abdelbasset, 2018	38 (23 females)	10	21.8	10 weeks 3 sessions/ week 40 min/session	Intensity: 50-70% HR_{max} Type: Walking	Conventional treatment	VO_{2max} 6-MWT PAQLQ	10 weeks of physical exercise had beneficial effects on pulmonary functions, aerobic capacity, and quality of life in children with asthma
Andrade, 2014	33 (12 females)	10	19.8	6 weeks 3 sessions/ week ~40 min/ session	Intensity: 70-80% HR_{max} Type: Treadmill	Usual care	6-MWT PAQLQ	An improvement was found in functional capacity, maximal respiratory pressure, quality of life and asthma-related symptoms
Basaran, 2006	62 (22 females)	10.4	18.3	8 weeks 3 sessions/ week 60 min/session	Intensity: NA Type: Calisthenics + submaximal basketball training	Home respiratory exercises	6-MWT PAQLQ	8-weeks of regular submaximal exercise has benefitial effects on quality of life and exercise capacity in asthmatic children
Coelho, 2018	37 (32 females)	46	28.6	12 weeks 5 sessions/ week 30 min/session	Intensity: moderate Type: Walking	Usual care	6-MWT AQLQ	Participants of the intervention group increased their exercise capacity and their daily steps
Dogra, 2011	36 (22 females)	34.1	24.7	24 weeks 3-5 sessions/ week NA min/ session	Intensity: 70-85% HR_{max} Type: outdoor jogging, treadmill, recumbent, or upright cycling, and ellitical or rowing machines	Usual care	VO_{2max} Mini-AQLQ	A structured exercise intervention can improve asthma control
Fanelli, 2007	38 (NA females)	10.5	18.1	16 weeks 2 sessions/ week 90 min/session	Intensity: 70% RM Type: Cycling and/ or treadmill and endurance exercises	Educational program	VO_{2max} PAQLQ	Supervised exercise training might be associated with benefitial effects on disease control and quality of life in children
França-Pinto, 2015	43 (34 females)	42	26.4	12 weeks 2 sessions/ week 30 min/session	Intensity: Vigorous (anaerobic threshold) Type: Yoga breathing exercises + treadmill	Yoga breathing exercises + sham intervention	VO_{2max} AQLQ	Adding exercise as an adjunct therapy to pharmacological treatment could improve the main features of ast
Jaakkola, 2019	89 (70 females)	39.7	24.9	24 weeks 3 sessions/ week ~30 min/ session	Intensity: NA Type: Aerobic exercise + muscle training	Usual care	VO_{2max}	Regular exercise improves asthma control
Mendes, 2010	101 (79 females)	39.3	24.8	12 weeks 2 sessions/ week 30 min/session	Intensity: 60-70% VO_{2max} Type: Yoga breathing exercises + aerobic exercises	Educational program	VO_{2max} AQLQ	Aerobic training can play an important role in the clinical management of patients with persistent asthma
Moreira, 2008	31 (14 females)	12.7	20.4	12 weeks 2 sessions/ week 50 min/session	Intensity: submaximal. Type: Aerobic exercises + strength training + balance adn coordination exercises	Usual care	AQLQ	There is no reason to discourage asthmatic children with controlled disease to exercise
Refaat, 2015	68 (37 females)	37.1	22.5	6 weeks 3 sessions/ week 30 min/session	Intensity: 60-80% HR_{max} Type: Cycling, step ups, wall squats and upper limb endurrance exercises	Usual care	AQLQ	Physical training can improve quality of life and pulmonary function in patients with moderate and severe bronchial asthma

(continúa)

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Sanz-Santiago, 2020	53 (29 females)	11.5	NA	12 weeks 3 sessions/ week 60 min/session	Intensity: moderate. Type: Cycling + resistance exercises	Usual care	VO_{2max} PAQLQ	Combined exercise training improved cardiorespiratory fitness and muscle strength in children
Shaw, 2011	44 (32 females)	21.9	27.1	8 weeks 3 sessions/ week 30 min/session	Intensity: 60% HR_{max} Type: Walking and/or jogging	Usual care	VO_{2max}	Aerobic exercise plus diaphragmatic inspiratory resistive breathing might be useful as an adjunct therapy in asthmatic patients
Turner, 2011	35 (19 females)	67.8	27.7	6 weeks 3 sessions/ week 80-90 min/ session	Intensity: 80% of the average walking speed + Borg scale Type: Walking + cycling + endurance exercises	Usual care	6-MWT AQLQ	Supervised exercise training improves symptoms and quality of life in these patients
Van Veldhsen, 2001	47 (13 females)	10.6	18.5	12 weeks 2 sessions/ week 60 min/session	Intensity: NA. Type: Fitness training + different physical activities	Usual care	VO_{2max}	Physical exercise program not only enhanced physical fitness, but also improved coping behavior with asthma
Wang, 2009	30 (10 females)	10	20	6 weeks 3 sessions/ week ~50 min /session	Intensity: 65% HR peak Type: Swimming	Usual care	VO_{2max}	Swimming may be an effective non-pharmacological intervention for the children or adolescent with asthma
Weisgerber, 2008	45 (24 females)	10.3	23	9 weeks 3 sessions/ week 30 min/session	Intensity: High (8-10 METs) Type: Swimming	Golf intervention	VO_{2max} AQLQ	Results suggest a potentially benefitial role for moderate to vigorous physical activity in childhood asthma

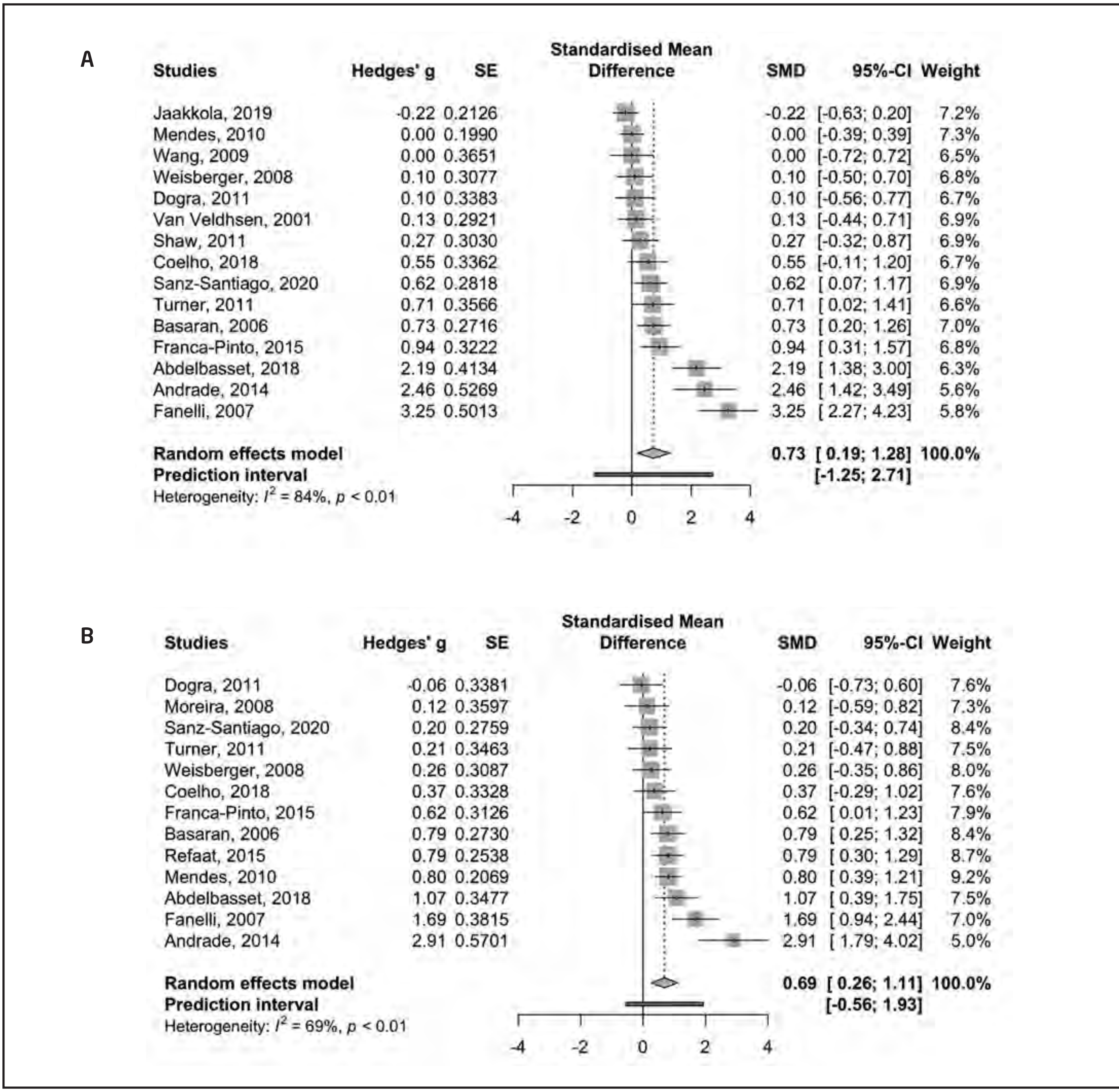
HR_{max}: Maximal Heart Rate; 6-MWT: 6-Minutes Walking Test; PAQLQ: Pediatric Asthma Quality of Life Questionnaire; AQLQ: Asthma Quality of Life Questionnaire.

Table 2. PEDro scale scores of the included studies.

Study	Eligibility criteria*	Random allocation	Concealed allocation	Baseline comparison	Blinded subjects	Blinded therapists	Blinded assessors	Adequate follow-up	Intention to-treat analysis	Between group comparison	Point estimates and variability	Overall
Abdelbasset, 2018	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Andrade, 2014	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Basaran, 2006	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Coelho, 2018	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Dogra, 2011	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Fanelli, 2007	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5
França-Pinto, 2015	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Jaakkola, 2019	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Mendes, 2010	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Moreira, 2008	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Refaat, 2015	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Sanz-Santiago, 2020	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Shaw, 2011	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Turner, 2011	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Van Veldhoven, 2001	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Wang, 2009	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Weisgerber, 2008	Yes	Yes	No	Yes	No	No	No	No	No	No	No	2

*Invalid criterion for final score.

Figure 2. Effect sizes for exercise on study outcomes. Studies are ordered according to their effect sizes. A) Aerobic capacity; B) Quality of life.



Methodological quality of included studies

We found that 6 studies[31,35,38,41–43] presented a good methodological quality, 10 studies[8,28–30,33,34,36,37,39,40] obtained a fair methodological quality score and only 1 study[32] presented a poor methodological quality. In summary, we can determine the methodological quality of our study as fair-good. All scores of the included studies are presented in Table 2.

Publication bias analysis

Eggers' test does not indicate the presence of funnel asymmetry (Table 3). After performing sensitivity analysis with the Pustejovsky-Rodges approach, our results also did not show the presence of funnel asymmetry, which indicates data consistency. To visualize the funnel symmetry, the funnel plots of both outcomes are illustrated in Figure 4.

Figure 3. Effect sizes and confidence ellipses of both outcomes. The diamonds near the axes are the estimates of the effect size of our variables and the black arrows represent their 95% CI. The diamond in the center is the combined effect for both variables. The red ellipse represents the 95% CI ellipse of our combined effect size. The black ellipse is 95% PI for all effects of all studies under a random-effects model. Each point represents a study and the dashed line its 95% CI.

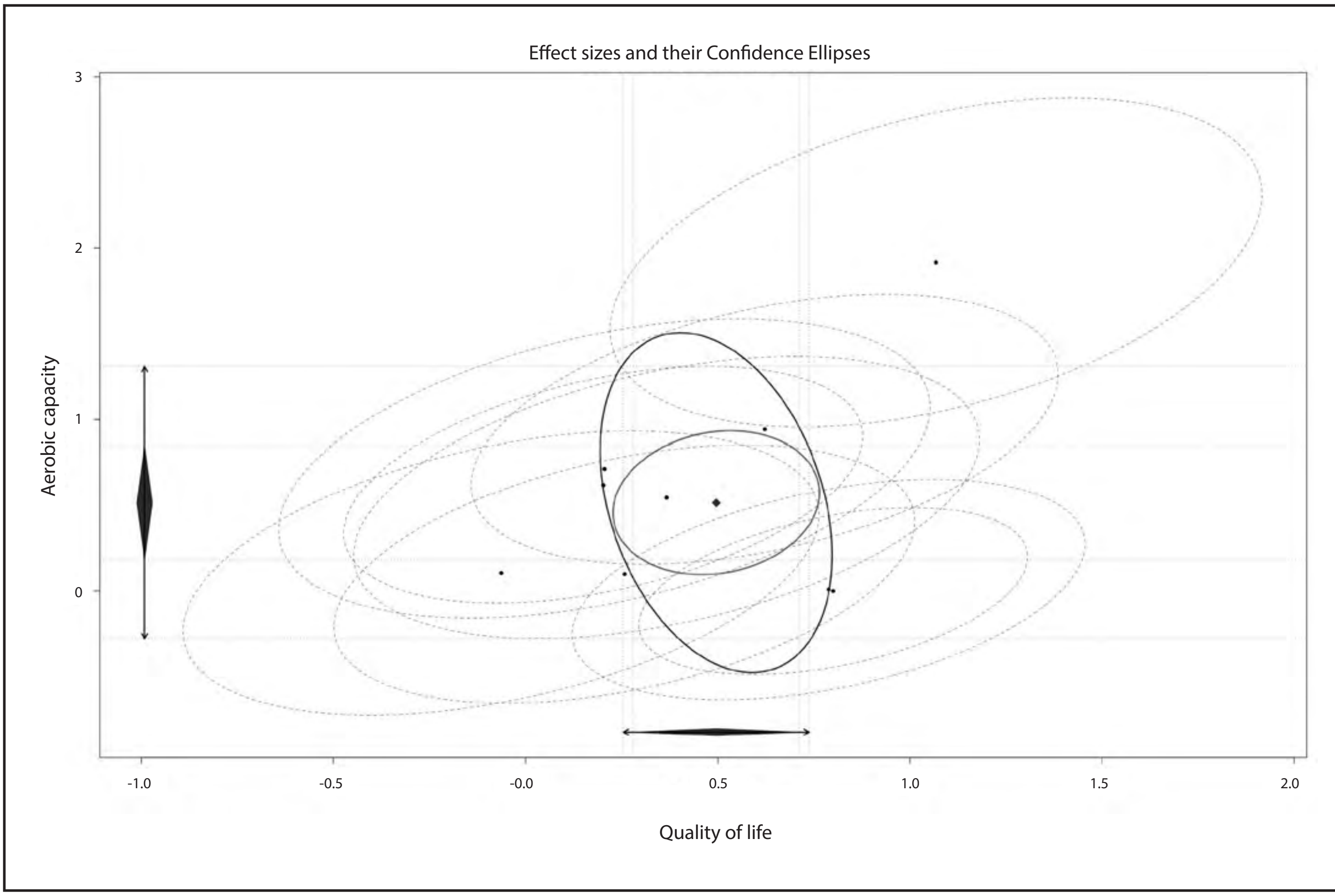


Figure 4. Contour-Enhanced Funnel Plots.

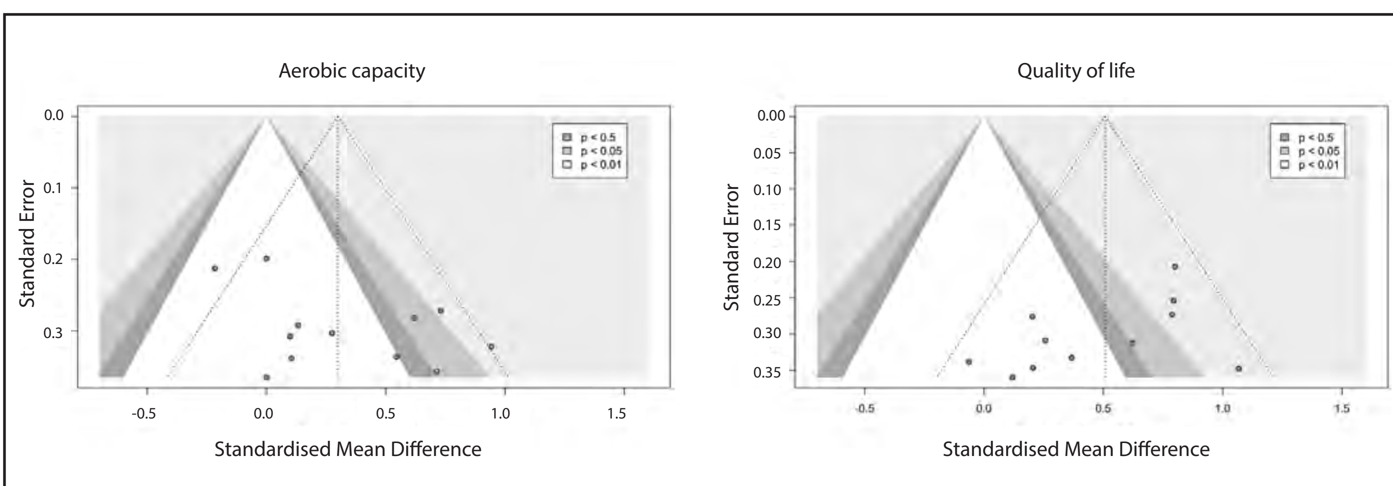


Figure 5. Leave-One-Out Meta-Analysis to identify the individual contribution to the heterogeneity and effect size. A) Aerobic capacity; B) Quality of life.

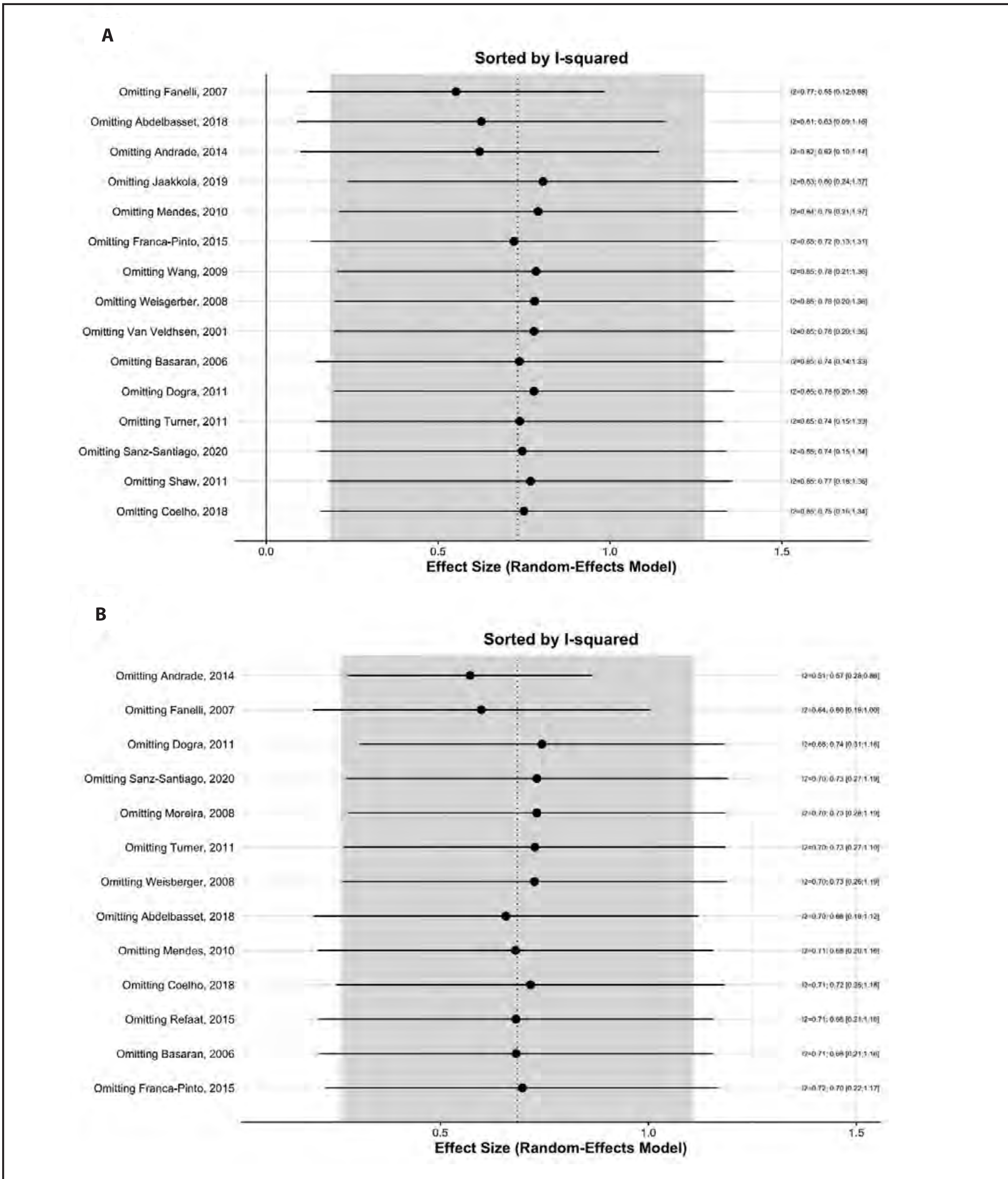


Table 3. Publication bias analysis results.

Method	Intercept	95% CI	t-value	p
Egger	−3.49	−7.10 – 0.12	−1.896	0.0904
Pustejovsky-Rodges	−1.28	−4.12 – 3.13	0.95	0.366

Sensitivity analysis

Observing the variance in effect sizes and heterogeneity through leave-one-out meta-analysis method, we detected 3 studies[30,38,41] for aerobic capacity outcome and 2 studies[30,38] for quality of life outcome that could have influenced the pooled effects. The individual contributions to the effect size and heterogeneity are illustrated in Figure 5. Removing the observed influential studies, the pooled effects of both outcomes decreased, but we obtained a significant reduction in the heterogeneity level and more accurate confidence and prediction intervals, suggesting significant positive effects of physical exercise on quality of life of these patients. All data referred to sensitivity analysis appeared in Table 4.

Discussion

To our knowledge, our meta-analysis, with a final representation of 1,329 patients with asthma (17 studies; 29 effect sizes), was the first-ever in reporting a significant correlation between aerobic capacity and quality of life effects in patients diagnosed with asthma. Furthermore, we found significant positive effects of physical exercise on aerobic capacity and quality of life in these patients. A point we must consider is that prediction intervals of both outcomes included zero in our main analyses. However, when we removed the influential studies, we obtained clear improvements on aerobic capacity and quality of life (i.e., prediction intervals did not include zero), a significant decrease in the heterogeneity levels, and more accurate intervals (i.e., confidence and prediction). In contrast, we also observed an effect size shrinking in that process. Lastly, we found a moderate positive correlation between both outcomes, suggesting that beneficial effects on quality of life may have been caused by benefits on aerobic capacity.

The results obtained in our meta-analysis are in line with other reviews[6,8–10], supporting the beneficial effects of exercise in asthmatic patients. Asthma is an inflammatory disease, and exercise and/or physical activity can play an important role in controlling its symptoms: improving the aerobic capacity of these patients may provide a reduction in exercise-induced bronchoconstriction (i.e., airway muscles contraction)[44], which is the main cause of the notorious sedentary behavior of people diagnosed with asthma[45], and a better physical exercise tolerance[46]. Hence, these benefits could be reflected on the overall quality of life of people with asthma, since the greater impact on any asthma symptom, the better their quality of life[47], which may partially explain the found correlation between both outcomes.

This research adds consistent evidence on the usefulness of physical exercise in the management and treatment of asthma. Considering our data and the current evidence[48], we hypothesize that physical exercise could improve some pathologies which share symptoms with asthma disease such as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), from common symptoms (e.g., cough) to severe ones (e.g., difficulty breathing, shortness of breath, or loss of movement), taken in account all pathology symptoms, the context, and patient status. However, in order to transfer this knowledge to clinical practice, we need to fill in the existing gaps in the literature about the optimal type and dose for these patients[49]. International organizations recommend keeping a healthy and active life, encouraging people with asthma to engage in regular physical activity[49], at least 30 minutes of moderately intense physical activity or structured physical exercise every day[49], resulting in global recommendations, not specifications. In order to establish optimal physical exercise for these people, there is limited evidence which suggests that aquatic activities (e.g., swimming) are more beneficial by reducing the airborne particles exposure[47], and that moderate-vigorous intensity activities could result in greater benefits[47]. This information scarcity could explain that we do not detect moderation effects differentiating by type of physical exercise (i.e., aerobic vs. multicomponent), although significant interactions could be hidden by lack of available data.

In this point, we can identify several key strengths to our study. Our meta-analysis is the first one that has been able to explain part of the benefits caused on quality of life by aerobic capacity improvements. Sensitivity analyses allow us to explain large amounts of heterogeneity given in the main analyses. Included studies presented a fair-good methodological quality. Additional analysis did not show the presence of publication bias. Conversely, we also detected some limitations. We have only focused on exercise, but future meta-analyses should include different types of physical activities (e.g., body-mind or aquatic activities).

Table 4. Sensitivity analysis results

Outcome	Analysis	Hedges' g	95% CI	p	95% PI	I^2	95% CI
Aerobic capacity	Main Analysis	0.73	0.16 - 1.28	0.01	−1.25 - 2.71	84%	75 - 90
	Infl. Cases Removed	0.30	0.06 - 0.54	0.002	−0.31 - 0.91	43%*	13 - 72
Quality of life	Main Analysis	0.69	0.26 - 1.11	0.004	−0.56 - 1.93	69%	45 - 82
	Infl. Cases Removed	0.51	0.27 - 0.74	< 0.001	0.03 - 0.98*	28%*	0 - 64

[1]Removed as outliers: Abdelbasset, 2018; Andrade, 2014; Franelli, 2007
[2]Removed as outliers: Andrade, 2014; Franelli, 2007
*Significanrt changes between models

Moreover, we had a low number of studies to observe moderation subgroup effects (e.g., evidence support that children may benefit more from physical exercise than older adults[50], and we did not detect it), which limits the differentiation on the effects.

Conclusions

This work contributes to broadening the horizon in the management and treatment of asthma, proposing physical exercise as a non-pharmacological treatment to improve the aerobic capacity and, consequently, the quality of life of people with asthma. Our meta-analysis has demonstrated that physical exercise is an intervention which deserves further analysis to lay the foundations for specific and efficient recommendations (i.e., optimal type and dose of physical activity) to improve the lives of these patients who suffer a disease that currently has no cure.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet.* 2020;396,10258:1204–22.
2. Hossny E, Caraballo L, Casale T, El-Gamal Y, Rosenwasser L. Severe asthma and quality of life. *World Allergy Organ J.* 2017;10:28.
3. Quirt J, Hildebrand KJ, Mazza J, Noya F, Kim H. Asthma. Allergy Asthma Clin Immunol. 2018; 14, Suppl 2: 50.
4. Loymans RJB, Gemperli A, Cohen J, Rubinstein SM, Sterk PJ, Reddel HK, *et al.* Comparative effectiveness of long term drug treatment strategies to prevent asthma exacerbations: network meta-analysis. *BMJ.* 2014;348:3009.
5. Cooper V, Metcalf L, Versnel J, Upton J, Walker S, Horne R. Patient-reported side effects, concerns and adherence to corticosteroid treatment for asthma, and comparison with physician estimates of side-effect prevalence: a UK-wide, cross-sectional study. *NPJ Prim Care Respir Med.* 2015;251:1–6.
6. Eijkemans M, Mommers M, Th. Draaisma JM, Thijs C, Prins MH. Physical activity and asthma: a systematic review and meta-analysis. *PLoS ONE*. 2012;7.
7. Dempsey JA. Challenges for future research in exercise physiology as applied to the respiratory system. *Exerc Sport Sci Rev.* 2006;34:92–8.
8. Jaakkola JJK, Aalto SAM, Hernberg S, Kiihamäki S-P, Jaakkola MS. Regular exercise improves asthma control in adults: a randomized controlled trial. *Sci Rep.* 2019;9:12088.
9. Hansen ESH, Pitzner-Fabricius A, Toennesen LL, Rasmusen HK, Hostrup M, Hellsten Y, *et al.* Effect of aerobic exercise training on asthma in adults: a systematic review and meta-analysis. *Eur Respir J.* 2020;56,1.
10. Feng Z, Wang J, Xie Y, Li J. Effects of exercise-based pulmonary rehabilitation on adults with asthma: a systematic review and meta-analysis. *Respir Res.* 2021;22:33.
11. Panagiotou M, Koulouris NG, Rovina N. Physical activity: a missing link in asthma care. *J Clin Med Res*. 2020;9,3.
12. Avallone KM, McLeish AC. Asthma and aerobic exercise: a review of the empirical literature. *J Asthma*. 2013;50:109–16.
13. Page MJ, McKenzie J, Bossuyt P, Boutron I, Hoffmann T, Mulrow C d., *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* 2021; 372,71.
14. Dharmage SC, Perret JL, Custovic A. Epidemiology of asthma in children and adults. *Front Pediatr.* 2019;7:246.
15. Hedges LV, Olkin I. Meta-analysis in the physical and biological sciences. *Statistical Methods for Meta-Analysis.* 1985;311–25.
16. Viechtbauer W. Bias and efficiency of meta-analytic variance estimators in the random-effects model. *J Educ Behav Stat.* 2005;30:261–93.
17. Knapp G, Hartung J. Improved tests for a random effects meta-regression with a single covariate. *Stat Med*. 2003;22:2693–710.
18. Stanescu S, Kirby SE, Thomas M, Yardley L, Ainsworth B. A systematic review of psychological, physical health factors, and quality of life in adult asthma. *NPJ Prim Care Respir Med*. 2019;29,1:37.
19. Core Team R. R. *A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna, Austria. 2017.
20. Lüdecke D, Lüdecke MD. *Calculator'from David BW.* Package "esc.". 2017.
21. Harrer M, Cuijpers P, Furukawa T, Ebert DD. dmetar: Companion R package for the guide' doing meta-analysis in R'. R package version 0 0. 2019; 9000.
22. Schwarzer G, Others. meta: An R package for meta-analysis. *R news*. 2007;7:40–5.
23. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Aust J Physiother*. 2009;55:129–33.
24. Cashin AG, McAuley JH. Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. *J Physiother.* 2020;66:59.
25. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ.* 1997;315,7109:629–34.
26. Pustejovsky JE, Rodgers MA. Testing for funnel plot asymmetry of standardized mean differences. *Res Synth Methods.* 2019;10:57–71.
27. Willis BH, Riley RD. Measuring the statistical validity of summary meta-analysis and meta-regression results for use in clinical practice. *Stat Med*. 2017;36:3283–301.
28. van Veldhoven NH, Vermeer A, Bogaard JM, GP Hessels M, Wijnroks L, Colland VT, *et al*. Children with asthma and physical exercise: effects of an exercise programme. *Clin Rehabil.* 2001;15:360–70.
29. Basaran S, Guler-Uysal F, Ergen N, Seydaoglu G, Bingol-Karakoç G, Ufuk Altintas D. Effects of physical exercise on quality of life, exercise capacity and pulmonary function in children with asthma. *J Rehabil Med.* 2006;38:130–5.
30. Fanelli A, Cabral ALB, Neder JA, Martins MA, Carvalho CRF. Exercise training on disease control and quality of life in asthmatic children. *Med Sci Sports Exerc.* 2007;39:1474–80.
31. Moreira A, Delgado L, Haahtela T, Fonseca J, Moreira P, Lopes C, *et al.* Physical training does not increase allergic inflammation in asthmatic children. *Eur Respir J.* 2008;32: 1570–5.
32. Weisgerber M, Webber K, Meurer J, Danduran M, Berger S, Flores G. Moderate and vigorous exercise programs in children with asthma: safety, parental satisfaction, and asthma outcomes. *Pediatr Pulmonol.* 2008;43:1175–82.
33. Wang J-S, Hung W-P. The effects of a swimming intervention for children with asthma. *Respirology.* 2009;14:838–42.
34. Mendes FAR, Gonçalves RC, Nunes MPT, Saraiva-Romanholo BM, Cukier A, Stelmach R, *et al.* Effects of aerobic training on psychosocial morbidity and symptoms in patients with asthma: a randomized clinical trial. *Chest.* 2010;138:331–7.
35. Shaw I, Shaw BS, Brown GA. Role of diaphragmatic breathing and aerobic exercise in improving pulmonary function and maximal oxygen consumption in asthmatics. *Sci Sports.* 2010;25:139–45.
36. Dogra S, Kuk JL, Baker J, Jamnik V. Exercise is associated with improved asthma control in adults. *Eur Respir J.* 2011;37:318–23.
37. Turner S, Eastwood P, Cook A, Jenkins S. Improvements in symptoms and quality of life following exercise training in older adults with moderate/severe persistent asthma. Respiration. 2011;81:302–10.
38. Andrade LB de, Britto MCA, Lucena-Silva N, Gomes RG, Figueroa JN. The efficacy of aerobic training in improving the inflammatory component of asthmatic children. Randomized trial. *Respir Med.* 2014;108:1438–45.
39. Refaat S, Aref H. Acute asthma in emergency department, prevalence of respiratory and non-respiratory symptoms. *Egypt J Chest Dis Tuberc.* 2014;63:771–6.
40. França-Pinto A, Mendes FAR, de Carvalho-Pinto RM, Agondi RC, Cukier A, Stelmach R, *et al*. Aerobic training decreases bronchial hyperresponsiveness and systemic inflammation in patients with moderate or severe asthma: a randomised controlled trial. *Thorax*. 2015;70:732–9.
41. Abdelbasset WK, Alsubaie SF, Tantawy SA, Abo Elyazed TI, Kamel DM. Evaluating pulmonary function, aerobic capacity, and pediatric quality of life following a 10-week aerobic exercise training in school-aged asthmatics: a randomized controlled trial. *Patient Prefer Adherence.* 2018;12:1015–23.
42. Coelho CM, Reboredo MM, Valle FM, Malaguti C, Campos LA, Nascimento LM, *et al.* Effects of an unsupervised pedometer-based physical activity program on daily steps of adults with moderate to severe asthma: a randomized controlled trial. *J Sports Sci.* 2018;36:1186–93.
43. Sanz-Santiago V, Diez-Vega I, Santana-Sosa E, Lopez Nuevo C, Iturriaga Ramirez T, Vendrusculo FM, *et al.* Effect of a combined exercise program on physical fitness, lung function, and quality of life in patients with controlled asthma and exercise symptoms: A randomized controlled trial. *Pediatr Pulmonol.* 2020;55:1608–16.

44. Mendes FAR, Almeida FM, Cukier A, Stelmach R, Jacob-Filho W, Martins MA, *et al*. Effects of aerobic training on airway inflammation in asthmatic patients. *Med Sci Sports Exerc*. 2011;43:197–203.

45. Reimberg MM, Pachi JRS, Scalco RS, Serra AJ, Fernandes L, Politti F, *et al*. Patients with asthma have reduced functional capacity and sedentary behavior. *J Pediatr*. 2021;96:53–9.

46. Del Giacco SR, Firinu D, Bjermer L, Carlsen K-H. Exercise and asthma: an overview. *Eur Respir J*. 2015;2:27984.

47. Freeman AT, Staples KJ, Wilkinson TMA. Defining a role for exercise training in the management of asthma. *Eur Respir Rev.* 2020;29:156.

48. Wittmer VL, Paro FM, Duarte H, Capellini VK, Barbalho-Moulim MC. Early mobilization and physical exercise in patients with COVID-19: A narrative literature review. *Complement Ther Clin Pract*. 2021;43:101364.

49. Riedler J. Innovations of the GINA 2020 for children and the effects of COVID-19 on children with asthma. *Padiatr Padol.* 2021;1–6.

50. Wanrooij VHM, Willeboordse M, Dompeling E, van de Kant KDG. Exercise training in children with asthma: a systematic review. *Br J Sports Med.* 2014;48:1024–31.

Archivos
de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

Índice completo

207-212
Volumen XXXIX. 2022

Sumarios 2022

Volumen 39(1) - Núm 207. Enero - Febrero 2022 / January - February 2022

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 39(2) - Núm 208. Marzo - Abril 2022 / March - April 2022

Editorial

Originales / Original articles

Revisiones / Reviews

Volumen 39(3) - Núm 209. Mayo - Junio 2022 / May - June 2022

Volumen 39(4) - Núm 210. Julio - Agosto 2022 / July - August 2022

Volumen 39(5) - Núm 211. Septiembre - Octubre 2022 / September - October 2022

Volumen 39(6) - Núm 212. Noviembre - Diciembre 2022 / November - December 2022

Índice analítico 2022

Índice de autores 2022

Lista de revisores evaluadores externos de los artículos recibidos en 2022 en Archivos de Medicina del Deporte

Abenza, Lucía *(Universidad Católica San Antonio de Murcia, España)*

Alacid Cárceles, Fernando *(Universidad de Almería, España)*

Aparecida Doimo, Leonice *(Universidad Politécnica de Madrid, España)*

Arboix, Jordi *(Universidad Ramón Llull, España)*

Azcarate Jimenez, Unai *(Universidad del País Vasco, España)*

Baena Chicón, Irene *(Conservatorio Superior de Música Rafael Orozco de Córdoba, España)*

Braga de Mello, Danielli *(Escola de Educaçao Fisica do Exercito, Brasil)*

Brager, Mark *(University of Calgary, Canadá)*

Castro, Aurora *(Universidad de Sevilla, España)*

de Pablo, Bernat *(Hospital Universitario Mutua Terrasa, España)*

Dziworski, August *(Universidad de Cracovia, Polonia)*

Esteban Iglesias, Diego *(Hospital Italiano de Buenos Aires, Argentina)*

Fernandes Da Silva, Sandro *(Universidade Federal de Lavras, Brasil)*

González Vargas, Sandra *(Universidad de los Llanos, Colombia)*

Gutiérrez-Sánchez, Águeda *(Universidad de Vigo, España)*

Lima e Silva, Leando *(Universidade do Estado do Rio de Janeiro, Brasil)*

Manuz González, Begoña *(Centro Médico Deportivo Begoña Manuz González, Cantabria, España)*

Martínez-Roríguez, Alejandro *(Universidad de Alicante, España)*

Moraga Muñoz, Rodrigo *(Universidad Adventista, Chile)*

Moreno Flores, Pedro Julián *(Universidad de Colima, México)*

Papoti, Marcelo *(Universidad de Sao Paulo, Brasil)*

Peidro, Roberto *(Universidad Favaloro, Argentina)*

Poggi Soria, Marcos Fabian *(Selección Uruguaya de Básquetbol en Silla de Ruedas, Uruguay)*

Quero Calero, Carmen *(Universidad Católica San Antonio de Murcia, España)*

Ribas Serna, Juan *(Universidad de Sevilla, España)*

Romero Arenas, Salvador *(Universidad Católica San Antonio de Murcia, España)*

Smew, Sabrin *(Escuela de tecnología, Brasil)*

Soler, Isabel *(Universidad de Granada, España)*

Soto García, Diego *(Complejo Hospitalario de Pontevedra, España)*

Valenti, Claudia *(Universidad Favaloro, Argentina)*

Vernetta Santana, Mercedes *(Universidad de Granada, España)*

La dirección de Archivos de Medicina el Deporte desea agradecer a todos su desinteresada colaboración.

Normas de publicación de Archivos de Medicina del Deporte

La Revista ARCHIVOS DE MEDICINA DEL DEPORTE (Arch Med Deporte) con ISSN 0212-8799 es la publicación oficial de la Sociedad Española de Medicina del Deporte (SEMED). Edita trabajos originales sobre todos los aspectos relacionados con la Medicina y las Ciencias del Deporte desde 1984 de forma ininterrumpida con una periodicidad trimestral hasta 1995 y bimestral a partir de esa fecha. Se trata de una revista que utiliza fundamentalmente el sistema de revisión externa por dos expertos (*peer-review*). Incluye de forma regular artículos sobre investigación clínica o básica relacionada con la medicina y ciencias del deporte, revisiones, artículos o comentarios editoriales, y cartas al editor. Los trabajos podrán ser publicados EN ESPAÑOL O EN INGLÉS. La remisión de trabajos en inglés será especialmente valorada.

En ocasiones se publicarán las comunicaciones aceptadas para presentación en los Congresos de la Sociedad.

Los artículos Editoriales se publicarán sólo previa solicitud por parte del Editor.

Los trabajos admitidos para publicación quedarán en propiedad de SEMED y su reproducción total o parcial deberá ser convenientemente autorizada. Todos los autores de los trabajos deberán enviar por escrito una carta de cesión de estos derechos una vez que el artículo haya sido aceptado.

Envío de manuscritos

1. Los trabajos destinados a publicación en la revista Archivos de Medicina del Deporte se enviarán a través del sistema de gestión editorial de la revista (http://archivosdemedicinadeldeporte.com/revista/index.php/amd).
2. Los trabajos deberán ser remitidos, a la atención del Editor Jefe.
3. Los envíos constarán de los siguientes documentos:
   a. **Carta al Editor** de la revista en la que se solicita el examen del trabajo para su publicación en la Revista y se especifica el tipo de artículo que envía.
   b. **Página de título** que incluirá exclusivamente y por este orden los siguiente datos: Título del trabajo (español e inglés), nombre y apellidos de los autores en este orden: primer nombre, inicial del segundo nombre si lo hubiere, seguido del primer apellido y opcionalmente el segundo de cada uno de ellos; titulación oficial y académica, centro de trabajo, dirección completa y dirección del correo electrónico del responsable del trabajo o del primer autor para la correspondencia. También se incluirán los apoyos recibidos para la realización del estudio en forma de becas, equipos, fármacos…
   c. **Manuscrito.** Debe escribirse a doble espacio en hoja DIN A4 y numerados en el ángulo superior derecho. Se recomienda usar formato Word, tipo de letra Times New Roman tamaño 12.
   Este texto se iniciará con el título del trabajo (español e inglés), resumen del trabajo en español e inglés, que tendrá una extensión de 250-300 palabras. Incluirá la intencionalidad del trabajo (motivo y objetivos de la investigación), la metodología empleada, los resultados más destacados y las principales conclusiones. Ha de estar redactado de tal modo que permita comprender la esencia del artículo sin leerlo total o parcialmente. Al pie de cada resumen se especificarán de tres a diez palabras clave en castellano e inglés (keyword), derivadas del Medical Subject Headings (MeSH) de la National Library of Medicine (disponible en: http://www.nlm.nih.gov/mesh/MBrowser.html).
   Después se escribirá el texto del trabajo y la bibliografía.
   En el documento de texto, al final, se incluirán las leyendas de las tablas y figuras en hojas aparte.
   d. **Tablas.** Se enviarán en archivos independientes en formato JPEG y en formato word. Serán numeradas según el orden de aparición en el texto, con el título en la parte superior y las abreviaturas descritas en la parte inferior. Todas las abreviaturas no estándar que se usen en las tablas serán explicadas en notas a pie de página.
   Las tablas se numerarán con números arábigos según su orden de aparición en el texto.
   En el documento de texto, al final, se incluirán las leyendas de las tablas y figuras en hojas aparte.
   e. **Figuras.** Se enviarán en archivos independientes en formato JPEG de alta resolución. Cualquier tipo de gráficos, dibujos y fotografías serán denominados figuras. Deberán estar numeradas correlativamente según el orden de aparición en el texto y se enviarán en blanco y negro (excepto en aquellos trabajos en que el color esté justificado).
   Se numerarán con números arábigos según su orden de aparición en el texto.
   La impresión en color tiene un coste económico que tiene que ser consultado con el editor.
   En el documento de texto, al final, se incluirán las leyendas de las tablas y figuras en hojas aparte.
   f. **Propuesta de revisores.** El responsable del envío propondrá un máximo de cuatro revisores que el editor podrá utilizar si lo considera necesario. De los propuestos, uno al menos será de nacionalidad diferente del responsable del trabajo. No se admitirán revisores de instituciones de los firmantes del trabajo.
   g. **Carta de originalidad y cesión de derechos**. Se certificará, por parte de todos los autores, que se trata de un original que no ha sido previamente publicado total o parcialmente.
   h. **Consentimiento informado.** En caso de que proceda, se deberá adjuntar el documento de consentimiento informado

que se encuentra en la web de la revista archivos de Medicina del Deporte.

i. **Declaración de conflicto de intereses.** Cuando exista alguna relación entre los autores de un trabajo y cualquier entidad pública o privada de la que pudiera derivarse un conflicto de intereses, debe de ser comunicada al Editor. Los autores deberán cumplimentar un documento específico.

En el sistema de gestión editorial de la revista se encuentran modelos de los documentos anteriores.

4. La extensión del texto variará según la sección a la que vaya destinado:
   a. **Originales**: Máximo de 5.000 palabras, 6 figuras y 6 tablas.
   b. **Revisiones**: Máximo de 5.000 palabras, 5 figuras y 4 tablas. En caso de necesitar una mayor extensión se recomienda comunicarse con el Editor de la revista.
   c. **Editoriales**: Se realizarán por encargo del comité de redacción.
   d. **Cartas al Editor**: Máximo 1.000 palabras.
5. **Estructura del texto**: variará según la sección a la que se destine:
   a. **ORIGINALES**: Constará de una **introducción**, que será breve y contendrá la intencionalidad del trabajo, redactada de tal forma que el lector pueda comprender el texto que le sigue. **Material y método**: Se expondrá el material utilizado en el trabajo, humano o de experimentación, sus características, criterios de selección y técnicas empleadas, facilitando los datos necesarios, bibliográficos o directos, para que la experiencia relatada pueda ser repetida por el lector. Se describirán los métodos estadísticos con detalle. **Resultados**: Relatan, no interpretan, las observaciones efectuadas con el material y método empleados. Estos datos pueden publicarse en detalle en el texto o bien en forma de tablas y figuras. No se debe repetir en el texto la información de las tablas o figuras. **Discusión**: Los autores expondrán sus opiniones sobre los resultados, posible interpretación de los mismos, relacionando las propias observaciones con los resultados obtenidos por otros autores en publicaciones similares, sugerencias para futuros trabajos sobre el tema, etc. Se enlazarán las conclusiones con los objetivos del estudio, evitando afirmaciones gratuitas y conclusiones no apoyadas por los datos del trabajo. Los **agradecimientos** figurarán al final del texto.
   b. **REVISIONES**: El texto se dividirá en todos aquellos apartados que el autor considere necesarios para una perfecta comprensión del tema tratado.
   c. **CARTAS AL EDITOR**: Tendrán preferencia en esta Sección la discusión de trabajos publicados en los dos últimos números con la aportación de opiniones y experiencias resumidas en un texto de 3 hojas tamaño DIN A4.
   d. **OTRAS**: Secciones específicas por encargo del comité editorial de la revista.
6. **Bibliografía**: Se presentará al final del manuscrito y se dispondrá según el orden de aparición en el texto, con la correspondiente numeración correlativa. En el texto del artículo constará siempre la numeración de la cita entre paréntesis, vaya o no vaya acompañado del nombre de los autores; cuando se mencione a éstos en el texto, si se trata de un trabajo realizado por dos, se mencionará a ambos, y si son más de dos, se citará el primero seguido de la abreviatura "*et al*". No se incluirán en las citas bibliográficas comunicaciones personales, manuscritos o cualquier dato no publicado.

   La abreviatura de la revista Archivos de Medicina del Deportes es *Arch Med Deporte*.

   Las citas bibliográficas se expondrán del modo siguiente:
   - **Revista:** Número de orden; apellidos e inicial del nombre de los autores del artículo sin puntuación y separados por una coma entre sí (si el número de autores es superior a seis, se incluirán los seis primeros añadiendo a continuación et al.); título del trabajo en la lengua original; título abreviado de la revista, según el World Medical Periodical; año de la publicación; número de volumen; página inicial y final del trabajo citado. Ejemplo: 1. Calbet JA, Radegran G, Boushel R, Saltin B. On the mechanisms that limit oxygen uptake during exercise in acute and chronic hypoxia: role of muscle mass. *J Physiol.* 2009;587:477-90.
   - **Capítulo en libro**: Número de orden; autores, título del capítulo, editores, título del libro, ciudad, editorial, año y páginas. Ejemplo: Iselin E. Maladie de Kienbock et Syndrome du canal carpien. En: Simon L, Alieu Y. *Poignet et Medecine de Reeducation*. Londres: Collection de Pathologie Locomotrice Masson; 1981. p. 162-6.
   - **Libro**. número de orden; autores, título, ciudad, editorial, año de la edición, página de la cita. Ejemplo: Balius R. *Ecografía muscular de la extremidad inferior. Sistemática de exploración y lesiones en el deporte*. Barcelona. Editorial Masson; 2005. p. 34.
   - **Material eléctrónico**, artículo de revista electrónica: Ejemplo: Morse SS. Factors in the emergence of infectious diseases. *Emerg Infect Dis.* (revista electrónica) 1995 JanMar (consultado 0501/2004).

     Disponible en: http://www.cdc.gov/ncidod/EID/ eid.htm
7. La Redacción de ARCHIVOS DE MEDICINA DEL DEPORTE comunicará la recepción de los trabajos enviados e informará con relación a la aceptación y fecha posible de su publicación.
8. ARCHIVOS DE MEDICINA DEL DEPORTE, oídas las sugerencias de los revisores (la revista utiliza el sistema de corrección por pares), podrá rechazar los trabajos que no estime oportunos, o bien indicar al autor aquellas modificaciones de los mismos que se juzguen necesarias para su aceptación.
9. La Dirección y Redacción de ARCHIVOS DE MEDICINA DEL DEPORTE no se responsabilizan de los conceptos, opiniones o afirmaciones sostenidos por los autores de sus trabajos.
10. Envío de los trabajos: Los trabajos destinados a publicación en la revista Archivos de Medicina del Deporte se enviarán a través del sistema de gestión editorial de la revista (http://archivosdemedicinadeldeporte.com/revista/index.php/amd).

Ética

Los autores firmantes de los artículos aceptan la responsabilidad definida por el Comité Internacional de Editores de Revistas Médicas http://www.wame.org/ (World Association of Medical Editors).

Los trabajos que se envían a la Revista ARCHIVOS DE MEDICINA DEL DEPORTE para evaluación deben haberse elaborado respetando las recomendaciones internacionales sobre investigación clínica y con animales de laboratorio, ratificados en Helsinki y actualizadas en 2008 por la Sociedad Americana de Fisiología (http://www.wma.net/es/10home/index.html).

Para la elaboración de ensayos clínicos controlados deberá seguirse la normativa CONSORT, disponible en: http://www.consort-statement.org/.

Campaña de aptitud física, deporte y salud

La **Sociedad Española de Medicina del Deporte**, en su incesante labor de expansión y consolidación de la Medicina del Deporte y, consciente de su vocación médica de preservar la salud de todas las personas, viene realizando diversas actuaciones en este ámbito desde los últimos años.

Se ha considerado el momento oportuno de lanzar la campaña de gran alcance, denominada **CAMPAÑA DE APTITUD FÍSICA, DEPORTE Y SALUD** relacionada con la promoción de la actividad física y deportiva para toda la población y que tendrá como lema **SALUD – DEPORTE – DISFRÚTALOS**, que aúna de la forma más clara y directa los tres pilares que se promueven desde la Medicina del Deporte que son el practicar deporte, con objetivos de salud y para la mejora de la aptitud física y de tal forma que se incorpore como un hábito permanente, y disfrutando, es la mejor manera de conseguirlo.

BIOAltitude®
by BIOLaster®

GENERADOR de HIPOXIA HIPEROXIA BIOA50

Hipoxia entre **9% y 20%** (Hasta 45 litros/minuto)

Hiperoxia entre **70% y 90%** (Hasta 5 litros/minuto)

Características Técnicas

Altitud Simulada 400m (FiO2 20 %) a ~ 6500m (FiO2 9,0 %)

Flujo De 0 a 3500m 45 litros/min. - A 6300m 18 litros/min.

Tipo de Hipoxia Dormir/Reposo

Método Separación del aire por método físico

Regulador Altitud/Flujo Manual/Electrónico, permite regular altitud y flujo

Aire Hiperóxico Sí. Máximo 5 litros/min.

Medidas/Peso 33 cm x 20 cm x 50 cm / 11 Kg

Nivel Sonoro 45 dB de base y picos de 65 dB

HIPOXIA INTERMITENTE

HIPOXIA NOCTURNA

Biolaster
@biolaster1
@_biolaster_
Biolaster

BIOLaster® 943 300 813 | 639 619 494 www.biolaster.com