ESCUELA INTERNACIONAL DE DOCTORADO
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MONITORIZACIÓN DE LOS EFECTOS AGUDOS, CRÓNICOS Y DE CONGESTIÓN SOBRE FACTORES DE RIESGO DE LESIÓN MODIFICABLES EN JUGADORAS DE HOCKEY HIERBA FEMENINO

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TESIS DOCTORAL

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MADRID, 2023

UNIVERSIDAD FRANCISCO DE VITORIA

AUTORIZACIÓN DE DIRECTORES DE TESIS PARA SU PRESENTACIÓN

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AUTORIZAN:

La presentación de la Tesis Doctoral titulada: "MONITORIZACIÓN DE LOS EFECTOS AGUDOS, CRÓNICOS Y DE CONGESTIÓN SOBRE FACTORES DE RIESGO DE LESIÓN MODIFICABLES EN JUGADORAS DE HOCKEY HIERBA FEMENINO" realizada por Dña. Violeta Sánchez-Migallón Millán, bajo nuestra inmediata dirección y supervisión y que presenta para la obtención del grado de Doctor en Biomedicina, Medicina y Ciencias Biosanitarias por la Escuela Internacional de Doctorado en la Universidad Francisco de Vitoria.

D. Álvaro López Samanes **D. Víctor Moreno Pérez**

MADRID, 2023

"Si quieres ir rápido ve sólo. Si quieres llegar lejos ve acompañado."
PROVERBIO AFRICANO

"Un viaje de mil millas comienza con el primer paso."
LAO-TSÉ

AGRADECIMIENTOS

Algo que sabemos pero que a veces olvidamos es que las mejores cosas de la vida no son cosas. Las mejores cosas de la vida son las personas que te acompañan durante la vida y te hacen el camino más fácil y más feliz.

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RESUMEN

El hockey hierba es un deporte de equipo altamente practicado a nivel mundial. Un partido de hockey está caracterizado por una combinación de acciones explosivas que combinan el tren superior (*e.g.,* golpeos) con acciones del tren inferior (*e.g.,* cambios de dirección) implicando altas demandas a nivel neuromuscular y metabólico. Además, las temporadas competitivas se caracterizan por ser largas y congestionadas (*i.e.,* participando en diferentes competiciones), conllevando la disputa de una gran cantidad de partidos, un escaso tiempo de recuperación y consecuentemente un aumento de la incidencia lesional. Como objetivo principal de esta Tesis Doctoral se busca monitorizar los efectos agudos, crónicos y de congestión sobre factores de riesgo de lesión modificables en jugadoras de hockey hierba femenino. Para alcanzar este objetivo principal se han realizado cuatro estudios con los siguientes objetivos: Estudio 1: Determinar el efecto provocado por la realización de un partido simulado de hockey hierba sobre la fuerza isométrica los músculos flexores de la rodilla y la fuerza isométrica de los músculos abductores y aductores de la cadera, además de analizar el ROM de la flexión de la cadera y dorsiflexión de tobillo en jugadoras de hockey hierba. Estudio 2: Examinar los efectos provocados por una congestión competitiva sobre la fuerza isométrica de los músculos flexores de la rodilla y ROM de la flexión de la cadera y dorsiflexión tobillo en jugadoras de hockey hierba. Estudio 3: Analizar los efectos provocados por una congestión competitiva sobre la fuerza isométrica de los músculos abductores y aductores de la cadera en jugadoras de hockey hierba. Estudio 4: Monitorizar las fluctuaciones que se producen durante un mesociclo competitivo (16 semanas) de una temporada sobre los factores modificables de riesgo de lesión en jugadoras de hockey semiprofesionales de hockey hierba. En general, el conocimiento generado por los estudios que componen esta Tesis Doctoral pretende dar información a los cuerpos técnicos de los equipos de hockey hierba que podrán aplicar los conocimientos aportados a la actividad profesional diaria, con el propósito de conseguir un impacto favorable en la salud y el rendimiento de sus deportistas.

ABSTRACT

Field hockey is a team sport played worldwide. A field hockey match play is characterized by a combination of explosive upper body (*e.g.,* hitting/striking) and lower body actions (*e.g.,* changes of direction) involving high neuromuscular and metabolic demands. In addition, competitive seasons are characterized by long and congested periods *(i.e.*, participating in multiple competitions), leading to a large number of matches being played with a short recovery period and consequently, increasing the risk of injury incidence. The aim of this Ph.D. thesis is to monitor the effects of acute, chronic, and congestion periods on modifiable injury risk factors in female field hockey players. For this, four studies were carried out with the following objectives: 1) To determine the effect of a simulated field hockey match on the isometric strength of the knee flexors, hip abductor, and hip adductor muscles, and the range of motion (ROM) of hip flexion and ankle dorsiflexion; 2) To examine the effects of consecutive matches on the isometric strength of the knee flexor muscles, and ROM of hip flexion and ankle dorsiflexion; 3) To analyze the effects caused by a congestion of competitive matches on the isometric strength of the abductor and adductor muscles of the hip; and 4) To monitor the fluctuations on modifiable injury risk factors that occur during a competitive mesocycle (16 weeks) of a season. In general, the knowledge generated by the studies of this doctoral thesis aims to provide relevant information to the technical and medical staff of field hockey teams who can use it to have a favorable impact on the health and performance of their athletes.

ESTUDIOS DERIVADOS DE ESTA TESIS DOCTORAL

La presente Tesis Doctoral, de acuerdo con el informe correspondiente autorizado por los directores de Tesis y en cumplimiento con la normativa aprobada por el Órgano Responsable del Programa de Doctorado de Biomedicina, Medicina y Ciencias Biosanitarias por la Escuela Inernacional de Doctorado de la Universidad Francisco de Vitoria, se presenta como un compendio de tres estudios publicados y un cuarto estudio en revisión. Las referencias completas de los estudios que constituyen el cuerpo de la Tesis Doctoral son los siguientes:

I. **Sánchez-Migallón V**, López-Samanes Á, Terrón-Manrique P, Morencos E, Fernández-Ruiz V, Navandar A, et al. The Acute Effect of Match-Play on Hip Isometric Strength and Flexibility in Female Field Hockey Players. Applied Sciences. 2020; 10 (4900); 1–10. (Factor de impacto: 2.47; Q2 Engineering, Multidisciplinary (38/90)).

II. **Sánchez-Migallón V**, Moreno-Pérez V, López-Samanes A, Fernández-Ruiz V, Gaos S, Díaz-Maroto JB, et al. Effects of Consecutive Matches on Isometric Hamstring Strength, Flexibility Values and Neuromuscular Performance in Female Field Hockey Players. A Prospective, Observational Study. Applied Sciences. 2021; 11 (8938): 1-11. (Factor de impacto: 2.68; Q2 Engineering, Multidisciplinary (39/92)).

III. **Sánchez-Migallón V**, López-Samanes Á, Del Coso J, Navandar A, Aagaard P, Moreno Pérez Effects of consecutive days of matchplay on maximal hip abductor and adductor strength in female field hockey players. BMC Sports Science, Medicine and Rehabilitation. 2022; 14 (3): 1–9. (Factor de impacto: 2.37; Q2 Rehabilitation (30/68)).

IV. **Sánchez-Migallón V**, Moreno-Pérez V, Terrón-Manrique P, Fernández-Ruiz V, Blake C, Navandar A, López Samanes A. Monitoring modifiable injury risk factors over an in-season mesocycle in semi-professional female field hockey players. BMC Sports Science, Medicine and Rehabilitation. (Factor de impacto: 2.37; Q2 Rehabilitation (30/68)). (en revisión)

1. INTRODUCCIÓN

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1.1. Características y demandas físicas del hockey hierba

El hockey hierba es un deporte altamente practicado a nivel mundial contando con 125 países donde se disputa esta modalidad deportiva y siendo una disciplina incluida en el programa olímpico desde los Juegos Olímpicos de Londres de 1908 (1). Además, esta disciplina deportiva se caracteriza por ser un deporte donde compiten dos equipos compuestos por 11 jugadores/as durante 4 tiempos de 15 minutos (2). Presenta ciertas similitudes a otros deportes de carácter intermitente, (*e.g.*, fútbol). Sin embargo, el hockey hierba destaca por el uso de implementos para el desarrollo del juego como el stick y la necesidad del uso de protecciones (*e.g.*, protector bucal) durante el desarrollo de entrenamientos y competiciones (3). Los partidos suelen disputarse en terrenos de juego con unas dimensiones de 91.4 × 55 metros, provocando que los jugadores de hockey hierba deban poseer una excelente combinación de habilidades técnico/tácticas y unos niveles moderados-altos de condición física (4).

Dentro de los requerimientos a nivel físico, el hockey hierba se caracteriza por la realización de numerosas acciones desarrolladas de forma intermitente a elevadas intensidades (*e.g.*, sprint, aceleraciones/desaceleraciones y cambios de dirección), intercalados con acciones de moderada a baja intensidad (*e.g.*, caminar) durante el desarrollo de un partido competitivo (5–7). Con el objetivo de conocer las características de las demandas físicas de las jugadoras de hockey hierba en un partido, en los últimos años gracias a los avances tecnológicos, se han empezado a utilizar sistemas de cuantificación de análisis de los desplazamientos de los jugadores de hockey hierba como los sistemas de posicionamiento global (GPS). Específicamente, durante un partido de hockey hierba, las jugadoras recorren aproximadamente entre 5300 y 6800 metros (8,9) de los cuales, alrededor del 20% se recorren a altas velocidades (*i.e.,* >15 km/h) (7,8), permitiendo así obtener valores de referencia para conocer las demandas reales de competición y poder optimizar el estado de preparación de los deportistas (9) a la hora de gestionar las cargas de trabajo, el diseño de tareas en situaciones de entrenamiento y de competición (10). Sin embargo, es conocido que las exigencias físico-fisiológicas del hockey hierba pueden verse afectadas por aspectos como, nivel competitivo, condición física ó posición específica del jugador en el campo (11). Cabe destacar que en el año 2015 se produjo un cambio en la normativa de las reglas del juego del hockey hierba que influyó en las demandas del juego, pasándose de jugar 2 tiempos de 35 minutos a 4 tiempos de 15 minutos (12). Aunque este cambio ha podido suponer un impacto en las demandas del juego, a fecha de hoy, pocos estudios han estudiado las diferencias del cambio de normativa a nivel físico-fisiológico, ya que bajo nuestro conocimiento únicamente McMahon et al. (2019) estudiaron este fenómeno reportando que antes del cambio de normativa en el año 2015 los jugadores de hockey hierba recorrían de promedio ≈ 4900 metros por partido, mientras que después del cambio de normativa estos valores aumentaron ligeramente hasta llegar aproximadamente hasta unos ≈ 5200 metros (13). Por lo tanto, este incremento en las demandas físico-fisiológicas durante los últimos años podría estar relacionado con un incremento en la incidencia lesional en los jugadores de hockey hierba.

1.2. Epidemiología e incidencia lesional en hockey hierba

La participación en un deporte de equipo como el hockey hierba puede contribuir a mejorar la salud de los jugadores gracias a los conocidos beneficios de la práctica del ejercicio físico de forma regular, sin embargo, practicar un deporte de equipo también puede conllevar un riesgo inherente de lesiones para los deportistas de élite, así como para los de nivel amateur (14). En general, las lesiones deportivas suponen un elevado coste para las entidades deportivas (15) dificultando alcanzar un rendimiento óptimo y comprometiendo el éxito a nivel deportivo (16). Conocer la magnitud de las lesiones deportivas en un deporte, es considerado un aspecto importante para identificar el alcance de las mismas (15) y puede ayudar a los cuerpos técnicos y médicos a desarrollar estrategias adecuadas para reducir y controlar la cantidad y la severidad de las lesiones (17). Referente a la incidencia lesional, diferentes autores han estudiado las lesiones relacionadas con el hockey hierba femenino reportando una tasa lesional de 5.36 por cada 1000 horas de exposición (18). Además, se ha observado una incidencia lesional mayor durante la competición (7.87-8.49 por 1000 horas de exposición) con respecto a los periodos de entrenamiento (3.70-4.3 por 1000 horas de exposición) (18). Otros autores, entre los que podemos destacar a Theilen et al. (2016), reportan una media de 29.1 lesiones por cada 1000 horas de exposición durante competiciones deportivas en jugadoras de hockey hierba femenino (19). Cuando se compara el hockey hierba con otros deportes de carácter intermitente como el fútbol o el baloncesto, diferentes autores afirman que los jugadores de hockey hierba tienen un alto riesgo de sufrir lesiones comparable a estos deportes de equipo (1,20,21). Sin embargo, es reseñable mencionar que es difícil comparar entre estos estudios por la diferentes acepciones que podemos encontrar para el término de lesión, debido a los diferentes grupos de edades seleccionados así como los niveles de competición examinados (21). Además, las lesiones en el hockey hierba se producen tanto en situaciones de contacto como en situaciones sin contacto (22), destacando que la mayoría son producidas en situaciones sin contacto (18) localizándose principalmente en las extremidades inferiores (23,24), en concreto, cadera, muslo y rodilla (18,24,25) (Figura 1).

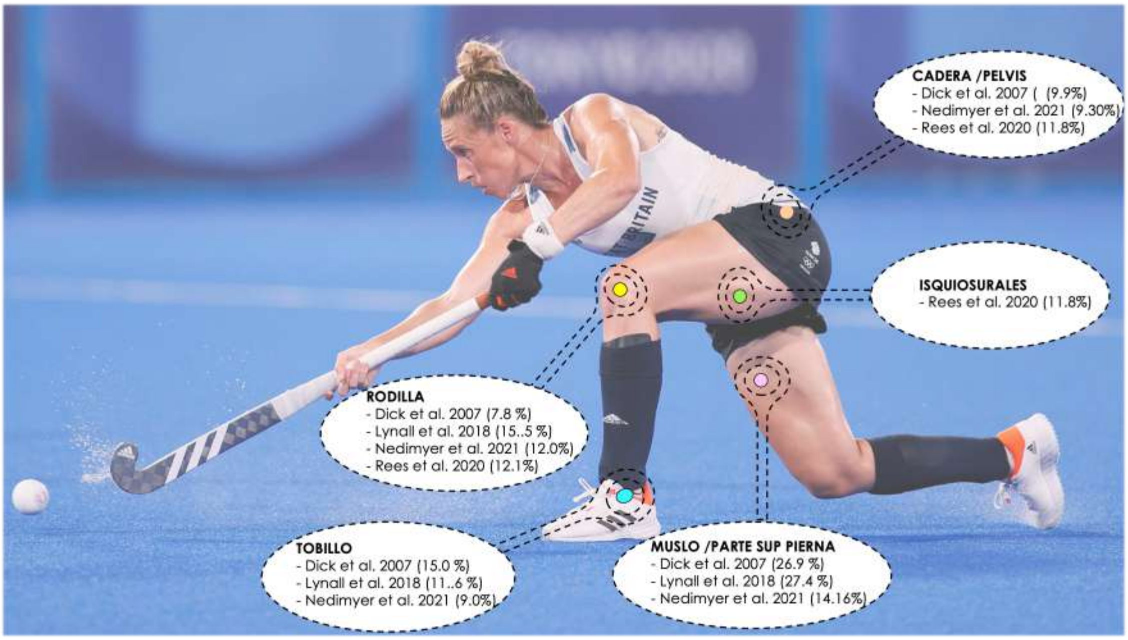

Figura 1. Localizaciones de lesión más frecuentes en hockey hierba.

Referente al tipo de lesiones, las distensiones musculares ocurren con gran frecuencia (26). Entre las lesiones a nivel muscular, destacan las lesiones de la musculatura isquiosural y las musculo-tendinosas de la región de la cadera/ingle en jugadores de hockey hierba (20,26–28). Específicamente, los desgarros musculares representan el 30% de las lesiones musculares agudas y las distensiones de la musculatura isquiosural fueron la causa del 11% de todas las lesiones por sobreuso (27). Acerca del momento de la lesión, la literatura ha descrito que durante los entrenamientos las distensiones musculares del muslo fueron el tipo de lesión más frecuente en el hockey femenino (20,24). Por otro lado, las lesiones en los músculos isquiosurales, la rodilla y el tobillo fueron las que más tiempo de baja causaron entre los deportistas de hockey hierba (28). Por tanto, para poder implementar estrategias de prevención sobre las lesiones más frecuentes en hockey hierba es imprescindible identificar los factores de riesgo que están asociados con la aparición de lesiones.

1.3. Factores de riesgo lesional

Con el objetivo de reducir la prevalencia, la gravedad y los costes derivados de las lesiones deportivas, la identificación de los factores de riesgo es esencial para intentar minimizar el riesgo de lesión en los deportistas (29–31). Un factor de riesgo puede definirse como "*cualquier atributo, característica o comportamiento de una persona/deportista que contribuye a la predisposición o susceptibilidad a sufrir una lesión*" (17,32). Actualmente, es bien conocido la naturaleza multifactorial en la aparición de las lesiones deportivas (33–35) que muestra la interacción compleja de factores de riesgo internos y externos y los mecanismos que provocan las lesiones deportivas (35). Los factores de riesgo se pueden dividirse en: I) factores de riesgo intrínsecos o internos, relacionados con el deportista (*e.g.,* las características biológicas y psicológicas del deportista) y II) factores de riesgo extrínsecos o externos, relacionados con el entorno (*e.g.,* ambientales y ajenos al deportista) (32).

Entendemos por factores de riesgo intrínsecos o internos aquellos aspectos internos del deportista. Los factores de riesgo intrínsecos ó internos se pueden dividir en modificables y no modificables (32). Entre los factores de riesgo intrínsecos modificables cabe mencionar: el control neuromuscular (34,36), la fuerza muscular (34,35,37), flexibilidad (38), la inestabilidad articular (39–41), rango de movimiento (ROM) (38,42,43), desequilibrios musculares (44), la fatiga (45) y la vuelta prematura a la competición (46). Entre los factores de riesgo intrínsecos no modificables destacan: la edad de los sujetos (40,41,47), el sexo (35,48), lesiones previas (34,40,46,49), alteraciones anatómicas (36), dominancia (50), ciclo menstrual (50), composición corporal (35,50), laxitud ligamentosa (40,51) y porcentaje de grasa corporal (49) (Figura 2). Por otro lado, entendemos como factores de riesgo extrínsecos (*i.e.,* externos) aquellos factores que no son implícitos del deportista, sino que están relacionados con causas externas a él (52). Entre los factores de riesgo extrínsecos (*i.e.,* externos) encontramos las superficies de juego (53), las protecciones utilizadas durante el juego (50), el tipo de calzado (34), las condiciones medioambientales (49), la posición del jugador (49), el número de partidos jugados (49) y el equipo rival (35) (Figura 2).

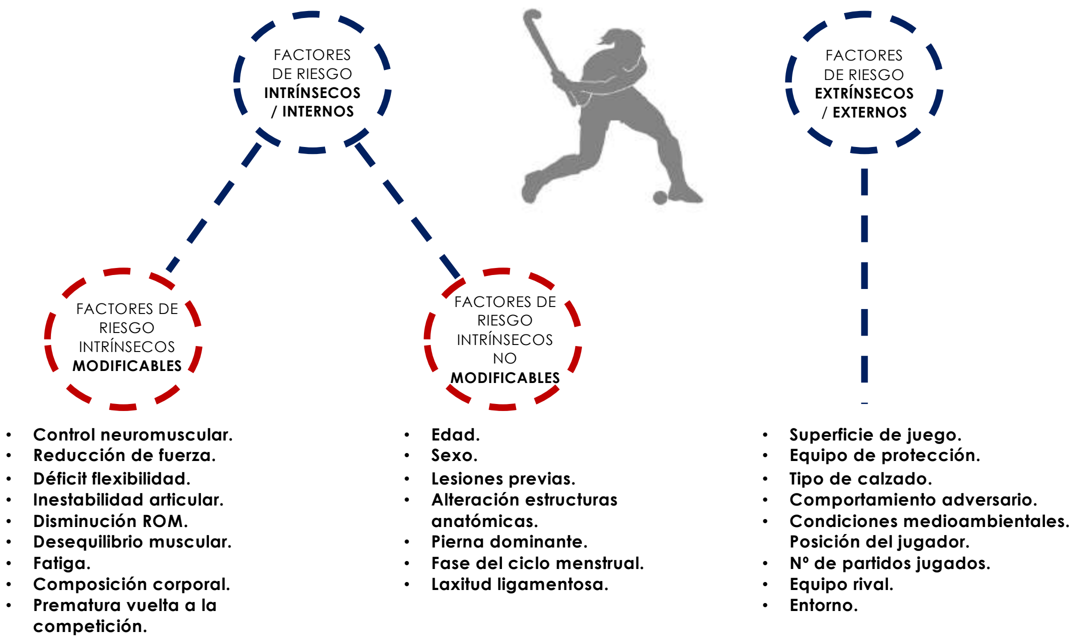

Figura 2. Factores de riesgo intrínsecos (internos) modificables y no modificables y factores de riesgo extrínsecos (externos).

Teniendo en cuenta estos factores intrínsecos (*i.e.,* modificables y no modificables) y extrínsecos, Bahr et al. (2005) propusieron un modelo que permitía comprender las diferentes causas que podían llevar a la aparición de una lesión deportiva. Para ello, expusieron todos los factores de riesgo, tanto intrínsecos como extrínsecos, que influyen en el momento en que se produce la lesión. (32) (Figura 3).

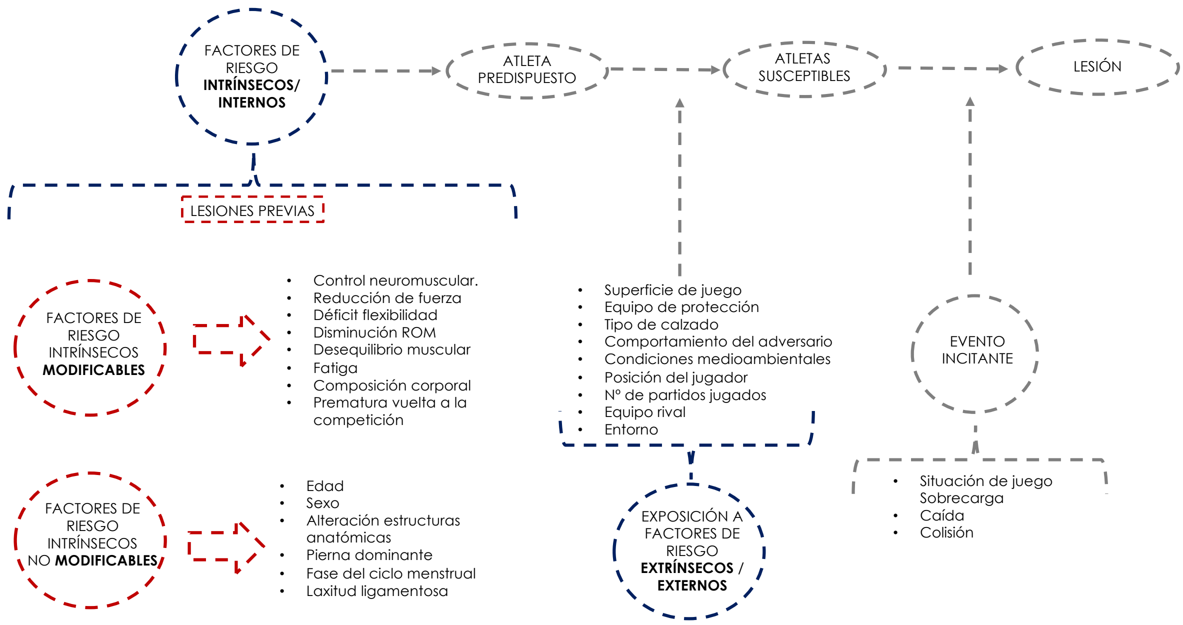

Figura 3. Factores de riesgo intrínsecos o internos (modificables y no modificables) y extrínsecos o externos.

1.4. Factores de riesgo lesional en hockey hierba y su relación con otros deportes intermitentes

La identificación de los factores de riesgo lesional sigue siendo un aspecto esencial del modelo de prevención de lesiones con el objetivo de disminuir la incidencia y la gravedad de varios tipos de lesiones (54). Mason et al. (2021) realizaron un estudio de cohortes en jugadores de hockey hierba de categoría profesional y juvenil durante una temporada en el que los autores de esta investigación determinaron que la edad, el déficit del control postural dinámico y la disputa de un mayor número de partidos fueron factores relacionados con el incremento del riesgo de lesión (1). Aunque en nuestro conocimiento no existen estudios previos que hayan analizado los factores de riesgo lesional en el hockey hierba, otras investigaciones en deportes de carácter intermitente similares al hockey hierba (*e.g.,* fútbol, rugby), han identificado varios factores de riesgo intrínsecos modificables que afectan al riesgo de sufrir una lesión inguinal (55,56) y de la musculatura isquiosural (42,57). Por un lado, los principales factores de riesgo intrínseco modificables que afectan al riesgo de sufrir una lesión inguinal según la literatura son: el déficit de flexibilidad (58,59), desequilibrio muscular (27,55,60–62) así como reducción de la fuerza isométrica de los músculos aductores de la cadera (60) y una menor fuerza muscular excéntrica (63). Las lesiones inguinales en el deporte se caracterizan por la dificultad de diagnóstico (64), la larga duración de la recuperación, (65,66) y el alto riesgo de volver a lesionarse (50).

Por otro lado, otros autores, previamente han identificado factores de riesgo intrínseco modificables que afectan al riesgo de sufrir una lesión en la musculatura isquiosural entre ellos se incluyen: edad elevada (67), lesiones previas (68), reducción de la fuerza de la musculatura isquiosural (69,70), la disminución del ROM de la extensión de la rodilla (38,42) y del ROM de la dorsiflexión del tobillo (43,71). Además, en deportes como el fútbol, la aparición de la fatiga se ha relacionado con una reducción en los valores de fuerza de la musculatura isquiosural, considerándose un factor de riesgo importante de lesión de la musculatura isquiosural (72).

1.5. Efecto agudo de un partido de hockey hierba y su relación con los factores de riesgo lesional y otros deportes.

Los partidos de hockey hierba se caracterizan por acciones intermitentes de alta intensidad (*e.g.,* aceleraciones/desaceleraciones) con un marcado carácter excéntrico durante tareas como por ejemplo durante las acciones con cambios de dirección (73). De acuerdo con la literatura existente en deportes de carácter intermitente (*e.g.*, fútbol), se ha observado que después de la disputa de un partido competitivo se producen descensos de la capacidad de realizar esfuerzos a altas velocidades. (74,75). La disputa de un partido competitivo está asociado a una gran cantidad de impactos (76) que pueden conllevar un aumento del daño muscular (*i.e.,* a través del incremento de la niveles de creatinkinasa (CK) tardando hasta 72 horas para recuperar sus valores basales*)* (77). Esta consecuencia, esto puede provocar una disminución del rendimiento físico por la aparición de la fatiga neuromuscular siendo esto uno de los factores de riesgo asociados al aumento de la incidencia lesional en deportes de carácter intermitente (78). Por fatiga podemos entender *"cualquier disminución del rendimiento muscular asociada a la actividad muscular"* (79), por tanto, la aparición de la fatiga neuromuscular puede provocar una reducción de los valores de fuerza isométrica de los músculos flexores y extensores de la rodilla después de un partido competitivo (80,81).

Estudios previos realizados en otros deportes (*e.g.*, fútbol, tenis y baloncesto) han mostrado el impacto producido por la realización de un partido en los valores de fuerza isométrica de los músculos abductores y aductores de la cadera, la fuerza isométrica de la musculatura isquiosural, así como el ROM de la flexión de la cadera y dorsiflexión del tobillo (82–84). Moreno Pérez et al. (2020) observaron que el ROM de la dorsiflexión del tobillo mostraba unos valores reducidos 48 horas después de la realización de un partido de baloncesto competitivo en jugadores de semiprofesionales. Referente a los valores de fuerza isométrica, Wollin et al. (2017) observaron que la realización de un partido de fútbol competitivo provocaba un aumento de los valores de fuerza isométrica a nivel de la musculatura isquiosural (84). Sin embargo, Moreno Pérez et al. (2019) tras la realización de un partido de tenis de competición simulada, mostraron una reducción de los valores de la fuerza isométrica de los músculos aductores de la cadera de la extremidad domiante y la ratio muscular de aductores/abductores en comparación con los valores previos al partido (85). Debido a esta variabilidad en los resultados, que puede estar influida por los diferentes patrones de desplazamiento de los diferentes deportes intermitentes, creemos que puede ser necesario determinar los factores a nivel agudo que puede provocar la realización de un partido competitivo en las variables de riesgo intrínsecas modificables en el hockey hierba femenino.

1.6. Efecto de un periodo de congestión competitiva de hockey hierba y su relación con los factores de riesgo lesional y otros deportes.

La competición en hockey hierba está caracterizada por la disputa de torneos con alta congestión competitiva especialmente durante eventos internacionales (*e.g.,* Juegos Olímpicos) (86). Normalmente, las competiciones exigen que los atletas jueguen una media de 7 partidos en un periodo de 10 días e incluso en ocasiones que disputen 3 partidos en periodos de 4 días. Por lo tanto, el calendario actual ofrece a los atletas un tiempo limitado para recuperarse entre partidos (2). Referente a lo anteriormente mencionado, podemos establecer que se denomina congestión competitiva a *"un mínimo de dos partidos sucesivos, con un periodo de recuperación entre partidos de < 96 h"* (87). En este sentido, McGuinness et al. (2020), observaron que tras la realización de 7 partidos en 2 semanas (*i.e.,* congestión competitiva) los jugadores de hockey hierba no tuvieron un tiempo suficiente para recuperarse entre partidos, debido a la gran exigencia a nivel físico-fisiológica impuesta al deportista por la propia competición, limitando su rendimiento físico en los siguientes partidos posteriores debido a una recuperación insuficiente (2,88). En este sentido, se ha relacionado que la acumulación de fatiga neuromuscular durante partidos consecutivos puede conducir a un declive en el rendimiento físico (89), provocando una reducción en la fuerza isométrica de los músculos aductores de la cadera (*e.g.*, fútbol) (90), limitando el tiempo de recuperación entre partidos, además de aumentar la fatiga residual que puede favorecer el riesgo de la aparición de lesiones (91), como así demuestran las investigaciones epidemiológicas que muestran un mayor índice de lesiones en competiciones con cuatro o menos días de recuperación en comparación con competiciones con seis o más días de recuperación (92). Sin embargo, se desconoce el efecto de congestión competitiva en las variables de riesgo intrínsecas modificables en el hockey hierba femenino.

1.7. Efecto de un mesociclo competitivo de competición en hockey hierba y su relación con los factores de riesgo lesional y otros deportes.

El control de la carga de entrenamiento a nivel deportivo es crucial para comprender las respuestas individuales al entrenamiento y la fatiga asociada a las demandas generadas (93). En los últimos años, el uso de formas no invasivas de monitorización de los jugadores (*e.g.*, GPS) ha demostrado su efectividad para conocer la respuesta de los jugadores a diferentes situaciones de entrenamiento y competición (94,95). Dentro de los factores de riesgo que predisponen a los deportistas a sufrir lesiones en diferentes deportes intermitentes, existe cierta controversia (96) que puede atribuirse a la diferente metodología empleada en muchos de los estudios (97), ya que, la mayoría de la literatura realizan análisis de los factores de riesgo únicamente durante el periodo preparatorio de la temporada (*e.g.,* pretemporada) (98). Las mediciones empleadas exclusivamente durante el periodo de la pretemporada, obvia los cambios que se producen en las variables mecánicas (*e.g.,* fuerza, ROM, estabilidad) durante el transcurso de la temporada competitiva (84).

Por otra parte, la fatiga acumulada durante la temporada competitiva puede influir en el riesgo de lesión inguinal en futbolistas profesionales (99), de ahí la importancia de medirlo en diferentes momentos de la temporada (100–102). Wollin et al. (2018) propusieron una estrategia de detección y gestión tempranas mediante la monitorización de la fuerza isométrica de los aductores de la cadera durante el transcurso de una temporada competitiva

(102). Esta herramienta de monitorización sencilla de implementación ha sido utilizada recientemente en diferentes deportes de carácter intermitente y se ha relacionado con la percepción subjetiva del esfuerzo (RPE), la calidad del sueño, dolor muscular general, fatiga, nivel de estrés y estado de ánimo (103,104). Sin embargo, se desconoce la monitorización de diferentes factores de riesgo de lesión intrínsecos modificables durante un mesociclo competitivo en jugadoras de hockey hierba femenino.

1.8. Monitorización específica para los factores de riesgo lesional modificables

La monitorización de los factores de riesgo durante el proceso competitivo es un elemento esencial del control de la posibles adaptaciones generadas por el entrenamiento, ya que permite clarificar todos aquellos factores o elementos que pueden posibilitar la aparición de lesiones y por lo tanto, establecer estrategias preventivas. Por ello, diferentes factores de riesgo anteriormente descritos se han monitorizado en la presente Tesis Doctoral mediante diferentes test específicos:

1.8.1. Fuerza isométrica de los músculos flexores de la rodilla

La fuerza isométrica de los músculos flexores de la rodilla de ambas extremidades se midió con un dinamómetro portátil (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA) y la evaluación se realizó colocando al sujeto desde la posición prona, con 15 grados de flexión de la rodilla. Uno de los examinadores colocó el dinamómetro en la parte distal del tríceps sural, tres centímetros por encima de la línea bimaleolar, mientras que otro examinador colocó la palma de la mano sobre el sacro del participante, para evitar la elevación durante la prueba (105). El primer examinador pidió a la jugadora que flexionase la rodilla para llevar el talón del pie a los glúteos. Las jugadoras realizaron una contracción isométrica voluntaria de cinco segundos contra el dinamómetro, repitiéndolo dos veces por cada pierna. Se dejó un período de descanso de treinta segundos entre cada medición (89,102). Se realizaron dos repeticiones tanto para la pierna dominante como para la no dominante y se cogió el valor más alto registrado para el análisis posterior. Este valor se normalizó en función de la masa corporal de la jugadora (N/kg) (Figura 4).

Figura 4. Test de medición de la fuerza isométrica de los músculos flexores de la rodilla.

1.8.2. Fuerza isométrica de los músculos abductores y aductores de la cadera

La medición de la fuerza isométrica de los músculos abductores y aductores de la cadera en ambas extremidades se realizaron con un dinamómetro manual (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA) de acuerdo al protocolo establecido por Thorborg et al. (2010). Cada jugadora se acostó en posición decúbito supino sobre la camilla, con las caderas en posición neutra y se le estabilizó sujetándole a ambos lados de la camilla. El examinador aplicó una resistencia estática mediante un dinamómetro colocado a cinco centímetros del borde proximal del maléolo medial (*i.e.,* para el aductor) y lateral (*i.e.,* para el abductor) mientras las jugadoras realizaban una contracción isométrica voluntaria de cinco segundos contra el dinamómetro (106). Se realizaron dos repeticiones para la extremidades dominante y no dominante respectivamente, con un período de descanso de treinta segundos entre repeticiones. Además, se seleccionó el valor más alto de fuerza isométrica de los músculos abductores y aductores de la cadera obtenida en la extremidad dominante y no dominante para el posterior análisis estadístico. Los datos se normalizaron por la masa corporal del participante (N/kg) tanto para la abducción (Figura 5) como para aducción de la cadera (Figura 6).

Figura 6. Test de medición de la fuerza isométrica de los músculos abductores de la cadera.

Figura 5. Test de medición de la fuerza isométrica de los músculos aductores de la cadera.

1.8.3. ROM de la flexión de la cadera

Para medir el ROM de la flexión de la cadera, se realizó el Straight Leg Raise test (SLR) (107). Para ello, se utilizó un inclinómetro ISOMED (Portland, OR, EE.UU.) con una barra de extensión telescópica. El inclinómetro se colocó aproximadamente en el maléolo externo y el brazo distal se alineó de forma paralela a una línea imaginaria bisectriz de la extremidad. La prueba finalizó cuando se cumplieron uno o varios de los siguientes criterios (108): (a) el examinador fue incapaz de continuar el movimiento articular evaluado debido a la gran resistencia desarrollada; (b) el examinador no pudo continuar con el movimiento de la articulación evaluada debido a la gran resistencia desarrollada por el grupo muscular estirado; (c) la jugadora informó de una sensación de incomodidad o aparición de dolor; (d) los examinadores observaron compensaciones que pueden aumentar la puntuación. Se realizaron dos repeticiones tanto para la extremidad dominante como para la no dominante, y el valor más alto registrado se tuvo en cuenta para el análisis posterior (Figura 7).

Figura 7. Test de medición del ROM de la flexión de la cadera.

1.8.4. ROM de la dorsiflexión del tobillo

El ROM de la dorsiflexión del tobillo se realizó siguiendo el protocolo propuesto por Calatayud et al. (2015) utilizando el test del sistema de movimiento LegMotion, (Check your Motion, Albacete, España). Los participantes se colocaron en posición de pie en la plataforma con el pie que se va a medir en la escala de medición. El pie contralateral se colocó fuera de la plataforma con los dedos del pie en su borde. Cada jugadora realizó la prueba colocando las manos en las caderas, con el pie asignado en el centro de la línea longitudinal, y justo detrás de la línea transversal de la plataforma. Mientras mantuvieron esa posición, las jugadoras fueron instruidas para realizar una flexión de la rodilla, haciendo que se moviesen hacia adelante para contactar la rótula con la varilla metálica. Cuando la participante fue capaz de mantener el contacto del talón con el suelo y llevar la rodilla a la máxima distancia, la varilla metálica se alejó de la rodilla y se registró la siguiente distancia alcanzada (109). Se realizaron dos repeticiones con cada pierna, con diez segundos de recuperación pasiva entre cada prueba, y se eligió la puntuación más alta entre estas mediciones para el análisis posterior (Figura 8).

Figura 8. Test de medición del ROM de la flexión dorsal del tobillo.

1.8.5. Carga interna

1.8.5.1. Cuestionario wellness (5-WQ)

Este cuestionario evaluó la fatiga subjetiva, la calidad del sueño, el dolor muscular general, los niveles de estrés y el estado de ánimo. Cada jugadora era puntuada utilizando el 5-WQ siguiendo el protocolo propuesto por McLean et al. (2010). Cada pregunta se puntuó entre 1 a 5 puntos (*i.e.,* con un incremento de 0.5 puntos), en la que los valores 1 (*i.e.,* nivel bajo) y 5 (*i.e.,* nivel alto) representaban peores o mejores niveles de bienestar, respectivamente. El grado de "bienestar general" se determina calculando la suma de las cinco puntuaciones (103) (Figura 9).

Figura 9. Cuestionario wellness (5-WQ).

1.8.5.2. Escala de percepción subjetiva del esfuerzo (RPE)

La carga interna de los entrenamientos y partidos se obtuvo utilizando la RPE (110). El valor RPE se determinó utilizando la escala CR-10 adaptada de Borg, que va de (*"ningún esfuerzo"* (1 punto) a *"esfuerzo máximo"* (10 puntos)) registrada treinta minutos después del final del partido (110). Además, se obtuvo el valor de RPE sesión (s-RPE) para cada partido multiplicando la calificación de intensidad de la sesión (valor RPE) por la cantidad de minutos disputados por el jugador durante el partido (tiempo efectivo de juego, en minutos), para obtener un valor s-RPE expresado en unidades arbitrarias (U.A.) (111) (Figura 10).

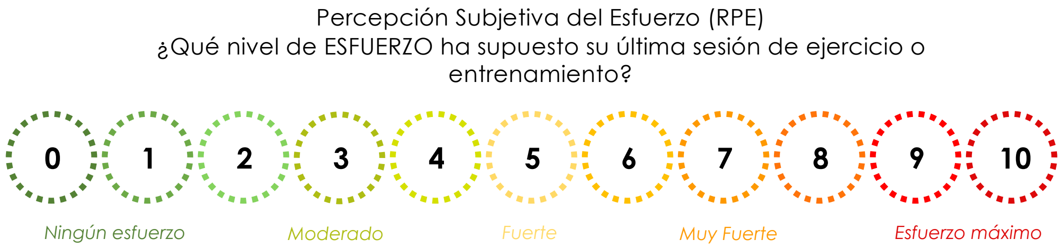

Figura 10. Escala de medición de percepción subjetiva del esfuerzo (RPE).

1.8.5.3. Test de calidad de recuperación (TQR)

Para determinar el estado de recuperación autopercibido, los jugadores de hockey hierba completaron el TQR, descrito por Kenttä et al. (112). Esta escala oscila entre 6 y 20 puntos, siendo 6 puntos el valor mínimo de recuperación (*i.e.,* recuperación nula o inexistente), y 20 puntos el valor más alto de recuperación (*i.e.,* recuperación total e incondicional) (Figura 11).

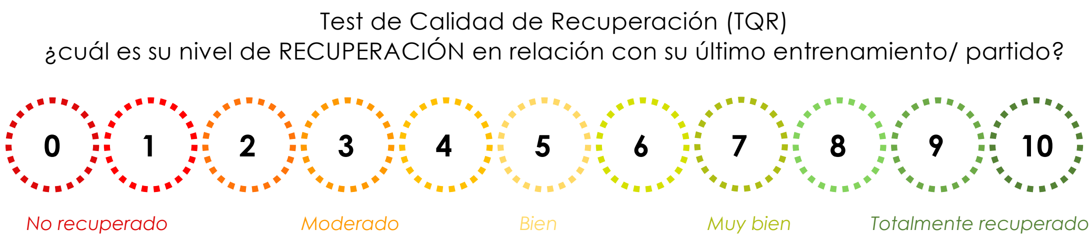

Figura 11. Test de calidad de recuperación (TQR).

1.8.6. Carga externa

1.8.6.1. Salto con contramovimiento (CMJ)

El test de salto con contramovimiento (CMJ) se realizó bilateralmente para evaluar la fatiga neuromuscular acumulada (113). A la orden de los examinadores, las jugadoras flexionaron las rodillas hasta llegar a la posición de 90 grados y saltaron tan alto como pudieron mientras mantenían las manos en las caderas. Se les indicó que saltasen y aterrizasen en el mismo lugar, con el cuerpo en posición vertical y las piernas extendidas durante el salto hasta el aterrizaje (114). Para la realización de la medición se utilizó la plataforma de contacto Chronojump Boscosystem (Barcelona, España), (115). Las jugadoras completaron dos repeticiones intercaladas con cuarenta y cinco segundos de recuperación pasiva. La medida más alta registrada se tuvo en cuenta para el análisis posterior (Figura 12).

Figura 12. Test de medición de salto con contramovimiento (CMJ).

1.8.6.2. Sistema de posicionamiento global (GPS)

Para determinar las demandas físicas, todas las jugadoras utilizaron un sistema de posicionamiento global (GPS) (Wimu ProTM, RealTrack Systems, Spain), que se fijó a un chaleco de lycra entre los hombros. Cada jugadora llevó unidades individuales durante los partidos y utilizó la misma unidad en ambos partidos (*i.e.,* cuando jugaron más de uno) para reducir el error de medición (116) (Figura 13).

Figura 13. Sistema de posicionamiento global (GPS).

2. OBJETIVOS E HIPÓTESIS

2. OBJETIVOS E HIPÓTESIS

2.1. Objetivos:

El objetivo de esta Tesis Doctoral consistió en el estudio de la monitorización de los efectos agudos, crónicos y de congestión sobre factores de riesgo de lesión modificables en jugadoras de hockey hierba femenino.

- *Objetivo estudio 1*

Determinar el efecto provocado por la realización de un partido simulado de hockey hierba sobre la fuerza isométrica de los músculos flexores de la rodilla, abductores y aductores de la cadera, además de evaluar el ROM de la flexión de la cadera y dorsiflexión de tobillo en jugadoras de hockey hierba.

- *Objetivo estudio 2*

Examinar los efectos provocados por la congestión competitiva sobre la fuerza isométrica de los músculos flexores de la rodilla y el ROM de la flexión de la cadera y de la dorsiflexión de tobillo en jugadoras de hockey hierba.

- *Objetivo estudio 3*

Analizar los efectos provocados por la congestión competitiva sobre la fuerza isométrica de los músculos abductores y aductores de la cadera en jugadoras de hockey hierba.

- *Objetivo estudio 4*

Monitorizar las fluctuaciones que se producen durante un mesociclo (16 semanas) durante una temporada competitiva sobre los factores intrínsecos modificables de riesgo de lesión en jugadoras de hockey hierba.

2.2. Hipótesis:

En el desarrollo de la presente Tesis Doctoral se plantearon las siguientes hipótesis basándose en las limitaciones de la literatura previa y que han sido corroboradas a través de los estudios realizados:

- *Hipótesis estudio 1*

En base de los resultados en diferentes deportes intermitentes como baloncesto (82), tenis (83) y fútbol (84) la disputa de un partido de hockey simulado puede provocar una reducción de los valores de la fuerza isométrica en los músculos abductores y aductores de la cadera así como de la fuerza isométrica los músculos flexores de la rodilla y una reducción en el ROM de la flexión de la cadera y dorsiflexión del tobillo en jugadoras de hockey hierba.

- *Hipótesis estudio 2*

Basándonos en los resultados obtenidos en deportes de dinámica intermitente como el fútbol (90), la congestión competitiva de hockey hierba conllevará una reducción de la fuerza isométrica los músculos flexores de la rodilla y una disminución en el ROM de la flexión la cadera y dorsiflexión de tobillo en jugadoras de hockey hierba.

- *Hipótesis estudio 3*

La disputa de un periodo de congestión competitiva de hockey hierba puede provocar una reducción de los valores de la fuerza isométrica de los músculos abductores y aductores de la cadera, así como un empeoramiento del estado de recuperación auto percibido en jugadoras de hockey hierba como ha sido observado en otros parámetros físicos en previos estudios (2).

- *Hipótesis estudio 4*

Como se ha podido observar en otros estudios de deportes de dinámica intermitente (117), la monitorización durante un mesociclo durante una temporada competitiva puede provocar un descenso de los valores de la fuerza isométrica de los músculos abductores y aductores de la cadera, así como de la fuerza isométrica los músculos flexores de la rodilla y los valores de ROM de la flexión de la cadera y dorsiflexión de tobillo en jugadoras de hockey hierba incrementarán a lo largo de un periodo de 16 semanas.

3. ARTICULOS PUBLICADOS

3. ESTUDIOS PUBLICADOS

3.1. Estudio 1: The Acute Effect of Match-Play on Hip Isometric Strength and Flexibility in Female Field Hockey Players.

Sánchez-Migallón V, López-Samanes Á, Terrón-Manrique, P, Morencos E, Fernández-Ruiz V, Navandar A, Moreno-Pérez V (2020). **The Acute Effect of Match-Play on Hip Isometric Strength and Flexibility in Female Field Hockey Players.** Applied Sciences; 10(4900) 1-10.

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Article

The Acute Effect of Match-Play on Hip Isometric Strength and Flexibility in Female Field Hockey Players

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Abstract: The aim of this study was to determine the acute effect of simulated field hockey match-play on isometric knee flexion, adductor (ADD) and abductor (ABD) strength, adductor/abductor (ADD/ABD) strength ratio, countermovement jump height (CMJ), hip flexion and ankle dorsiflexion range of motion (ROM). Thirty competitive female field hockey players (23.0 ± 3.9 years old) participated in the study. Apart from the afore-mentioned variables, external (through GPS) and internal load (through RPE) were measured before (pre-match) and immediately after simulated hockey match-play (post-match) in both limbs. Isometric knee flexion strength (+7.0%, $p = 0.047$) and hip flexion ROM (+4.4%, $p = 0.022$) were higher post-match in the non-dominant limb, while CMJ values reduced (−11.33%, $p = 0.008$) when comparing from pre-match data. In addition, no differences were observed for isometric hip ADD, ABD, ADD/ABD strength ratio, passive hip flexion ROM and ankle dorsiflexion ROM test. A simulated field-hockey match produces an increment in hip isometric strength and hip flexion ROM values in the non-dominant limb and a decrease in jump height capacity. As a result, CMJ assessment should be considered post-match in order to identify players who would require further rest before returning to training.

Keywords: risk factors; performance; team sport; fatigue; groin; hamstring

1. Introduction

Field hockey is an intermittent sport where hockey players perform repeated actions such as changes of direction, dribbles, sprints, accelerations, decelerations and body impacts alternating high and moderate with low intensity efforts [1]. During an official field hockey match, consisting of four quarters of fifteen minutes each, hockey players cover around 6000–8000 m [2,3] primarily at low and medium intensities, with high-intensity efforts (>19 km/h^{-1}) making up around 6% of the total playing time [2]. Previous studies have reported an average of 14 to 48 injuries per 1000 h attributed to the high physical demands of this sport [4,5]. Specifically, most of these field hockey injuries have been reported in the lower limbs, especially in the thigh and groin [6], with the hamstring strain injury being the most frequent muscle injury (32%) [4], followed by the groin injury (10%) [6]. Consequently, identification of the risk factors associated with groin and/or hamstring injury occurrence is essential.

In this sense, previous studies in different intermittent sports such as football [7], tennis [8] and ice hockey [9], have identified several modifiable intrinsic risk factors as causing an increased likelihood of developing groin and hamstring injuries. Among them, a weakness in the isometric adductor strength (ADD) [7,10] and lower adduction/abduction strength ratio (ADD/ABD) [9] have been associated with a higher risk of sustained groin injuries, while a lower hamstring strength [11–13], decreased range of hip flexion [14] and ankle dorsiflexion range of motion (ROM) have been associated with hamstring strain injuries [15]. However, some conflicting results have been found in literature regarding these factors [16–18]. Notably, most researches have investigated these risk factors before the commencement of the season or in off-season situations [19]. However, the ability to capture fluctuations in ROM and/or strength profile in-season, specifically in response to match-play, has not been studied [19].

Similar to other intermittent sports, field hockey players reported a higher incidence of injuries during matches compared to training [6] probably due to the higher intensity reported in matches versus training, and the appearance of fatigue [20,21]. It is well known that there is a decrement of lower limbs' power performance after match-play, and this measure is one of the potential factors in injury causation in intermittent sport [22]. Appearance of fatigue is known to reduce sports performance through reduced muscle strength, neuromuscular control and ROM [22]. In this line, the impact of match-play on ADD, ABD, hamstring strength and ROM during hip flexion and ankle dorsiflexion has been studied recently in several sports such as tennis, football and basketball [19,23–25]; however, to the best of the authors' knowledge, there is no information regarding this effect in field hockey. Therefore, the aim of this study was to examine the acute effect of hockey match-play on several risk factors such as isometric knee flexion and hip ADD and ABD strength, ADD/ABD strength ratio, passive hip flexion ROM and ankle dorsiflexion ROM and countermovement jump (CMJ) in elite female hockey players.

2. Materials and Methods

2.1. Subjects

Thirty highly competitive female hockey players (age, 23.0 ± 3.9 years; body mass, 60.0 ± 7.5 kg; height, 1.60 ± 0.09 m; body mass index, 22.0 ± 2.1 kg·m^2; hours per week, 9.4 ± 4.4; playing experience, 14.3 ± 4.9 years) volunteered to participate in this investigation. The players were recruited from two different professional teams. The inclusion criteria were: (a) To be healthy and able to complete a full game of field hockey; (b) to be uninjured and declared match-fit by the medical and coaching staff at the time of the experiment and not to have taken any type of medication to treat pain or musculoskeletal injuries at the time of the study; and (c) to have an absence of late onset muscle pain during the training session [26]. All players were informed of the tests they were to perform and signed the consent form. The experimental procedure of this study was conducted in accordance with the Declaration of Helsinki and the approval by the Ethics Committee of the University Francisco de Vitoria, number 45/2018.

2.2. Experimental Protocol

Following their arrival, female hockey players filled out a questionnaire which included personal information such as body mass, height, medical history, training frequency and experience (practice hours per week and playing experience in field hockey). Testing (i.e., ROM, isometric strength, and countermovement jump) was performed in the clinical area of each field hockey club. Testing was conducted by two sports physiotherapists: a senior physiotherapist with over nineteen years of experience and a junior physiotherapist with two years of experience, to ensure participants' positioning during measurements. Considering recommendations by Wollin, Thorborg and Pizzari [19], the testing order of the players and the selection of the leg tested were randomly chosen prior to the pre-match test. Pre-match testing was performed 60 min prior to match-play, and the post-match re-testing was performed immediately after the match. At the beginning of the pre-match testing, participants carried out a standardized warm-up that consisted of 5 min of jogging at 10 km·h^{-1} and 5 min of static stretches and joint mobility exercises [27]. Subsequently, participants played the simulated field hockey match according to the International Hockey Federation rules on a rectangular surface, 91.40 m long and 55.00 m wide. The external load of the simulated matches were estimated using a global positioning system (GPS) (Wimu ProTM, RealTrack Systems, Spain) placed in specific vests worn by the players, these devices operated at a sampling frequency of 10 Hz and its validity and reliability have been reported previously [28]. In addition, subjective internal load of the game was obtained using the modified RPE scale (i.e., 0–10 points) within 30 min of match termination [29]. The following variables were used to assess the external load during match-play, total distance covered per minute at different velocities ranges during a 60 min match as previously reported [3]. To reduce the interference of uncontrolled variables, all subjects were instructed to maintain their habitual lifestyle and normal dietary intake before and during the study, and refrain from caffeine ingestion 24 h before the experiment [30].

2.3. Isometric Strength of Abductors (ABD) Adductors (ADD) and Knee Flexion

Hip isometric ADD and ABD strength were measured according to the methodology previously reported [31] using a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA). Participants were placed in a supine position with their hips in a neutral position and told to stabilize themselves by holding onto the sides of the table. Examiner 1 applied a resistance on a fixed position (ABD: At 5 cm proximal to the lateral malleolus; ADD: At 5 cm proximal to the medial malleolus). The hockey players were instructed to exert a voluntary contraction for a maximum of 5 s against the dynamometer [31]. Two attempts were registered for each contraction of each limb and a 30 s rest period between attempts. Regarding the isometric knee flexion, the strength test was evaluated by placing the subject in the prone position, with 15 degrees of knee flexion and with their hips in a neutral position [32]. Examiner 1 placed the dynamometer on the distal portion of the sural triceps, three centimeters above the bimalleolar line. Examiner 2 clamped the subject's pelvis over the sacrum, to prevent elevation during the test. Examiner 1 requested the participant to flex their knee with the intention of bringing the heel of the foot to the gluteus. Similarly, two repetitions were recorded for each limb with a 30 s rest between attempts. Isometric hip ADD, ABD and knee flexion strength was expressed as the maximal hip and knee torque per kilogram of body weight (Nm·kg^{-1}) using the external lever arm and body weight of each participant. The mean value out of two attempts was recorded and selected for further analysis.

2.4. Ankle Dorsiflexion ROM

Unilateral ankle dorsiflexion ROM was measured with LegMotion System (LegMotion, Check your Motion, Albacete, Spain). The testing was carried out following the methodology previously described by Calatayud et al. [33]; participants were in a standing position on the LegMotion System with the tested foot on the measurement platform and the contralateral foot out of the platform with the toes at the edge of it. Each player performed the test with their hands on the hips and the assigned foot in the middle of the longitudinal line behind the transversal line of the platform. From this position, subjects were instructed to flex the knee forwards, placing it in contact with the metal stick. When the subject was able to maintain heel and knee contact, the metal stick was progressively moved away from the knee, and the following achieved distance was recorded. Two attempts were allowed for each limb (i.e., left and right), with 15 s of passive recovery between trials. The mean value of the two attempts was selected for further analysis.

2.5. Hip Flexion ROM

Passive hip flexion ROM values with the knee extended were evaluated with the Straight Leg Elevation Test (SLET). Participants made two maximum passive attempts for the dominant and non-dominant leg, when the difference between one attempt and another was greater than 5%, a third attempt was made, selecting the mean value of the two attempts whose results were similar for further statistical analysis [34]. A unilevel inclinometer ISOMED (Portland, OR, USA) with a telescopic was used for the measurement. The test ended with one or more of the following criteria: (a) The examiner was unable to continue the joint movement evaluated due to the high resistance developed by the stretched muscle group; (b) The participant reported an important sensation of discomfort; or (c) The examiners noted compensations that could increase the ROM [35]. The inclinometer was placed approximately on the external malleolus and the distal arm was aligned parallel to an imaginary bisecting line of the extremity [35]. The mean value out of two attempts was recorded and selected for further analysis.

2.6. Countermovement Jump (CMJ)

Participants carried out three repetitions of CMJ using a contact mat jump system (Chronojump Boscosystem, Barcelona, Spain) with their arms on hips [36]. They were instructed to jump and land in the same place, with the body in an erect position during the jump until landing. Each participant performed two maximal CMJs interspersed with 45 s of passive recovery. In addition, the mean value out of two attempts was recorded and selected for further analysis.

2.7. Statistical Analysis

Data were calculated as means/standard deviation. The Shapiro–Wilk test was selected to assess the normal distribution. All study variables were compared using a *t* test (pre- vs. post-match). The statistical significance level was set at $p < 0.05$. Cohen's effect sizes were calculated and presented with their respective 95% confidence intervals (C.I.) based on the following criteria: Trivial effect (0–0.19), small effect (0.20–0.49), medium effect (0.50–0.79) and large effect (0.80 and greater) [37]. All the statistical analyses were completed using the SPSS software version 25 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Match-Play Workload

The internal match-play workload was 6.83 ± 0.80 units (RPE). In addition, female hockey players covered a mean distance of 5456.50 ± 699.09 m across different velocity profiles (Table 1).

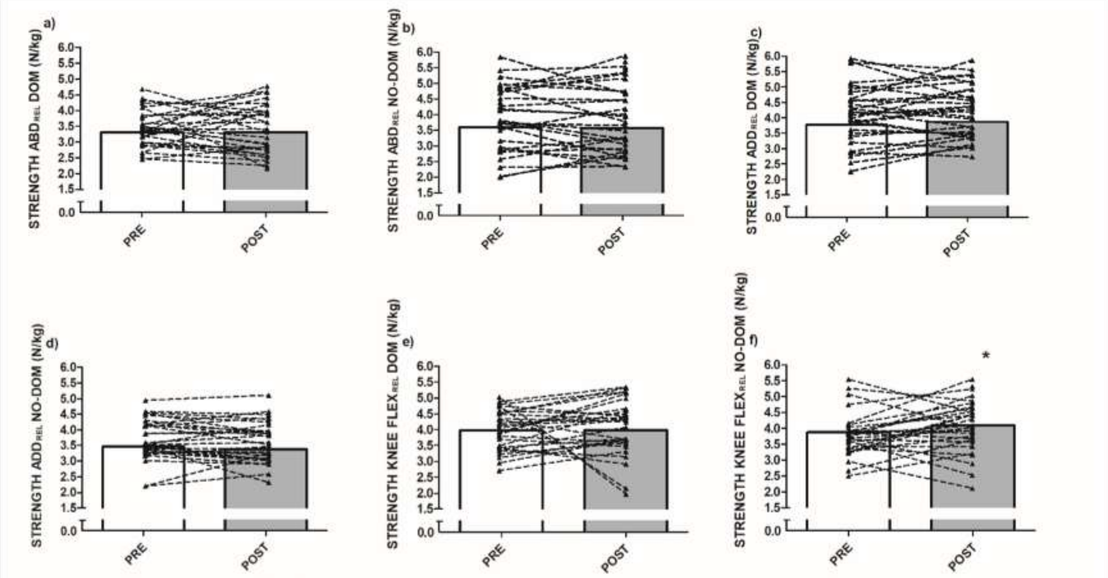
Table 1. Mean distances and % of total distance covered during the match at different velocity ranges.

Velocity Range	Distance Covered (m)	Total Distance (%)
0.0–6.0 km·h^{-1}	2692.04 ± 614.70	49.36 ± 9.71
6.1–12.0 km·h^{-1}	1781.15 ± 380.97	32.47 ± 4.53
12.1–18.0 km·h^{-1}	851.66 ± 282.16	15.74 ± 5.48
18.1–21.0 km·h^{-1}	107.59 ± 75.87	1.98 ± 1.40
21.1–24.0 km·h^{-1}	21.59 ± 23.66	0.40 ± 0.44
>24.1 km·h^{-1}	2.47 ± 6.19	0.05 ± 0.12

Abbreviations: km·h^{-1} = kilometers/hour; m = meters.

3.2. Isometric Strength and Countermovement Jump

No statistical differences were seen in relative isometric hip ABD strength in the dominant (+2.42%, $p = 0.864$, ES [C.I.] = 0.01 [−0.08, 0.11]) (Figure 1a) and non-dominant limb (−1.46%, $p = 0.834$, ES [C.I.] = −0.02 [−0.12, 0.07]) (Figure 1b); nor in the relative isometric hip ADD strength in the dominant(−2.10%, $p = 0.399$, ES [C.I.] = 0.10 [0.00, 0.19]) (Figure 1c) and non-dominant limb (+3.38%, $p = 0.349$, ES [C.I.] = 0.11 [0.02, 0.21]) (Figure 1d). In addition, no differences were obtained in ADD/ABD strength ratios in dominant (1.14 vs. 1.19, $p = 0.220$, ES [C.I.] = 0.28 [0.19–0.37]) and non-dominant limbs (0.98 vs. 0.96, $p = 0.600$, ES [C.I.] = 0.14 [0.05–0.24]) when comparing them pre and post-match. However, for isometric knee flexion strength, statistical differences were obtained in the non-dominant limb (7.0%, $p = 0.047$; ES [C.I.] = 0.29 [0.20, 0.38]) (Figure 1f) but no differences were reported in the dominant limb (0.1%, $p = 0.983$; ES [C.I.] = 0.11 [0.02, 0.21]) (Figure 1f). Finally, neuromuscular fatigue was measured by a countermovement jump test after match-play (23.0 ± 4.9 vs. 20.5 ± 6.6 cm, $p = 0.008$, ES [C.I.] = 0.44 [0.34, 0.53]).



Abbreviations: DOM = dominant; NO-DOM = non-dominant; ADD = Adductor; ABD = Abductor; FLEX = flexion; REL = relative. * Significant differences compared to the PRE values at p < 0.05.

Figure 1. Hip and knee isometric hip abduction (ABD), adduction (ADD) and knee flexion strength values. (**a**) Relative isometric hip ABD strength in the dominant limb; (**b**) relative hip abductor strength in the non-dominant limb; (**c**) relative hip adductor strength in the dominant limb; (**d**) relative hip adductor strength in the non-dominant limb; (**e**) relative knee flexion strength in the dominant limb; (**f**) relative knee flexion strength in the non-dominant limb.

3.3. Hip Flexion and Ankle ROM

A significant increase was found when comparing the ROM in the hip flexion (straight leg elevation raise test) for the non-dominant limb (+4.38% $p = 0.022$). However, no differences were found in the dominant limb (+1.19%, $p = 0.753$) (Table 2). In addition, no differences were obtained for ankle dorsiflexion ROM values after field hockey match in the dominant limb (−3.77%; $p = 0.316$) and non-dominant limb (−2.34%; $p = 0.362$) (Table 2).

Table 2. Hip and ankle range of motion (ROM).

Variables	Pre-Match	Post-Match	*p*-Value	ES [95%CI]
Straight Leg Elevation Test DOM (°)	81.1 ± 12.3	82 0 ± 9.1	0.753	0.09 [0.00–0.18]
Straight Leg Elevation Test NO-DOM (°)	81.4 ± 10.3	84.9 ± 9.9	0.022 *	0.35 [0.26–0.45]
Ankle dorsiflexion DOM (cm)	10.9 ± 2.5	10.4 ± 2.7	0.316	0.16 [0.06–0.25]
Ankle dorsiflexion NO-DOM (cm)	11.1 ± 2.7	10.8 ± 2.7	0.362	0.10 [0.00–0.19]

Abbreviations: DOM = dominant-side; NO-DOM = non-dominant side; ° = degrees; cm = centimeters; * Significant differences compared to the PRE values at $p < 0.05$.

4. Discussion

The aim of this study was to determine the acute effect of hockey match-play on several risk factors such as isometric knee flexion, hip ADD and ABD strength, ADD/ABD strength ratio, passive hip flexion ROM, ankle dorsiflexion ROM and CMJ in competitive female hockey players. To the best of the authors' knowledge, this is the first study that analyzed the acute effects of hockey match-play on several risk factors in female athletes. The main results showed that hockey match-play acutely produced a decrease in CMJ performance, and an increase in isometric knee flexion strength and hip flexion ROM with knee extension in the non-dominant limb. However, no significant differences were found in isometric hip ADD, ABD strength and ADD/ABD strength ratio and ankle dorsiflexion ROM in both limbs.

The CMJ is one of the most important tests used to evaluate the lower-limb muscles fatigue [38,39]. The results in this study showed a significant reduction in levels of performance in CMJ (−11.33%) after match-play which was in agreement with previous studies conducted in other intermittent sports [40,41]. Recent research from Kim and Kipp [42] has shown that the gastrocnemius, soleus and vastus muscles have the largest contribution to vertical center of mass (COM) acceleration during the CMJ, and the soleus and gastrocnemius muscles function closest to their maximal capacities. If one were to look at the distances covered by the players (Table 1), one can observe that most of the distance had been covered at lower intensities. Here, the production of the horizontal force has been attributed to the muscles of the lower limb: namely tibialis anterior, gastrocnemius and soleus [2]. This indicates that a greater fatigue caused by distances ran at these intensities appears to have increased the neuromuscular fatigue associated with the CMJ, leading to a decrease in performance. In addition, albeit speculative, another possible reason for the decrease values in the CMJ test after match-play has been attributed to disruptions within the muscular fibers [41], increasing some markers of muscle damage (e.g., creatine-kinase, myoglobin) after a match in intermittent sports [41,43]. Moreover, previous literature described the inflammatory responses and fibrillar damage to the muscles and showed a decrease in metabolic indices in athletes after playing a match; however, this speculation requires further investigation.

Muscle strength in the lower limbs is essential to produce explosive actions in hockey (e.g., accelerations, changes of direction). The results obtained in the present study showed improvements in the isometric knee flexion strength (+7.0%) immediately post-match in the non-dominant limb. While no previous study has reported knee flexion strength values in field hockey players, these results differ from previous studies conducted in other intermittent sports, which revealed a lower knee flexion strength post-match-play [19,44]. The lack of agreement between studies could be related to the different match-play demands of the participants (e.g., total distance covered, duration of match, etc.). While in the current study hockey players reported an average of 5456.50 ± 699.09 m total distance covered and 21.59 ± 23.66 m at high speeds over 21 $km \cdot h^{-1}$, previous studies in female soccer players showed they covered distances over 10,000 m during a match (90 min duration), of which at least 600 m were at high speed running intensities [45]. The current results suggest that the effect provoked by field-hockey match-play did not decrease the isometric knee flexion strength in the dominant limb, which has been related to a higher hamstring injury risk in previous studies [46,47]. The absence of changes in the isometric knee flexion strength can be attributed to the lower distances covered at high running speeds. Extensive research [47] has shown that the hamstring muscles are most active in this phase, when their function is to increase stride frequency and produce a greater horizontal force as the contact time reduces. Given the distances covered in the different zones, it can be assumed that the hamstring muscles are not fatigued as in sports such as soccer, where a greater distance is covered at these intensities.

A reduced ROM during the straight leg raise test and dorsiflexion of the ankle ROM has been linked to the risk of hamstring injury [14,15]. Present results have shown an increase in the straight leg raise ROM levels for the non-dominant limb (+5.81%) and no significant differences in the dominant limb. No differences were seen for the ankle dorsiflexion ROM either for both legs after match-play. To the best of the authors' knowledge, only Wollin et al. (2017) analyzed the straight leg raise ROM after match-play on intermittent sports and report no significant differences after match-play [19]. Concerning ankle dorsiflexion ROM, some previous studies conducted in football [24], basketball [25] and Australian-rules football [44] showed different results. While Charlton et al. [44] reported reductions in ankle dorsiflexion ROM immediately after an Australian-rules football match, Wollin et al. [19] showed non-significant decrements in football players, and finally Moreno-Pérez et al. [24,25] in football and basketball observed increased ROM values post-match from pre-match in dominant and non-dominant limbs. While these sports involve the same multidirectional movements (e.g., accelerations, decelerations, changes of direction) during practice, they cannot be compared due to the differences in the characteristics of the sport; for example, the total duration is less in field hockey than other intermittent sports. Thus, increases in hip flexion ROM immediately post-match are likely due to the increase in tissue extensibility induced by temperature increment which leads to a reduction of the viscous resistance of muscle tissues and joints [48,49]. However, this is a speculation that needs to be elucidated in future studies.

As far as isometric hip ADD and ABD strength values and ADD/ABD strength ratio go, the results showed no significant differences between post-match from pre-match. While is difficult to establish comparisons, as no previous study has reported isometric hip ADD and ABD strength values in hockey players, the findings of the current study were similar to those of a previous study [50] conducted with 14 rugby players. However, the present results disagree with the results reported by a previous study in tennis players [23]. This lack of agreement between studies may be due to differences in physical demands and tactical aspects between the sports. In tennis, players are required to perform repetitive short high-intensity movements, which impose an elevated concentric and eccentric load on the ADD muscles, while hockey players perform multiple different movements at several intensities. One must also consider that hockey, like in rugby, permits rolling substitutions.

This study contains limitations that require acknowledgment. Firstly, as the current study was conducted with a specific sample of female field hockey players, conducted during a simulated match, the characteristics of the players do not permit a generalization of the results found. In addition, the selected measures in this study in response to hockey match-play were performed immediately post-match; future studies should evaluate these variables using several time-points to understand the recovery fatigue induces, for example registering data 48 h after the match. This study looked at the effect following a single simulated match; more data collected over a series of official matches, or even, over an entire season could provide more conclusive results about the effects of match-play on these potential risk factors.

5. Conclusions

A simulated field-hockey match increases hip isometric flexion strength and hip flexion ROM in the non-dominant limb and decreases jump height capacity. However, no differences were reported in isometric ADD and ABD strength and ADD/ABD strength ratio in the dominant and non-dominant limb, or in dominant hip flexion and ankle dorsiflexion ROM values between the pre- and post-match examinations. Finally, female hockey players who present a decrease in jump height capacity, may require additional rest between training and competitions.

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3.2. Estudio 2: Effects of Consecutive Matches on Isometric Hamstring Strength, Flexibility Values and Neuromuscular Performance in Female Field Hockey Players.

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Effects of Consecutive Matches on Isometric Hamstring Strength, Flexibility Values and Neuromuscular Performance in Female Field Hockey Players. A Prospective, Observational Study

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Abstract: This study aimed to analyze the effects of match congestion in a short period on isometric hamstring strength and hip/ankle range of motion in female field hockey players. Fourteen professional female field hockey players (age: 20.0 ± 5.4 years) played two consecutive hockey matches in 24 h and maximal isometric hamstring strength and hip and ankle range of motion were obtained before and after the first match, after the second match, and 48 h after the second match. Furthermore, locomotion patterns and ratings of perceived exertion were recorded during hockey competitions. Isometric knee flexion strength showed significantly higher values 48 h after the second match for the non-dominant limb ($p \leq 0.005$, $\eta p^2 = 0.19$), while no differences were reported in the dominant limb ($p = 0.370$, $\eta p^2 = 0.05$). In addition, no differences were reported in the range-of-motion (ROM) variables such as the straight leg raise test or ankle dorsiflexion test ($p = 0.075$–0.217, $\eta p^2 = 0.01$–0.03). The countermovement jump height steadily increased over the matches except between post-match 2 and 48 h after post-match 2 ($p < 0.001$, $\eta^2 = 0.382$). Two consecutive official league field hockey matches played within 24 h did not have a negative effect on lower-limb risk factors (strength, hip and ankle ranges of motion, and ratings of perceived exertion) in female field hockey players directly, but they improved 48 h after the matches. This could indicate that 48 h recovery period following matches might be ideal for female field hockey players.

Keywords: team sport; hamstrings; fatigue; fixture congestion; countermovement jump; flexibility

1. Introduction

Field hockey is an intermittent sport characterized by high-intensity bouts interspersed with moderate to low periods combined with continuous accelerations, decelerations, and changes in direction [1]. During a field hockey match, female players approximately cover between 5300 and 6800 m [2,3] over a sixty minutes period of which around 20% is covered at high speeds [2,4].

During official field hockey competitions, teams often play two consecutive games in less than twenty-four hours. This imposes high physical demands on an athlete, limiting physical performance in subsequent matches due to an insufficient recovery [5]. In other intermittent team sports such as soccer, research has shown that the demands of a single match can induce muscle damage and post-match fatigue that can last up to seventy-two hours [6]. This has resulted in a reduction in the ability to maintain high speeds and in the number of accelerations/minute [7], being attributed to peripheral fatigue appearance due to depletions in muscle glycogen concentrations [8]. As a result, limited recovery time between matches increases residual fatigue and consequently increases the risk of injury [9], as evidenced by epidemiological research. Research has shown higher injury rates in competitions where there were four or fewer days of recovery when compared to competitions with six or more days of recovery [10].

Furthermore, epidemiological research has shown that the lower limbs are the most affected by injuries in field hockey, with the hamstring strain injury being one of the most frequent muscle injuries [11]. Hamstring injuries are common in other intermittent sports, occurring during maximal or sub-maximal sprinting [12] when there is constant, repetitive stress placed on these muscles when the fibers are rapidly lengthened and contracted during the sprint cycle [13]. Since previous research in similar intermittent sports has shown that the incidence of such injuries is higher during matches [14], playing consecutive games with insufficient recovery can not only affect physical performance but can also increase the injury risk. To implement preventive strategies, the identification of risk factors, both intrinsic and extrinsic, associated with hamstring injury occurrence is crucial. These include: age [15], previous injury [16], hamstring strength [17–19], decreased range of knee extension [20,21], and ankle dorsiflexion [22,23]. Specifically, in the case of an intermittent sport such as field hockey, fatigue has been linked to a decrease in hamstring strength values, and this is an important risk factor for a hamstring injury [24]. Moreover, an incomplete recovery could lead to lower strength values in the hamstrings [25]. Despite the relevance of cumulative fatigue on the hamstring musculoskeletal characteristics of athletes, the effect of consecutive matches on hamstring injury risk factors has not yet been examined in field hockey players during the accumulation of several matches. Therefore, this study aimed to examine the effects of two consecutive official league field hockey matches, played within 24 h, on lower-limb risk factors of hamstring injuries such as isometric knee flexion strength, passive hip flexion [21], and ankle dorsiflexion range of motion [26]. Based on previous research, it was hypothesized that the registered values for these variables will reduce over the duration of the matches and recover partially 48 h after the 2nd match.

2. Materials and Methods

2.1. Participants

Fourteen semiprofessional female field hockey players (age: 20.0 ± 5.4 years (range: 15–28 years); weight: 60.7 ± 7.2 kg; height: 1.67 ± 0.1 m, years of experience: 11.0 ± 6.0 years; weekly training time: 6.3 ± 0.8 h) volunteered to participate in the study. The participants belonged to a club that played in the second division hockey league in Spain. Players were included in the study if they had the clearance of the medical and technical staff to complete a full match of field hockey, not having sustained a medically diagnosed, serious injury (layoff > 3 weeks) in the last six months prior to the study, and not having taken any type of medication to treat pain or musculoskeletal injuries at the time of the study. All players were informed of the study they were to conduct, informed of the tests that they were to undertake, and signed informed consents. Participants were excluded if they sustained an injury during the matches and could not complete the tests. The experimental procedure of this study was in accordance with the guidelines stated in the Declaration of Helsinki and was approved by the Ethics Committee of Universidad Francisco de Vitoria (number 45/2018).

2.2. Experimental Design

The required sample size was determined by statistical power calculation on the basis of previous studies [25]. The minimum number of participants required to detect a difference in isometric hamstring strength performance between two groups, with a power of 1.20 and two-tailed level set at 0.05, was estimated as six per group using the GPower statistical program (v. 3.6.1) [27]. A prospective, descriptive study (Figure 1) was carried where players were tested in four moments: sixty minutes before the first match (pre-match 1), immediately after the first match (post-match 1), immediately after the second match (post-match 2), and 48 h after the conclusion of the second match (48 h post-match 2).

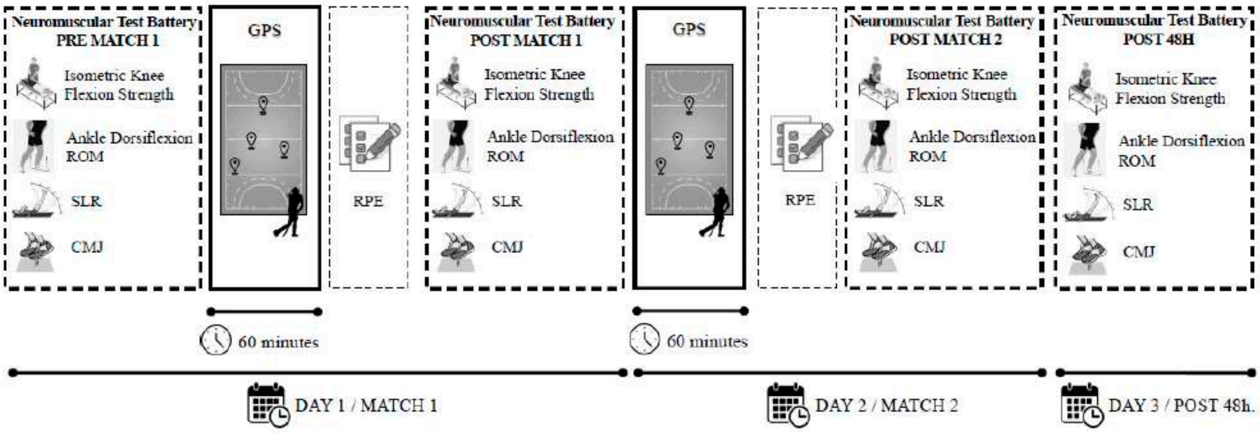

Figure 1. The experimental protocol used in the study.

2.3. Experimental Protocol

One week before the onset of the experiments, a familiarization session that included the execution of all tests was carried out by participants and anthropometric data, age, medical history, training frequency, and years of experience were collected. On the experimental days, participants arrived at field hockey facilities for each evaluation session. On the first day, participants performed a standardized warm-up consisting of continuous running for 2 min, dynamic joint mobility for 2 min, and specific exercises such as squats and forward lunges for 1 min. The participants then underwent the neuromuscular test battery consisting of isometric knee flexion strength, hip flexion range of motion (ROM) with the knee extended with the straight leg raise test (SLR), ankle dorsiflexion ROM, and countermovement jump (CMJ). The order of the tests and the selection of players were randomly determined before the measurements [28]. All tests were conducted by three physiotherapists with over five years of experience. During the matches, the players carried a portable GPS device with a built-in accelerometer in a customized vest from which the external load was measured. Therefore, thirty minutes after the end of each hockey match, female participants reported RPE values [29]. Between the different matches, hockey players ingested the same meals, slept at least 7 h, and were advised not to drink caffeine or energy drinks to avoid the influence of circadian rhythms on caffeine ingestion [30]. During the 48 h after the second match, they were advised not to exert exhausting efforts.

2.3.1. Isometric Knee Flexion Strength

The isometric knee flexion strength of either limb was measured using a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA). The hamstring strength test was evaluated by positioning the subject from the prone position, with 15 degrees of knee flexion [31]. One examiner placed the dynamometer in the distal portion of the triceps surae, three centimeters above the bimalleolar line, while another placed their palm over the participant's sacrum, to prevent elevation during the test. The first examiner requested the player to flex their knee to bring the heel of the foot to the glutes. The players performed voluntary contractions for a maximum of five seconds against the dynamometer and repeated the exercise twice for each leg. There was a rest period of thirty seconds between each measurement [28,32]. Two repetitions were performed for both dominant and non-dominant legs, and the highest recorded measurement was considered for further analysis. This value was normalized based on the body mass of the participant.

2.3.2. Ankle Dorsiflexion ROM

The ankle dorsiflexion ROM was performed on both ankles following the protocol of Calatayud et al. [33] using the leg-motion system test (LegMotion, Check your Motion, Albacete, Spain). Participants were in a standing position in the leg-motion system with the foot to be measured on the measurement scale. The contralateral foot was placed outside the platform with the toes on its edge. Each player performed the test with their hands on their hips, with the assigned foot in the middle of the longitudinal line, and just behind the transverse line of the platform. While maintaining this position, the subjects were instructed to flex their knees, causing it to move forward to contact the metal stick. When the participant was able to maintain ground contact with their heel, and take the knee to the maximum distance, the metal rod moved away from the knee, and the next distance reached was recorded [33,34]. Two repetitions were performed on each leg, with 10 s of passive recovery between each test, and the highest score between these measurements was chosen for further analysis.

2.3.3. Straight Leg Raise Test

The SLR test was used to measure the flexibility of the hamstring muscles [35]. An ISOMED (Portland, OR, USA) unilevel inclinometer with a telescopic extension rod was used for the measurement. The inclinometer was placed approximately on the external malleolus, and the distal arm was aligned parallel to an imaginary bisecting line of the limb. The test ended when one or more of the following criteria were met [36]: (a) the examiner was unable to continue the joint movement evaluated, due to the high resistance developed by the stretched muscle group; (b) the participant reported a significant sense of discomfort or appearance of pain; (c) the examiners noted compensations that could increase the score. Two repetitions were performed for both the dominant and non-dominant leg, and the highest recorded measurement was considered for further analysis.

2.3.4. Vertical Jump with Countermovement Test (CMJ)

The CMJ test was performed bilaterally to evaluate the neuromuscular fatigue accumulated [37]. On command, participants flexed their knees at 90° and jumped as high as possible while maintaining their hands on their hips and were instructed to jump and land in the same place, with the body in an upright position and legs extended during the jump until landing [38]. The Chronojump Boscosystem (Barcelona, Spain) contact platform [39] was used to measure the vertical jump height during CMJ. Participants completed two repetitions of a CMJ interspersed with 45 s of passive recovery, and the highest recorded measurement was considered for further analysis.

2.3.5. Global Positioning System and Accelerometer Device (GPS)

To determine the physical demands, all players were equipped with a 10 Hz portable GPS (Viper pod 2, STATSports, Belfast, Northern Ireland), which was attached to a lycra vest between the shoulders. Each field player carried individual units during matches and used the same unit in both matches to reduce measurement error [40]. The duration and frequency of movement activities were quantified with respect to the percentage of time and meters traveled by the players based on six activity zones bounded by various speeds [41]: walking (0–6.0 km/h); low-intensity running (6.1–12.0 km/h); medium-intensity running (12.1–14.0 km/h); high-intensity running (14.1–18.0 km/h); very high-intensity running (18.1–25.0 km/h); sprinting (>25.1 km/h). Except for the total distance, all variables analyzed were relativized per minute of match play.

2.3.6. Internal Match Load (RPE)

The intensity of all matches was determined using Borg CR-10's modified scale of perceived effort rate (RPE); each player provided a score 30 min after the end of the match [1].

2.4. Statistical Analysis

The means and standard deviations of the performance and test variables were determined. The measures of external load and internal load were compared between the two matches using a paired samples *t*-test.

For the data analysis of the test variables registered at the four different moments, pre-match 1, post-match 1, post-match 2, and 48 h post-match 2, a repeated-measures analysis of variance (ANOVA) was used to determine differences in the measures across the four instances. If significant differences were found, a Bonferroni post hoc test was performed. In cases where the sphericity assumption was violated, a Greenhouse–Geisser adjustment for *p*-values was reported. The effect sizes of the repeated measures ANOVA were measured using partial η_p^2 values, and the following thresholds were used: trivial ($\eta_p^2 \leq 0.01$); small ($0.01 < \eta_p^2 \leq 0.06$); medium ($0.06 < \eta_p^2 \leq 0.14$); large ($\eta_p^2 > 0.14$) [42]. Differences between GPS registered-running variables across the two consecutive matches were tested with a paired samples *t*-test, and effect sizes were determined using Cohen's d [43]. These were then converted to partial eta squared values based on the equations presented by Cohen and the thresholds mentioned earlier. Significance was set at $p < 0.05$. The statistical analysis was carried out using Jamovi (version 1.8.1, [43]).

3. Results

The variables registered from the GPS showed a significant increase in the total distance covered between matches one and two (6589.0 ± 2372.27 m vs. 7439.80 ± 2177.96 m; $p = 0.040$; $\eta_p^2 = 0.092$), but no significant differences were obtained for the distance run at different intensities or between the RPE values registered after the matches either (Table 1).

Table 1. Difference between GPS measured variables across the two matches.

Variable	Match 1	Match 2	p	η_p^2
Relative walking distance [0–6.0 km·h^{-1}] (m·min^{-1})	68.84 ± 38.63	75.21 ± 21.40	0.522	0.009
Relative low-intensity running distance [6.1–12.0 km·h^{-1}] (m·min^{-1})	51.94 ± 28.10	48.10 ± 14.21	0.498	0.010
Relative medium-intensity running distance [12.1–14.0 km·h^{-1}] (m·min^{-1})	11.74 ± 4.99	12.09 ± 4.36	0.877	0.001
Relative high-intensity running distance [14.1–18.0 km·h^{-1}] (m·min^{-1})	12.90 ± 7.96	14.13 ± 6.01	0.564	0.007
Relative very high-intensity running distance [18.1–25.0 km·h^{-1}] (m·min^{-1})	3.81 ± 3.43	3.94 ± 2.19	0.670	0.004
Relative sprinting distance [>25 km·h^{-1}] (m·min^{-1})	0.17 ± 0.48	0.01 ± 0.02	0.331	0.027
Session RPE (AU)	346.18 ± 231.73	392.31 ± 203.82	0.170	0.061

Abbreviations: km·h^{-1} = kilometers/hour; m = meters; AU: arbitrary units.

The isometric knee flexion strength (Figure 2) showed significant differences for the non-dominant limb ($F_{(1.43,15.70)} = 10.60$, $p = 0.003$, $\eta_p^2 = 0.198$) and the post hoc tests showed that 48 h post-match 2 values were significantly higher than in all other tests ($p \leq 0.005$). In the dominant limb, no significant differences were found ($F_{(1.13,12.47)} = 1.08$, $p = 0.370$, $\eta_p^2 = 0.052$).

Considering the ROM variables (Figure 3), the SLR test showed no differences in the dominant ($F_{(3,33)} = 1.56$, $p = 0.217$, $\eta_p^2 = 0.031$) or non-dominant limbs ($F_{(3,33)} = 1.28$, $p = 0.296$, $\eta_p^2 = 0.014$). Similarly, the ankle dorsiflexion ROM showed no significant differences for the dominant ($F_{(3,33)} = 1.30$, $p = 0.289$, $\eta_p^2 = 0.022$) or non-dominant limb ($F_{(3,33)} = 2.51$, $p = 0.075$, $\eta_p^2 = 0.025$).

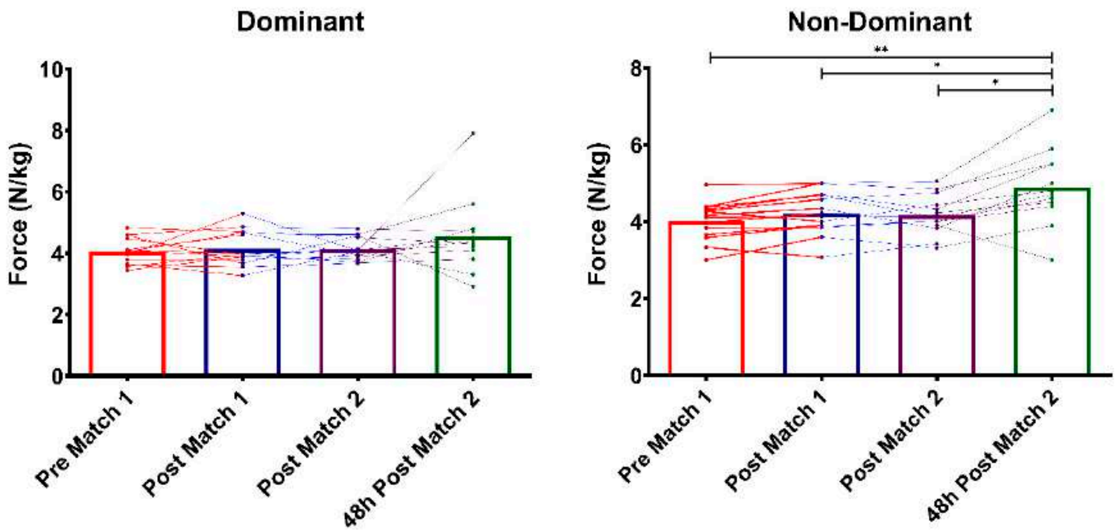

Figure 2. Mean and individual isometric knee flexion strength in the dominant and non-dominant limbs at the different tests. * represents a significant difference at $p < 0.05$, and ** represents a significant difference at $p < 0.001$.

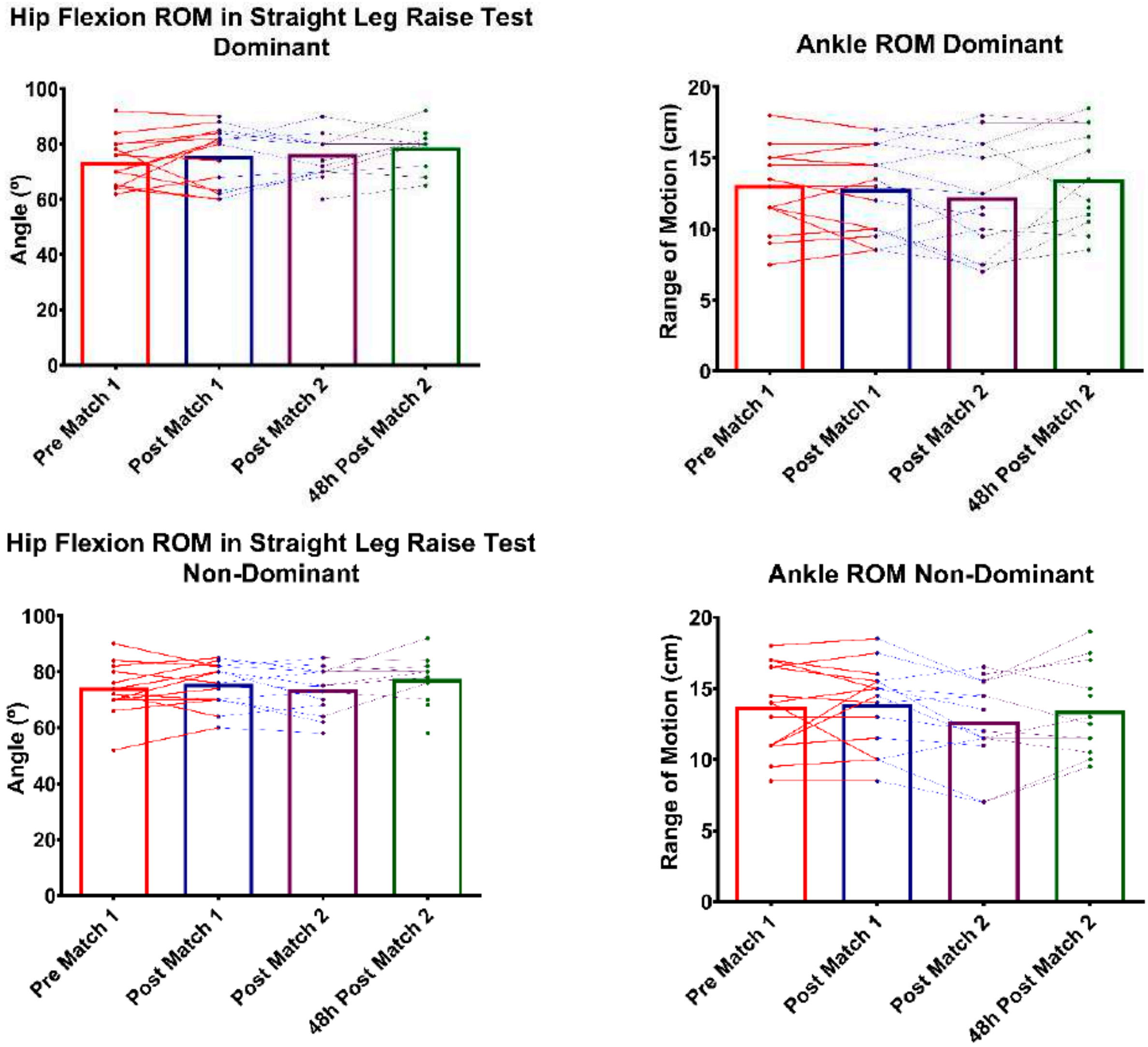

Figure 3. Mean and individual hip flexion and ankle dorsiflexion ROM in the dominant and non-dominant limbs.

Significant differences were obtained when comparing the CMJ height ($F_{(3,33)} = 11.00$, $p < 0.001$, $\eta_p^2 = 0.382$; Figure 4). The post hoc tests showed that pre-match 1 values were lower than at all other test moments ($p \leq 0.003$). Moreover, post-match 1 values were lower than both tests before and after the second match ($p \leq 0.004$).

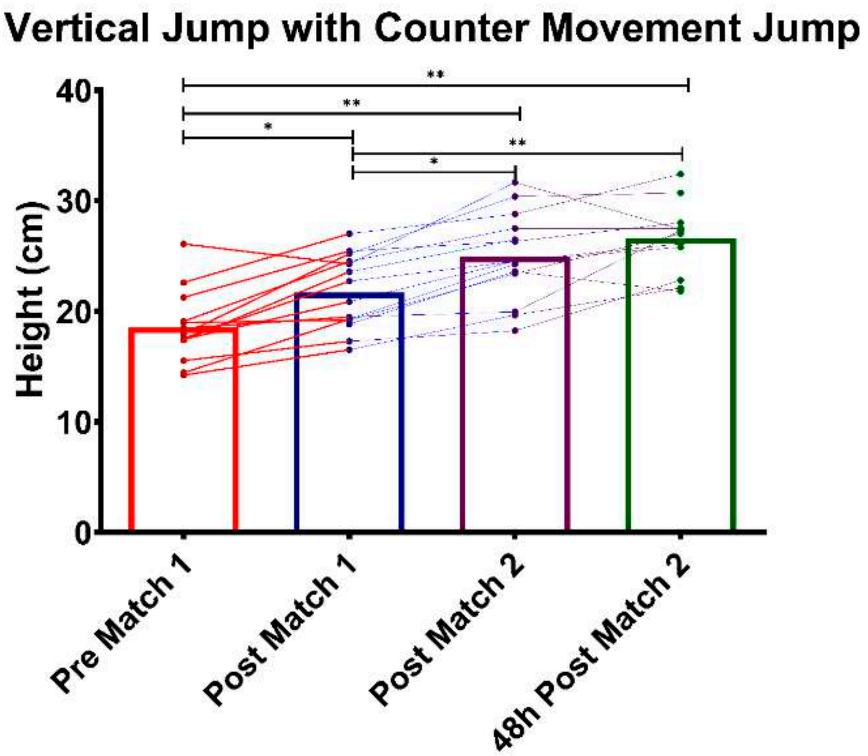

Figure 4. Mean and individual variations in the countermovement jump height at the different tests. * represents a significant difference at $p < 0.05$, and ** represents a significant difference at $p < 0.001$.

4. Discussion

This study examined the effect of two consecutive official league field hockey matches played within 24 h on lower-limb risk factors (strength, ROM, RPE) in female field hockey players. The main findings were that no differences between the identified risk factors, except for an increase in the isometric knee flexion strength in the non-dominant limb 48 h after the second competitive match and increased CMJ height over the matches.

No differences in isometric knee flexion strength were reported in the dominant leg; however, strength increases were reported in the non-dominant limb 48 h after the 2nd match (except for a single player, individual data values are plotted in Figure 2). This could be either due to a learning effect by the players or due to an absence of fatigue when performing these tests. In both cases, it could be argued that hamstring muscles do not accumulate excessive fatigue between matches, given that the distances covered at very high intensities and sprint speeds are low (Table 1) when compared to distances covered in other intermittent sports such as soccer [44], where soccer players cover greater distances at high intensities and sprint speeds when compared to field hockey players [4]. It has been shown in previous research that the hamstring muscles are most active at these high speeds [45], not having a predominant role at lower speeds [46]. In a previous study involving consecutive soccer matches, a decrease in hamstring strength was observed [32]. It is important to consider that the GPS-measured distances reported in this study are similar to values reported by Casamichana et al. [4] in 155 players, although they measured data over matches consisting of two halves of thirty-five minutes (as per the older rules), compared to four quarters of fifteen minutes in this study. The values were slightly lower than those reported by Morencos et al. [3] (9.99 m at >19 km/h and 0.87 at >23 km/h in match 1, 8.08 m at >19 km/h, and 0.91 m at >23 km/h in match 2), but this might be explained due to Morencos et al. [3] studying hockey male players, while female players participated in this study [47]. There appears to be lower fatigue noted in the hamstring muscles as evidenced by the lack of significant differences between the values obtained in the straight leg raise test for either limb (Figure 3). A limited range of motion (ROM) has been considered a relevant risk factor for injuries in intermittent team sports in the lower limb [22]. However, an important characteristic of field hockey is the trunk flexion employed by the players when dribbling, passing, or shooting the ball with the stick, which could also influence the stretch and range of motion on the hamstrings. These results agree with a similar protocol carried out in tennis [48], which compared the hip range of motion before and after a single match. Similarly, no differences were obtained in the ankle range of motion for both the dominant leg and the non-dominant leg, a result that coincides with those of Wollin et al. [25] where the ankle dorsiflexion was not affected by this congested period of two matches [28]. These results suggest that the potential risk factors for hamstring injuries are not affected by playing two consecutive field hockey games. Although this might be in line with research recently published in soccer [49], one must remember that the majority of the distances run by the players has been at low and walking intensities, and the distances covered at medium or high instances are much smaller compared to soccer. Additionally, it is worth mentioning one of the characteristics of field hockey: a match is played over four quarters of fifteen minutes with rolling substitutions, allowing the players to recover when substituted. This is evident from the GPS registered data, which shows a difference in the total distance, but no differences when the playing time was considered. This can be further explained by the lack of neuromuscular fatigue seen in the lower-limb power as detected by the CMJ.

The CMJ showed a pattern of increasing successively over the games. The increase in values is contrary to previously published literature in different sports [5,50,51]. This finding could be explained by a couple of reasons. Firstly, a reduced, five-minute warm-up was performed in the pre-match 1 testing, focusing mainly on joint mobility exercises for the lower limb, since they went on to perform the match-specific warm-up after the tests, thus, warm-up intensity could have been insufficient. Secondly, the increase in the CMJ height could be linked to greater activation of the muscles of the tibialis anterior, gastrocnemius, and soleus muscles as a result of the large volume of medium-intensity runs performed during the match [52], which in turn, results in an optimal stiffness of the ankle and better transmission of the nerve impulses due to the increase in muscle temperature of active muscles [53]. These muscles play an important role in determining CMJ performance [54], and a greater activation could result in a better performance. However, it is important to note that the role of post-activation performance enhancement (PAPE) effects [55] elicited by actions during the game is unlikely for a couple of reasons: PAPE has a short-term, acute effect lasting for about five to thirty minutes [56], and the fact that no differences were seen between post-match 2 and 48 h post-match 2 values. Not only in the case of CMJ values, but looking at all data, it appears that the 48 h of recovery permitted a complete recovery following participation in consecutive matches. Moreover, in other studies featuring field hockey [57] or ice hockey players [58], PAPE has had minimal or no effect on performance.

Limitations

The current investigation has several limitations. Firstly, the results of this study must be treated with caution given that not all players played the same number of minutes, resulting in the individual variation of the data, as previously reported. Nevertheless, this reflects a professional setting and shows the real demand the elite players are exposed to during a game. Perhaps definitive results can be obtained by following the team over an entire season, and not just a single period of two matches. Secondly, the tests were chosen so that they could be carried out before and after a match in the players' dressing room itself and used inexpensive material for rapid tests to identify risk factors of hamstring injuries. All tests were carried out in random order to ensure that all players were able to perform the tests without having to wait, and only peak values were used for analyses [26].

Finally, the sample only included female hockey players; it remains to be seen if the effects associated with repeated exposure matches in a short period (i.e., 24 h) are similar in men's field hockey players who tend to cover more distances at higher intensities.

5. Conclusions

Based upon the findings of this study, we conclude that two consecutive official league field hockey matches played within 24 h did not have a negative effect on lower-limb risk factors (strength, ROM, RPE) in female field hockey players directly and improved 48 h after the matches. However, surprisingly, it had a positive effect on explosive performance, as measured with the CMJ. This was probably due to a reduced warm-up before the first testing session and better nerve transmissions in activated muscles of the lower limb.

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3.3 Estudio 3: Effects of consecutive days of matchplay on maximal hip abductor and adductor strength in female field hockey players.

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RESEARCH

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Effects of consecutive days of matchplay on maximal hip abductor and adductor strength in female field hockey players

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Abstract

Background: The purpose of this study was to examine the effects of two competitive field hockey matches, played on consecutive days, on maximal isometric hip adductor and abductor strength, wellness and fatigue.

Methods: Fourteen professional female field hockey players (age: 20.4 ± 5.4 years; body mass: 60.7 ± 7.2 kg; height: 167.0 ± 1.0 cm) volunteered to participate in this investigation. Maximal isometric hip adductor and abductor strength were obtained before (pre-match 1) and after the first match (post-match 1), after the second match (post-match 2), and 48 h after the second match. Locomotion patterns during the matches were obtained with portable Global Positioning System (GPS) and perceived exertion (RPE) was assessed after each match. In addition, Wellness Questionnaire (5-WQ) and the Total Quality Recovery Scale (TQR) were employed before the matches and 48 h after the second match.

Results: For the non-dominant limb, the maximal isometric hip adductor and abductor strength were lower after post-match 2 when compared to pre-match 1 ($p = 0.011$). Hip abductor strength in the non-dominant limb remained reduced 48 h after post-match 2 ($p < 0.001$). There were no differences in the total distance covered when comparing match 1 and match 2. Players reported more acute fatigue (5-WQ, $p = 0.009$) and increased muscle soreness on pre-match 2 compared to pre-match 1 ($p = 0.015$), while fatigue returned to pre-competition levels 48 h after post-match 2 ($p = 0.027$). No changes were observed in the TQR.

Conclusion: The assessment of maximal adductor and abductor strength before and after competitive matches, in addition to evaluating self-perceived fatigue by a wellness questionnaire can help to identify field hockey players with excessive fatigue responses during tournaments with a congested match program.

Keywords: Team sports, Risk factors, Consecutive matches, External load

Background

Groin injuries are one of the most frequent overuse injuries in field hockey, accounting for up to 10% of all injuries reported in competitive field hockey teams [1]. Preventing groin injury in field hockey is essential to reduce the burden on players and teams [2]. Thus, the implementation of preventive measures, the identification of the risk factors associated with the development of the injury, and the understanding of potential mechanisms exacerbating the severity of groin injury are paramount for this aim [3]. The complexity involved to ascertain the causes of groin injuries is well recognized, as in most cases the cause of injury is multifactorial [4].

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However, previous studies conducted in other sports have identified several modifiable factors that affect the risk of groin injury, such as reduced flexibility [5, 6] and muscle weakness [7–11]. Amongst the modifiable risk factors, low levels of isometric hip adductor strength and/or imbalance in the hip adductor/abductor strength ratio have received much attention in the literature across a range of team sports [8]. However, the evidence remains somewhat conflicting and there is still no consensus regarding the role of low hip adductor/abductor muscle strength in the etiology of a groin injury.

Irrespective of the complexities of risk factors, field hockey match-play has been consistently associated with a several-fold greater incidence of muscle injuries when compared to training [1]. The combination of high physical demands during match play together with insufficient recovery time in between games may in part explain the higher injury rates reported during field hockey match play compared to training [12]. Field hockey match-play involves frequent explosive actions that require a high rate of force development (RFD) and significant eccentric muscle loadings, such as change of directions, accelerations, and decelerations [13].

Previous studies have shown that demands of match play in intermittent explosive sports such as football can induce muscle damage and post-match fatigue lasting up to 72 h, the latter due to a marked depletion in muscle glycogen concentrations [14]. Field hockey players are habitually exposed to densely packed match programs with a high number of matches performed in daily conjunction, particularly during international tournaments (e.g. Olympic Games) [15]. Previous reports have suggested that the accumulation of neuromuscular fatigue during successive matches may lead to an altered physical performance of the players [16]. In addition, the effects of a congested calendar in intermittent sports may also include reductions in maximal hip adductor strength [17].

Further, Crow et al. [6] reported that hip adductor muscle strength was reduced (−6%) during the week that preceded, or in the actual week, of sustaining a groin injury in elite under-age Australian footballers. Thus, it is possible that residual hip muscle fatigue due to limited recovery between successive matches could compromise the physical performance and lead to acutely reduced levels of hip adductor and abductor strength in field hockey players.

Therefore, the aim of this study was to examine the effects of two consecutive official field hockey matches, played on consecutive days, on selected risk factors for groin injury such as maximal hip adductor and abductor strength as well as self-perceived recovery status in female field hockey players. We hypothesized that there would be a progressive decline in the maximal hip adductor and abductor strength because the short time between successive matches would be insufficient to allow for complete neuromuscular recovery.

Material and methods

Participants

Fourteen healthy professional female field hockey players (age: 20 ± 5.4 years; body mass: 60.7 ± 7.2 kg; height: 167.0 ± 1.0 cm) took part in this prospective study. Participants were recruited from a Second Division field hockey team in Spain and they were training ~ 6.3 ± 0.8 h/week in the previous 3 months typically performing a single competitive match per week. Participants had an average of 11 ± 6 years of field hockey experience. Exclusion criteria were: (a) a history of adductor or abductor injury or related orthopaedic problems within the three previous months prior to testing; (b) impossibility to be tested due to other types of lower limb injury; (c) experiencing lower limb muscle soreness at time of baseline testing; (d) intake of medications or dietary supplements (e.g. caffeine) for the duration of the study. Goalkeepers were excluded due to the different nature of their activity during both training and match activities. Before taking part in the study, participants were fully informed about the experimental protocol and provided their written informed consent. This investigation was performed in accordance with the Declaration of Helsinki 2013 and was approved by the local Ethics Committee of the Universidad Francisco de Vitoria (45/2018).

Data collection

This study was a prospective and descriptive experiment that involved two official competitive field hockey matches played on consecutive days. Anthropometric data, age, medical history, training frequency, and years of experience were recorded for all participants before the start of the study. The matches were performed in November 2019 during a week that the field hockey team had two consecutive matches of the Spanish National League. Field hockey players were tested on four different occasions: before the first match (pre-match 1), immediately after the first match (post-match 1), after the second match (post-match 2), and again 48 h after the second match (48 h post-match 2; Fig. 1). Specifically, players were tested for maximal isometric hip adductor and abductor strength in both limbs 60 min pre-match 1 and immediately post-match 1, post-match 2, and 48 h post-match 2. According to previous procedures [18], the order of the tests and the selection of players were chosen at random. Limb dominance preference was defined as the leg used for kicking a ball determined by a questionnaire filled out by the participants [19]. Before pre-match

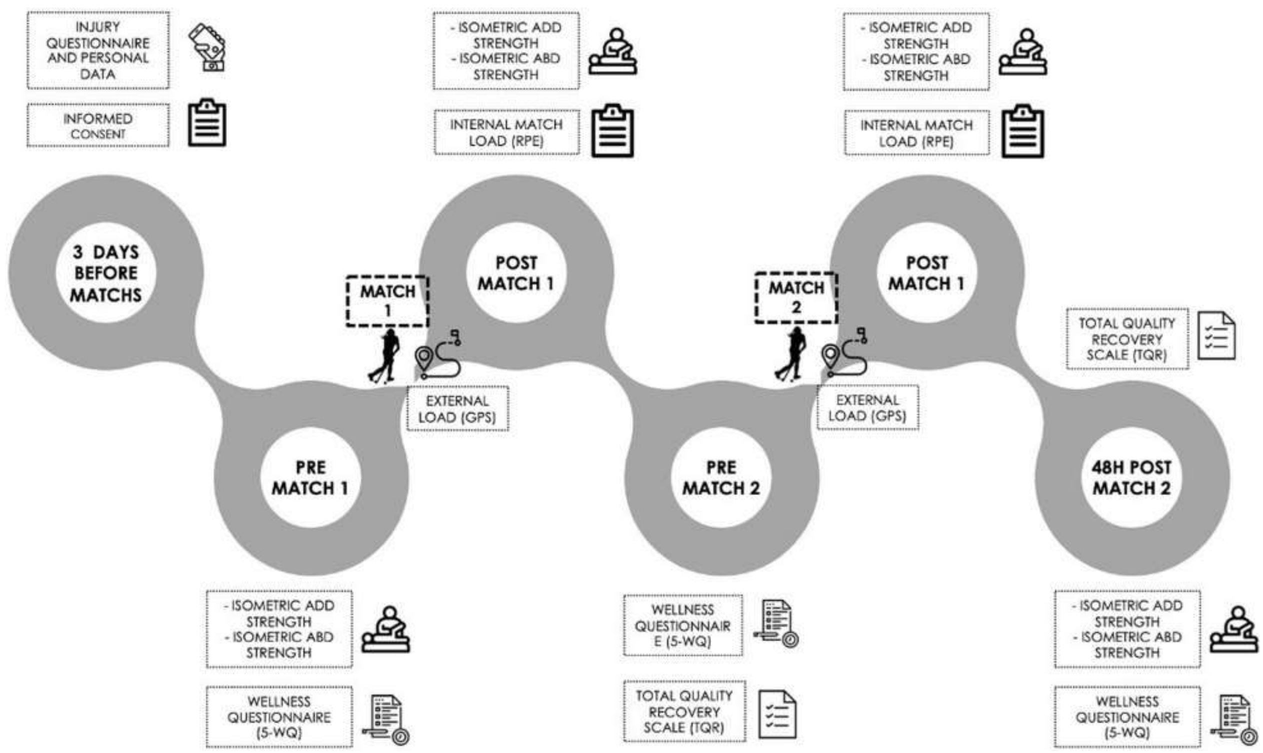

Fig. 1 Study design of the measures obtained during the tournament

testing, all players performed a five-minute warm-up including static stretches and joint mobility exercises [20]. All tests were conducted by three physiotherapists with several years of test experience. Moreover, the players completed the subjective Wellness Questionnaire (5-WQ) before pre-match 1, pre-match 2, and 48 h post-match 2 and Total Quality Recovery Scale (TQR) before pre-match 2 and 48 h post-match 2. Internal match load was reported using the session rate of perceived exertion (s-RPE) obtained from each player and it was measured 30 min after the end of the matches. Trunk-based accelerometer and Global Positioning System (GPS) units were used to record running and locomotion patterns during the matches. A month prior to baseline data collection, players performed a familiarization session to reduce the potential influence of learning effects on the outcomes of the investigation. The players were instructed to avoid alcohol and caffeine-containing foods/drinks for 24 h before and during the duration of the study.

Measurements

Isometric hip adductor and abductor strength

Measurements of hip adductor and abductor isometric strength in both limbs were obtained with a hand-held dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA) according to the protocol by Thorborg et al. [20]. For this measurement, each participant lay supine on a stretcher, with their hips in a neutral position and stabilizing themselves by holding on to the sides of the stretcher. The examiner applied static resistance via a dynamometer placed 5 cm proximal to the proximal edge of the medial (for adductor) and lateral (for abductor) malleolus while the participants performed a 5-s maximum voluntary contraction against the dynamometer. Two repetitions were performed for both the dominant and non-dominant limbs, respectively, with a resting period of 30 s between successive. The best (highest peak force) of the two trials in the dominant and non-dominant limbs was selected to represent maximal hip adductor and abductor strength. Data were normalized by the body mass of the participant (N/kg).

Wellness questionnaire (5-WQ)

Subjective fatigue, sleep quality, general muscle soreness, stress levels, and mood were rated by each player using a validated five-point scale (5-WQ) by following the protocol proposed by McLean et al. [21]. Each question was scored by using a 1-to-5-point scale (0.5-point increase), with 1 and 5 representing poor and very good levels of well-being, respectively. The degree of "overall well-being" was determined by calculating the sum of the five scores.

Total Quality Recovery Scale (TQR)

To determine the self-perceived state of recovery, hockey players completed the TQR scale, as described by Kenttä et al. [22]. This scale ranges from 6 to 20 points, with 6 points being the minimum recovery value (i.e., representing zero or no recovery), and 20 points being the highest value of recovery (i.e., representing full, unconditional recovery).

External match load

The external match load was monitored using 10-Hz portable GPS and accelerometer units (Viper pod 2, STATSports, Belfast, Northern Ireland). The GPS units were placed in a neoprene harness on the players' backs between both scapulae. According to the manufacturer's recommendations, all devices were activated 15-min before the initiation of data collection to allow the acquisition of satellite signals and synchronization of the GPS clock with the satellite's atomic clock. The relative total distance (m/min) and the number of accelerations and decelerations above 3 m s^{-2} were recorded.

Internal match load

Internal match load was estimated using the session rating of perceived exertion (s-RPE [23]). The RPE value was determined using the Borg's CR-10 scale, [ranging from "very, very easy" (1 point) to "maximal" (10-points)] recorded 30 min after the end of the match [23]. We obtained an s-RPE value for each match by multiplying the session intensity rating (RPE value) by the player's involvement in the match (effective time of play, in minutes), to obtain an s-RPE value expressed in arbitrary units (A.U.) [24].

Statistical analysis

Descriptive statistics (mean and standard deviation) were calculated for all variables obtained. Shapiro–Wilk test was used to assess the normal distribution of data. All variables presented a normal distribution in the test. Differences in s-RPE and running parameters, respectively, between the two matches, were evaluated using paired t-testing. A repeated-measures analysis of variance (ANOVA) was used to evaluate changes in isometric hip adduction and abduction strength across four different time points (pre-match 1, post-match 1, post-match 2, and 48 h after post-match 2). In case a significant time-effect was found, post-hoc testing was carried out subjected to Bonferroni correction. The effect sizes of the repeated measures ANOVA were measured using partial η^2 values and the following thresholds were used: trivial ($\eta^2 \leq 0.01$); small ($0.01 < \eta^2 \leq 0.06$); medium ($0.06 < \eta^2 \leq 0.14$); and large ($\eta^2 > 0.14$) [25]. A *post-hoc* power analysis was performed for the primary outcome variable considering large differences for effect size and the sample size, a power of 0.79 was obtained. The subjective variables obtained with the 5-WQ test were compared using non-parametric repeated measures Friedman's analysis of variance (pre-match 1, pre-match 2, and 48 h after post-match 2). Post-hoc pairwise comparisons were done with the Durbin–Conover tests. The TQR was compared between pre-match 2 and 48 h after post-match 2 using paired t-testing. A confidence interval of 95% was determined for all analyses and statistical significance was set at $p < 0.05$. The statistical analysis was carried out using Jamovi (version 1.2.17; www.jamovi.org).

Results

Isometric hip muscle strength showed significant differences in the non-dominant limb for hip adduction (F (3,33) = 4.30, $p = 0.011$, partial $\eta^2 = 0.175$, Fig. 2). The post-hoc tests showed a significant difference between pre-match 1 and post-match 2 values ($p_{bonferroni} = 0.014$), while no other significant differences were found between any time points. For the dominant limb, no difference in time effect was observed (F (3,33) = 2.79, $p = 0.056$, partial $\eta^2 = 0.119$), but no significant difference was found between successive time points of measurement.

In the case of isometric hip abductor strength, a time-effect was observed for the non-dominant limb (F (3,33) = 4.30, $p < 0.001$, partial $\eta^2 = 0.312$), with post-hoc tests revealing a decrease at post-match 1 ($p_{bonferroni} = 0.034$), post-match 2 ($p_{bonferroni} = 0.002$) and 48 h after post-match 2 ($p_{bonferroni} < 0.001$) compared to pre-match 1 values. In contrast, no time-effect was observed for the dominant limb time-effect (F (3.33) = 1.52, $p = 0.227$, $\eta^2 = 0.081$).

No significant changes were observed between the two matches for any of the locomotion variables investigated. The physical performance variables showed no significant differences between the matches (Table 1).

Self-perceived wellness measured by 5-WQ (Table 2) remained unchanged between the three-time points of measurement ($\chi^2 = 2.00$, df = 2, $p = 0.368$). However, a significant time effect was observed for fatigue rating ($\chi^2 = 7.15$, df = 2, $p = 0.028$), with players experiencing more fatigue on pre-match 2 compared to pre-match 1 ($p = 0.009$), while players recovered back to pre-competition levels at 48 h post-match 2 ($p = 0.027$). No difference in time-effect was observed for the muscle soreness parameter ($\chi^2 = 5.82$, df = 2, $p = 0.055$), with significant differences emerging between pre-match 1 and pre-match 2 ($p = 0.015$). The remaining parameters

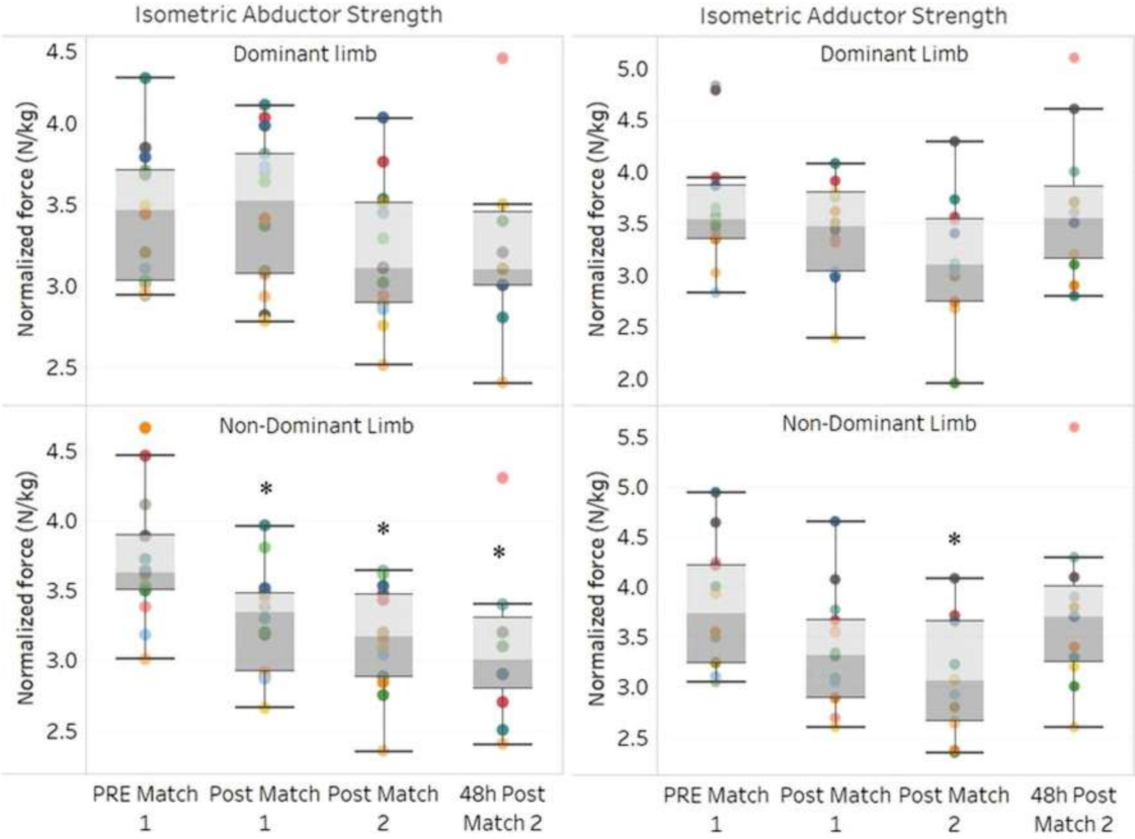

Fig. 2 Isometric hip adductor and abductor strength in professional field hockey players performing two matches on two consecutive days. *Depicts a difference from pre-match 1, $p < 0.05$

Table 1 Physical performance variables and s-RPE values reported for the two matches

	Match 1	Match 2	*p* value
Relative total distance covered (m min^{-1})	149.40 ± 80.10	153.47 ± 44.57	0.917
Number of accelerations above 3 m s^{-2}	10.23 ± 8.22	11.00 ± 6.47	0.785
Number of decelerations exceeding 3 m s^{-2}	4.31 ± 3.77	5.62 ± 4.56	0.083
s-RPE	6.73 ± 1.90	7.21 ± 2.12	0.121

AU arbitrary units

Table 2 Items obtained in the subjective wellness questionnaire (5-WQ) in professional field hockey players competing in two matches on consecutive days

(5-WQ)	Pre-match 1	Pre-match 2	48 h post-match 2	Pre-match 1 versus pre-match 2 *p*	Pre-match 1 versus 48 h post-match 2 *p*	Pre-match 2 versus 48 h post-match 2 *p*
Fatigue	3.79 ± 0.89	3.21 ± 1.05	3.75 ± 0.75	0.009	0.639	0.027
Sleep	3.79 ± 0.70	3.79 ± 0.80	3.58 ± 0.90	1.000	0.374	0.374
Soreness	3.64 ± 0.63	3.14 ± 0.86	3.42 ± 0.51	0.015	0.198	0.198
Stress	3.79 ± 0.80	3.79 ± 0.97	3.50 ± 1.17	0.810	0.904	0.904
Mood	4.00 ± 0.88	4.36 ± 0.63	4.00 ± 0.74	0.243	0.882	0.306
Total wellness	19.00 ± 2.66	18.29 ± 3.00	18.25 ± 2.93	0.232	0.232	1.000

showed no differences between the three-time points of data collection. Similarly, no differences were found in TQR between pre-match 2 and 48 h after post-match 2 ($t = 1.57$, $p = 0.142$).

Discussion

The primary aim of this study was to examine the accumulated effect of successive official field hockey matches, played on consecutive days on selected risk factors for groin injury (i.e., maximal hip adductor and abductor strength). The secondary aim was to analyze the locomotive demands (i.e., GPS) and self-perceived exertion and recovery parameters in female competitive field hockey players. The main findings of this investigation indicate that abductor and adductor muscle strength in the non-dominant limb was reduced in comparison to pre-competition values, suggesting that muscle weakness accumulated during the two consecutive matches. Notably, match performance (locomotion profile) in the second match was similar to the first match. This may indicate that professional field hockey players are at a higher risk of groin injury when exposed to successive matches on consecutive days, although match performance may not be substantially affected by the accumulation of fatigue. From a practical application view, physiotherapist/strength and conditioning coaches could monitor maximal isometric hip strength during congested calendars to assess the likelihood of sustaining a groin injury [6].

To our best knowledge, no previous investigation has examined the effects of consecutive match play on maximal hip adductor muscle strength in field hockey players. However, previous research has demonstrated that hip adductor muscle strength is significantly reduced after football matches played consecutively with insufficient recovery (≤96 h of rest between matches) compared to baseline levels [17, 26]. Thus, in line with previous reports, the present data revealed that isometric adductor strength decreased (−10.6%) acutely after the first match (post-match 1) in the non-dominant limb and after the second match (post-match 2) further decreased both in the non-dominant (−17.5%) and dominant limbs (−13.4%) when compared to pre-match 1 levels.

The acute decrements in maximal hip strength observed following match-play may potentially be explained by onset of neuromuscular fatigue [27] imposed by the specific physical demands of field hockey play. In support of this notion, field hockey players perform a high number of short high-intensity accelerations, decelerations, and rapid changes in direction including side-cutting during matchplay [13], which are likely to require very high concentric and eccentric contraction forces by the hip adductor muscles. In addition, it is well known that short congestion periods of high loads in field hockey may increase muscle damage markers (i.e., creatine kinase) and residual fatigue that could require a rest period to recovery previous fitness levels [28]. Assuming a similar match load for competitive field hockey players, this may explain the augmented decrease in hip adductor strength observed at post-match 2 in the present study. Consequently, the acute and sustained reductions in maximal hip adductor muscle strength presently observed for the non-dominant side (10.6–17.5%) following consecutive days of match play might represent a significant risk factor for the development of groin injury, especially in players most prone to injury (indicated by low strength levels of the hip adductor and restricted hip ROM [16].

According to previous reports, reduced strength of hip abductor muscles may affect the normal kinematics of the hip joint. Specifically, hip abductor weakness may increase the range of internal hip rotation and knee abduction, respectively, subsequently increasing the risk of injury including non-contact ACL rupture during sport [29, 30]. Therefore, monitoring hip abduction muscle strength could be useful to control the injury risk associated with acute or long-term reductions in this variable. In the present study, maximal hip abductor strength was found to decrease in the non-dominant limb when comparing post-match 1 (−11.1%), post-match 2 (−14.9%) and 48 h post-match 2 (−17.0%) levels to baseline (pre-match 1). Since no previous study has analyzed hip isometric abductor muscle strength in field hockey players, comparisons to the literature are not possible. A possible reason for the decrease in hip abduction strength observed at post-match 2 on the non-dominant side could be related to sarcomere disruptions within the muscular fibres due to the repeated overextension actions that occur during the different field hockey movements (e.g. accelerations, deceleration, change of directions) [31] and/or accumulating fatigue. It is well known that the diverse movement patterns and joint activities involved with field hockey require vigorous involvement of both the dominant and non-dominant lower limbs, for example during the repetitive unidirectional pivoting movements performed during forehand strokes and drag-flicks (i.e., preferred method of scoring during penalty corners in field hockey, mentioning that small number of players are specialized players in drag flicking actions) [32]. These strokes and player actions involve a combination of powerful trunk rotations, high muscle force production, and synchronization of lower limb movements [33] that altogether may predispose for overuse injuries (e.g. hip or lower back) not least due to the high volume of skill-specific training required to develop and maintain expertise in drag flicking [34]. In addition, a recent biomechanical study has shown that field hockey actions (such as above) characterized by hip flexion performed near the end range of motion (i.e. highly flexed) combined with hip joint rotation and abduction may contribute to an increased prevalence of hip injuries in field hockey players [35].

Very few studies have examined the relationship between congested match demands and mechanical muscle function in field hockey players. McGuinness and coworkers (2018) examined the physical state and physiological capacity of elite field hockey players during a condensed tournament program where seven matches were played in less than 2 weeks [36]. Notably, high intensity running during the matches progressively decreased throughout the tournament, with lower distances covered in games five, six, and seven when compared to game one [36]. The present results showed that running activity (i.e., distance covered and speed of movement, in many team sports) could be sustained in the second game, in spite of the fact that there was less than one day of recovery. Consequently, despite physiological impairments in hip muscle strength caused by two field hockey matches played on consecutive days, this did not lead to measurable decrements in playing performance (distance covered, acceleration-deceleration profiles). It is possible, however, that performance impairments would occur in the case of a longer tournament with a higher number of consecutive matches.

Measures of subjective wellness have been considered a useful tool to quantify and report the internal response to given activities of physical loading [37]. In the current study, female hockey players showed elevated indices of fatigue and muscle soreness 48 h after pre-match 2 in comparison with baseline levels (pre-match 1). No temporal changes were observed for any other variables included in the 5-WQ analysis. Accumulating fatigue and muscle soreness as well as signs of impaired subjective wellness may generally be explained by the engagement in repeated match demands [26]. The present results support the use of subjective wellness monitors such as the 5-WQ tool to evaluate mental recovery during periods of condensed and congested match play, as it could provide insightful information to coaches to individualize recovery strategies and to manage training load exposure in the preparation for subsequent matches.

In terms of perceived exertion of the players, the present study reported similar s-RPE (346.1 ± 231.7 AU in match 1 and 392.31 ± 203.82 AU in match 2) when compared to previous reports [34] (348 ± 61 AU in match 1 and 436 ± 85 AU in the match 2). In addition, McGuinness et al. [38] reported significant increases in s-RPE between match 1 and match 2, which was supported by a strong tendency ($p = 0.056$) for an increase in-s-RPE following match 2 in comparison with pre–post-match 1. Considering that it is common for professional hockey players to participate in consecutive daily matches during packed tournaments as part of their competition schedule, further research could prove useful to identify the relationship between physical demands imposed during consecutive matches in field hockey players and the resulting changes in s-RPE [39].

As for self-perceived recovery (TQR), no significant changes were found in the present study. Since there are no previous studies in hockey analyzing the perceived recovery via TQR in field hockey players, comparisons with the literature were not possible. The present lack of changes in TQR is partially supported by previous observations in other intermittent-type team sports such as football Gjaka et al. [39], with players engaging in either one or two matches per week over a 4-week period. Collectively, the available data thus suggest TQR to be less sensitive than wellness measures in the monitoring of field hockey players during the time course of condensed match programs.

Limitations

Some potential limitations may be recognized for the experimental design used in this investigation. Firstly, the present study participants represented a specific sample of female field hockey players, and the present findings may therefore not extend to goalkeepers, younger players, male field hockey players nor to athletes from other team sports. In addition, the results of this investigation are specific to the field hockey competition entailing two consecutive matches while other competitive scenarios with a higher number of matches or higher recovery periods may present different results. Further, the match-induced changes in hip muscle strength found in the present investigation were not directly compared against the actual incidence of groin injuries because the duration of the investigation was insufficient to obtain a representative number of groin injuries/complaints. Hence, the outcomes of this investigation should be confirmed with more prolonged experiments, where the development of groin injuries can be compared to fluctuations in maximal hip abductor and adductor muscle strength. Last, although hip muscle weakness, especially for the hip adductors, appears to represent a recurrent finding in previous investigations of risk factors for groin injury in team sports [7–9] the present observations of acute and more prolonged (+48 h) hip muscle weakness do not per se entail the development of groin injury.

Conclusions

In summary, isometric hip adductor and abductor strength in the non-dominant limb were reduced at post-match 1 and post-match 2 compared to baseline (pre-match 1) levels. These observations suggest that two consecutive matches of field hockey, played on consecutive days, may increase the risk of groin injury in professional female players due to transient (+48 h) hip abductor weakness. In addition, the current study showed signs of enhanced fatigue and muscle soreness at pre-match 2 compared to pre-match 1, while fatigue was recovered 48 h after the second match (5-WQ). These outcomes point toward a progressive accumulation in fatigue during densely packed tournaments, although not affecting running performance when assessed in match 2. Collectively, the current data underline the necessity of monitoring the hip adductor and abductor strength and the fluctuations in players' wellness in hockey competing in a congested match program. These routines may help identify field hockey players with excessive fatigue, who may be prone to groin injury due to acute and persistent (+48 h) hip muscle weakness.

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Authors' contributions
VSM, ALS, AN, and VMP contributed to the conception and design of the study. VSM, ALS AN, and VMP collected the data, VSM and AN analyzed the participant data. VSM, JDC, ALS, AN, PAA, and VMP wrote the manuscript. VSM, JDC, ALS, AN, PAA, and VMP read and approved the final version of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
Full data for this research is available through the corresponding author upon request.

Declarations

Ethics approval and consent to participate
The study was approved by Universidad Francisco de Vitoria Ethics Committee (UFV 45/2018) and conducted in agreement with the Declaration of Helsinki. In advance of their participation, all of the participants were fully informed about the purpose and experimental procedures of the study. Informed consent was obtained prior written from each participant. The participants were informed that all data collected would be processed anonymously.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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3.4 Estudio 4: Monitoring modifiable injury risk factors over an in-season mesocycle in semiprofessional female field hockey players.

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Monitoring modifiable injury risk factors over an in-season mesocycle in semi-professional female field hockey players

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Monitoring modifiable injury risk factors over an in-season mesocycle in semi-professional female field hockey players

ABSTRACT

Objective: This study aimed to determine the fluctuations of modifiable injury risk factors and fatigue parameters during a mesocycle (four months of the competitive season) in semi-professional female field hockey players (Spanish 2nd Division). ***Methods:*** Fourteen players (age: 22.6 ± 4.9 years) participated in the study over four months of the competitive season (September-December 2019). The players were tested each month for their: maximal isometric knee flexion, hip adduction and abduction muscle strength; passive straight leg raise and ankle dorsiflexion range of motion (ROM); countermovement jump height; and perceptual fatigue (through a wellness questionnaire). ***Results:*** Statistical differences were reported in isometric knee flexion strength in the dominant and non-dominant limb ($p = <0.001$, $\eta_p^2=0.629,0.786$ respectively), non-dominant isometric hip abductors strength ($p = 0.016$, $\eta_p^2=0.266$) and isometric hip adductors strength in dominant and non-dominant limbs ($p = <0.001$, $\eta_p^2=0.441\text{-}546$). Also, significant differences were reported in the straight leg raise test ($p = <.001$, $\eta_p^2=0\text{-}523, 0.556$) and ankle dorsiflexion ($p = 0.001$, $\eta_p^2=0.376, 0.377$) for the dominant and non-dominant limb respectively. Finally, the jump height measured showed significant differences ($p = <.001$, $\eta_p^2=0.490$), while no differences were reported in fatigue parameters ($p =0.089\text{-}0.459$). ***Conclusion:*** Fluctuations in maximal isometric muscle strength, ROM values, and vertical jumping capacity are reported during a competitive season. This information can be used to target recovery strategies to make them more efficient.

Keywords: team sports; injury risk; season; neuromuscular, fatigue.

INTRODUCTION

Field hockey is an intermittent team sport played in more than 125 countries worldwide, according to the International Field Hockey Federation, being included amongst the team sports disciplines that participate in the Olympic program [1]. This sport involves speed, agility and the ability to access a ground-level ball with a hockey stick and therefore places considerable effort on the lower limbs. Previous studies have reported that lower limb injuries account for 51% of all injuries in female field players being thigh (18%) and hip/groin (12%) were regions identified as most susceptible to injury [2, 3] in the lower limbs. From a clinical viewpoint, the identification of meaningful risk factors is essential to implement preventive strategies during female field hockey practice [4].

It is well recognized that the probability of suffering a muscle injury is determined by the interaction between several non-modifiable and modifiable extrinsic and intrinsic risk factors such as age [5], previous injury [3], reduced hamstring muscle strength [5], decreased knee extension range [6]decreased ankle dorsiflexión range of motion (ROM) [7] or the appearance of fatigue during training and matches [8].

Fatigue can result in a condition of overload and/or overtraining, which is associated with physiological and physiological consequences including an elevated injury incidence [9]. Previous research has shown that acute fatigue appearance after one or consecutive matches has been related to changes in hip abductor and adductor maximal isometric muscle strength [10], neuromuscular control [11] and ROM values [12]. However, the evidence for both the degree of variability and the value of controlling these variables over a competitive field-hockey season is scarce. Thus, it is paramount to provide empirical information to underpin the development of prevention strategies and correction programs by strength and conditioning coaches and physiotherapists.

Thus, this study aimed to evaluate fluctuations of intrinsic modifiable field hockey injury risk factors such as ROM, isometric muscle strength and neuromuscular performance measured by countermovement jump and physical/perceptual fatigue for four months during of competitive season in semi-professional field hockey female players.

MATERIAL AND METHODS

Participants

Fourteen semi-professional female field hockey players took part in this study (age: 22.6 ± 4.9 years; weight: 63.4 ± 5.8 kg; height: 167.0 ± 0.1 cm; body mass index: 22.6 ± 1.7; field hockey training experience: 12.9 ± 5.8 years; training per week: 6.7 ± 1.1 hours). All the female hockey players played in a semi-professional team that competed in the 2nd Division of the Spanish Female Field Hockey League. Exclusion criteria were a) goalkeepers, b) female field hockey players who were not able to perform the test due to an injury, sickness, or any physical complaint were excluded from the final sample of this study All players received information of test procedure and signed a consent form for participating in this study. The experimental procedure of this study was in accordance with the guidelines outlined in the Declaration of Helsinki 2013 and was approved by the [redacted] Ethics Committee (number 45/2018).

Experimental design

The current investigation is a cohort study, planned to be conducted monthly during the 2019-2020 season. However, the appearance of the COVID-19 pandemic in

March 2020, caused the training and competition to be stopped immediately. Since the Spanish field-hockey season is paused during the winter months of January and February (an indoor competition is played during this time), data was recorded only from September 2019-December 2019. Thus, the assessments were performed at four different separate time points during the competitive season (Figure 1): September 2019 (M1) (i.e., three weeks after the preseason period); October 2019 (M2) (i.e., after completing the first four matches of the season); November 2019 (M3) (i.e., after completing seven official competitive games); December 2019 (M4) (after completing the eleven official competitive games), a schedule which was predetermined based on player availability and match schedule. The players were tested before the training session, on the last day of the month in a physiotherapy room at the training facility of the field hockey club.

During each testing session, hockey players participated in: anthropometric measurements, ROM tests (ankle dorsiflexion and straight leg raise test), and maximal isometric muscle strength tests (hip adduction and abduction and knee flexion) in their dominant and no dominant limbs. Also, fluctuations in their neuromuscular performance (i.e., measured by countermovement jump) were recorded. Two physiotherapists with over ten and six years of experience supervised the measurements.

Figure 1 near here

Figure 1. Experimental design.

Perceptual fatigue was measured using a wellness questionnaire recorded before each training session [13] to detect fatigue status and the mean for each session/week was recorded for subsequent analysis. In addition, each month female hockey players filled injury questionnaire and all the measurements were undertaken at the same time of the day (i.e., to avoid the influence of circadian rhythms) on neuromuscular performance that has been reported in other female team sports [14].

Prior to each testing session, the players conducted a standardized warm-up that consisted of five minutes of jogging and five minutes of static stretching and joint mobility exercises [15]. All the female players were previously familiarized with the testing procedures because the muscle strength test employed in this investigation was part of an ongoing injury preventive program employed by the club which had been initiated a few months before this study. Based on the recommendations of Wollin et al [16] the order in which the players were tested, and the selection of the tested leg were chosen randomly. Limb dominance preference was determined through a questionnaire. To minimize interference from uncontrolled variables, subjects were instructed to maintain their usual lifestyle and normal dietary intake on the days of measurement and to refrain from caffeine intake 24 h before the experiment [17].

Isometric knee flexion muscle strength

Maximal isometric muscle knee flexion strength of hamstrings on both sides was measured using the previously described methodology [18] with a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA) . For this measurement, each player was positioned in a prone position on a bench, with 15 degrees of knee flexion. The examiner (first physiotherapist) placed the dynamometer in the distal portion of the sural triceps, three centimeters above the bimalleolar line while the assistant (second physiotherapist) held the subject's pelvis over the sacrum, to prevent elevation during the test. The examiner requested a knee flexion with the intention of bringing the heel of the foot to the buttock. Players performed voluntary contractions for a maximum of 5 seconds against the dynamometer and repeated the exercise twice for each leg. There was a rest period of 30 seconds between each measurement [19] and two repetitions were performed for both the dominant and non-dominant leg. The highest value obtained was recorded for subsequent analysis.

Isometric hip adductor and abductor muscle strength

Maximal isometric strength of the hip adductors and abductors on both sides were measured using a portable handheld dynamometer (Nicholas Manual Muscle Tester; Lafayette Indiana Instruments, Lafayette, IN, USA). Participants were in a supine position with their hips in a neutral position and told to stabilize by holding onto the sides of the table. The first physiotherapist applied resistance in a fixed position, 5 centimeters to the proximal edge of the lateral for abduction or medial for adduction malleolus, while the second physiotherapist maintain the correct position of the patient. Participants performed voluntary contractions for a maximum of 5 seconds against the dynamometer and repeated the exercise twice for each leg. There was a rest period of 30 seconds between each measurement [20, 21]. Two repetitions were performed for both the dominant and non-dominant leg. The highest value obtained was recorded for subsequent analysis.

Hip flexion range-of-motion (Straight Leg Raise Test)

To measure the flexibility of the hamstrings through hip flexion ROM with the knee extended, the straight leg raise test was performed [19, 22]. An ISOMED Unilevel inclinometer (Portland, Oregon) with a telescopic extension long arm was used for the measurement. The inclinometer was placed approximately on the external malleolus and the distal arm was aligned parallel to an imaginary bisecting line of the limb [23]. The test ended with one or more of the following criteria: a) The examiner was unable to continue the joint movement evaluated, due to the high resistance developed by the stretched muscle group; b) The examinee reports a significant sense of distrust; c) noted compensations that could increase the measurement; d) the appearance of pain.

Ankle dorsiflexion range of motion (ROM)

Unilateral ankle dorsiflexion ROM was measured using the LegMotion System (LegMotion, Check your Motion, Albacete, Spain). Each player took a standing position on the LegMotion System with their hands on the hips and the foot of the ankle being tested placed on the measurement platform. The contralateral foot was positioned off the platform with the toes positioned at the edge of the platform. While maintaining this position, players were instructed to flex the knee on the same leg as the tested ankle, with the knee contacting a metal stick placed in front of the toe. Once contact between the knee and stick, and between the heel and ground, were maintained for 3 s, the stick was progressively moved away from the knee in 1-cm increments each time until the knee could not contact the stick or heel contact with the ground could not be maintained [24] The furthest achieved distance (cm) of the metal stick from the closest toe was recorded. Two attempts were permitted for each ankle (dominant and non-dominant legs) with 10 s of passive recovery administered between attempts. The dominant leg for each player was determined as their preferred leg for kicking a ball [25]. Additional attempts were performed until two ankle dorsiflexion measurements with less than 10% difference for each ankle were attained. The highest value of the two attempts for each ankle was used for further analysis.

Countermovement jump

Vertical jump height was measured following established procedures [26]. For measuring each jump a validated contact platform was used (Chronojump Boscosystem®, Barcelona, Spain) [27]. Specifically, female players performed a countermovement jump without arm swing with their hands on their hips. Each player performed two maximal attempts, with each attempt interspersed with 45 s of passive recovery. Additional attempts were performed until two jumps differed in height by less than 10% for each jump type. The greatest jump height (cm) for each jump type was used for analysis.

Wellness questionnaire.

Perceptual fatigue was measured using a psychological questionnaire designed to assess subjective well-being (5-WQ). The players completed a 5-item psychometric questionnaire that included questions generally related to fatigue, perceived levels of sleep quality, muscle pain, stress level, and mood. A five-point Likert scale (i.e., values of 1-5 with 0.5 point increments) was used. Total well-being was determined by summing the 5 questions to obtain a score ranging 5 to 25 [13].

Statistical analysis.

Given the observational design and exploratory nature of the study involving volunteer participants, *a priori* sample size estimates for hypothesis testing were not carried out. However, where differences in the measured variables were observed over time, the magnitude of the effect size and p-value are reported.

The Shapiro–Wilk test was first used to assess the normal distribution of data. Means and standard deviations of the data were determined. These were compared for the ROM, strength, countermovement jump and wellness test variables registered at the four different months (September, October, November, and December) using a repeated-measures analysis of variance (ANOVA). If significant differences were found between the measures across the four instances, a Bonferroni post hoc test was performed. In cases where the sphericity assumption was violated, a Greenhouse–Geisser adjustment for p-values was reported. The effect sizes of the repeated measures ANOVA were measured using partial n_p^2 values, and the following thresholds were used: trivial ($n_p^2 \leq 0.01$), small ($0.01 \leq n_p^2 < 0.06$), medium ($0.06 \leq n_p^2 < 0.14$) and large ($n_p^2 \geq 0.14$).

Wellness values were compared using the non-parametric Friedman's test of repeated measures, and effect sizes were determined using Kendall's coefficient of concordance (Kendall's W), the following thresholds were used: trivial ($W \leq 0.1$), small ($0.1 \leq W < 0.3$), moderate ($0.3 \leq W < 0.6$) and large ($W \geq 0.6$). Significance was set at $p < 0.05$. Statistical analysis was carried out using Jamovi (version 2.3.12, www.jamovi.org).

RESULTS

Differences were observed over time for each of the measured variables, within this cohort of female hockey players. Testing protocol proved feasible and acceptable for the team roster and hockey players and we reported a very good data completeness due to the 14 female hockey players competed all testing days.

Isometric knee flexion muscle strength

Isometric knee flexion muscle strength showed significant differences and a large effect size for the dominant limb ($F(3,33) = 18.6$, $p = <0.001$, $\eta_p^2=0.629$), with the post hoc tests showing that month 4 (M4) values were significantly higher than previous months (i.e., M1, M2, M3) (p=0.001-0.003) (Figure 2a). For the non-dominant limb, significant differences with a large effect size were also present ($F_{(3,33)} = 40.3$, $p = <.001$, $\eta_p^2=0.786$), with post-hoc analysis showing higher M4 values compared to previous months (i.e., M1, M2, M3) (p=<0.001-0.004) and also higher M2 values compared to M1 ($p = <0.001$) (Figure 2b).

****Figure 2 near here****

Figure 2. Isometric strength values in female field hockey players. N=newton; kg=kilograms; DOM= Dominant; NO-DOM=non-dominant. *Statistical

differences comparing M4 ($p<0.05$). ** Statistical differences comparing M2. ($p<0.05$).*** Statistical differences comparing M2. ($p<0.05$).

Isometric hip adductor and abductor muscle strength.

Significant changes with large effect sizes were seen in the isometric hip adductor muscle strength measurements for the dominant limb ($F_{(3,33)} = 5.18$, $p = 0.005$, $\eta_p^2=0.320$) (Figure 2c), but post-hoc testing showed no statistical differences in values. Similarly, the non-dominant limb also showed a significant effect of month ($F_{(3,33)} = 3.98$, $p = 0.016$, $\eta_p^2=0.266$) with the reported M3 values being significantly higher when compared to those from M2 ($p = 0.032$) (Figure 2d).

Isometric hip adductors muscle strength showed significant differences and large effect size for the dominant limb ($F_{(3,33)} = 8.67$, $p = <0.001$, $\eta_p^2=0.441$) (Figure 2e), and post-hoc tests showed lower values at M1 values when compared to M4 ($p <.001$) and M3 ($p = 0.028$). Similarly, in the non-dominant limb, statistical differences were also reported ($F_{(3,33)} = 13.2$, $p = <0.001$, $\eta_p^2=0.546$) (Figure 2f). Values at M4 were higher than those at M2 ($p = 0.035$) and M1 ($p = 0.024$), and also higher at M3 compared to M2 ($p = 0.002$) and M1 ($p=0.012$) respectively.

ROM values (hamstring and ankle dorsiflexion)

Hip flexion ROM with the knee extended showed a large effect size and significant differences for the dominant limb ($F_{(3,33)} = 13.8$, $p = <.001$, $\eta_p^2=0.556$). The post hoc tests showed that M4 values were significantly higher than previous months (i.e., M1, M2, M3) ($p=0.002-0.030$) (Figure 3a). Similarly, for the non-dominant limb significant differences were reported ($F_{(3,33)} = 435.7$, $p = <.001$, $\eta_p^2=0.523$) with post hoc tests confirming higher values at M4 compared to the previous months (i.e., M1, M2, M3) ($p=0.001-0.004$) (Figure 3b).

****Figure 3 near here****

Figure 3. ROM values in female field hockey players. N=newton; kg=kilograms; DOM= Dominant; NO-DOM=non-dominant. *Statistical differences comparing M4 ($p<0.05$).

Ankle dorsiflexion ROM showed significant, differences over time with lower values at M4 compared to M1, M2, M3 in both the dominant ($F_{(3,33)} = 6.64$, p = 0.001, $\eta_p^2=0.376$) (Figure 3c) and the non-dominant limb ($F_{(3,33)} = 6.65$, p = 0.001, $\eta_p^2=0.377$) (Figure 3d).

Countermovement jump

Countermovement jump height also varied across the four months ($F_{(3,33)} = 9.62$, p = <.001, $\eta_p^2=0.490$) with significant differences between values at M1, M2, and M4 versus M3 (p=0.005- 0.010).

Wellness Questionnaire

No significant differences were found in fatigue parameters ($\chi^2=2.59$, df =3, p=0.459, Kendall's W=0.067), sleep ($\chi^2=3.42$, df =3, p=0.331, Kendall's W=0.087), soreness ($\chi^2=4.01$, df =3, p=0.261, Kendall's W=0.103), stress ($\chi^2=2.78$, df =3, p=0.426, Kendall's W=0.071), mood ($\chi^2=6.52$, df =3, p=0.089, Kendall's W=0.167), and total wellness measurement ($\chi^2=4.85$, df =3, p=0.183, Kendall's W=0.124) in the 4 months measured (Table 1).

DISCUSSION

The aim of this study was to examine the variation in a range of indicators, proposed to contribute to modifiable intrinsic injury risk, during four months of the competitive season in semi-professional female field hockey players. These variables include objective physical measures; hamstring and adductor and abductor isometric muscle strength, hamstring and ankle dorsiflexion ROM and neuromuscular performance (i.e., measured by a countermovement jump) as well as subjective perceptual fatigue (measured by a wellness questionnaire).

The main motivation reason for conducting this investigation was based on previous studies that suggested that both acute [12] and congestion related [10] demands associated with field-hockey matches provoked changes in isometric muscle strength and ROM values. However, it remains unknown to what extent these risk variables are modulated during a chronic period such as several months during the field-hockey competitive season. The main findings of this study were isometric muscle strength, ROM values and neuromuscular performance generally increased progressively during the season while no significant changes were reported in fatigue perceived levels (i.e., measured by wellness questionnaire) and finally a reduction in dorsiflexion ROM values was reported.

The present data revealed that isometric knee flexion muscle strength values increased after 4-months of a competitive season compared to the pre-season values (M1) in the dominant and non-dominant limbs (39.0-43.1%) respectively. This outcome agrees with previous studies that reported an increment (12.3%) of knee isometric hamstring muscle strength in semi-professional football players after 18 weeks of the competition season (comparing pre-season vs mid-season) [28]. A possible explanation for the observed increment in isometric knee flexion muscle strength during between the 4-

month follow-up could be attributed to the players starting the preseason in September (M1) after 3-months of a transition period characterized by complete cessation of all training activities which could influence a decrement in physiological and performance adaptations [29]. However, the findings regarding hip abductor and adductor strength are contradictory to a previous study in semi-professional male football players reported changes in isometric abductor strength between pre to mid-season (July vs January) while no differences were reported in isometric adductor strength [30].

An adequate ROM in the lower limbs is essential in field hockey due to the continuous flexed positions and multidirectional movements that field hockey players carry out during training and competitions [31, 32]. Although previous studies have analyzed the acute [12] or congestion [10] effects on ROM values in female hockey players, to the best of our knowledge, no previous investigation has evaluated the longitudinal changes in hamstring and ankle flexibility during several months of the competitive season in female field hockey players. Our data showed statistical increasements in hip flexion ROM levels with the knee extended for the dominant and non-dominant limb after 4-months (M4) comparing with previous months (M1, M2, M3) reporting differences with previous studies that no reported differences across the season in semi-professional football players [28]. However, the difference obtained between studies could be explained by the sample characteristics (male vs female) or physical demands between sports (football vs field hockey). Regarding ankle dorsiflexion ROM values, a statistical decrement was observed comparing M4 comparing to previous months which is in agreement with previous studies in semi-professional football players, where a decrement of 8.9-9.6 % was reported for the dominant and non-dominant limbs respectively [25]. A possible reason for these decrements in ankle dorsiflexion ROM could be attributed to chronic muscle adaptations related to; the demands associated with continuous training/matches during the competitive season and the high number of accelerations/ decelerations realized as well as changes-of-direction and jumping that involves high-intensity eccentric actions increasing muscle/tendons stiffness [33] and decreasing joint ROM [34].

Strength and muscle power have been associated with success in field hockey performance due to the potential for increments in strength and power to produce faster ball speeds and shoot more powerfully [35, 36]. Thus, monitoring changes in strength/muscle power along the season is crucial for controlling the neuromuscular performance in players [37] and for detecting their fatigue status [38]. Although multiple devices (e.g. isokinetic machines, linear position transducers) have been proposed to evaluate these neuromuscular changes, in the last years the use of the countermovement jump has become popular due to the low cost, simplicity, and ease of implementation. Our data findings showed that countermovement jump levels were lower in November (M3) compared to previous (M1, M2) and following months (M4) which could be linked to a higher number of field hockey games played during the M3 comparing the other months. These results contradict previous studies in team-sports disciplines (e.g. football) that did not show changes in jump capacity during the in-season period [39]. These can be explained by the differences in the monitoring period (1-week period in Malone et al. vs 4-months here) and the differences between participants (young male vs female).

A wellness questionnaire has been proposed as a non-invasive method for assessing players' fatigue during training or competition events [13]. According to the wellness questionnaire, no significant changes were found in the present study during the 4-months (16-weeks) periods in the measured fatigue variables (e.g. sleep, soreness, stress, and mood). There were only small differences observed (effect size < 0.3). These results are in agreement with previous study that reported no evidence of long-term reductions over the seven-week mesocycle [40] in team sport athletes. Thus, a wellness questionnaire could be less sensitive than a countermovement jump for monitoring changes in female field hockey during a 4-month period.

Aside from its strengths, which include the prospective design, the rigorous assessment protocol and good data completeness, the current investigation has several limitations that should be discussed to enhance its applicability to real sports context scenarios. Firstly, the initial investigation had to be cut short because of the COVID-19 pandemic which led to a complete cessation of activities for over six months. As a result, the changes obtained in the short-time intervention period (16 weeks) could be different compared to the possible changes provoked during an entire competitive season of nine months. Secondly, since only a single cohort of a limited number of players participated in the study, the findings may not be readily extended to male s or youth players.

CONCLUSION

Fluctuations in isometric muscle strength, ROM values, and vertical jumping capacity are reported during the competitive season. Specifically, the strength in the adductors, abductors, and hamstrings progressively increase as the players get more game time, but the ankle ROM decreases. However, the neuromuscular performance levels, determined through the countermovement jump, varied with a greater load exhibited when more matches were played. This information is useful as strength coaches and physiotherapists can target recovery strategies to make them more efficient. Thus, the regular monitoring of modifiable intrinsic risk factors can be useful to provide information on the status of the hockey players.

CONFLICT OF INTEREST

The authors report there are no competing interests to declare.

Authors' contributions

VSM, VMP, AN and ALS contributed to conception and design of the study. VSM, VFR, PTM collected the data, VSM and AN analyzed the participant data. VSM, VMP, CB, AN, ALS wrote the manuscript. VSM, VMP, VFR, PTM, CB, AN and ALS read and approved the final version of the manuscript.

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Availability of data and materials

Full data for this research is available through the corresponding author upon request.

Ethics approval and consent to participate.

The study was approved by Universidad Francisco de Vitoria Ethics Committee (UFV 45/2018) and conducted in agreement with the Declaration of Helsinki. In advance of their participation, all of the participants were fully informed about the purpose and experimental procedures of the study. Informed consent was obtained prior written from each participant. The participants were informed that all data collected would be processed anonymously.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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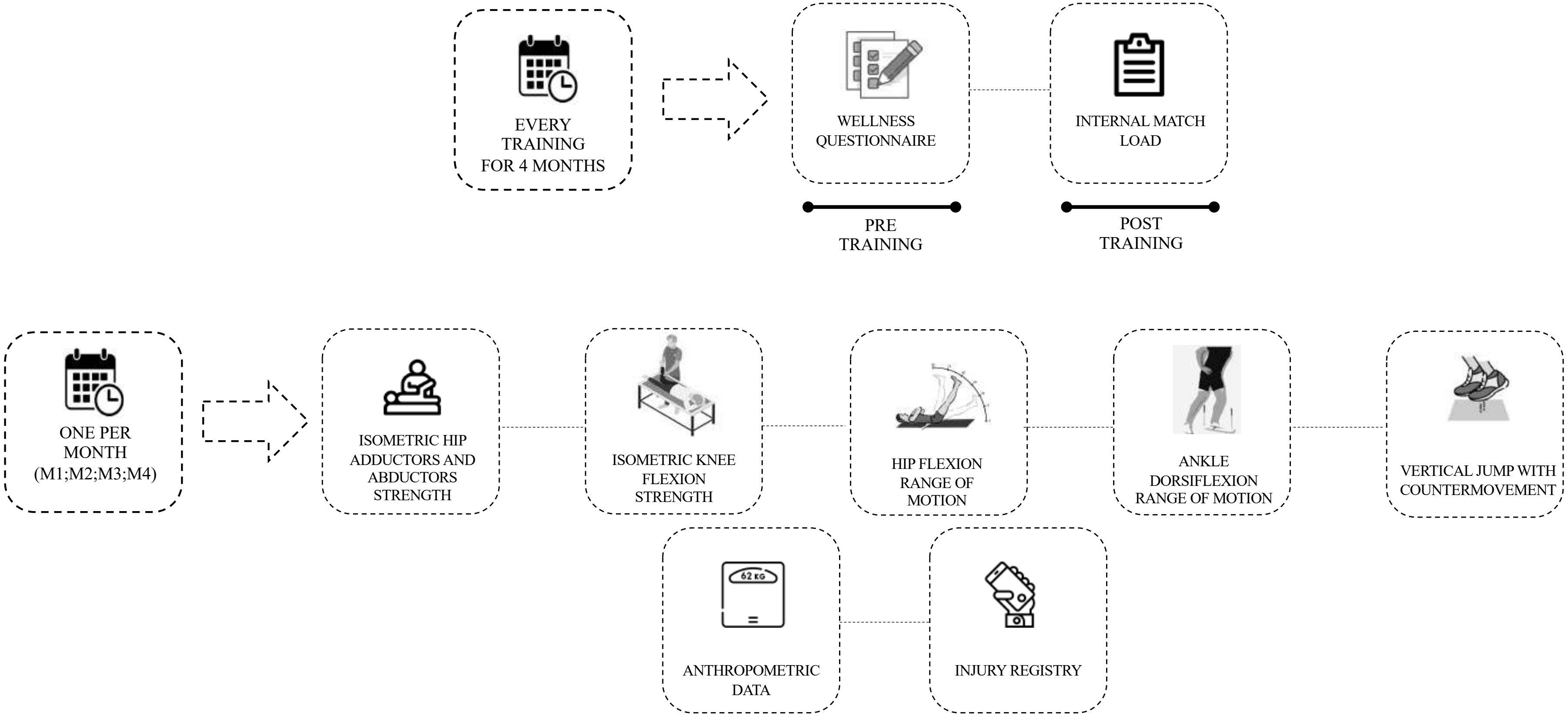
TABLES AND FIGURES

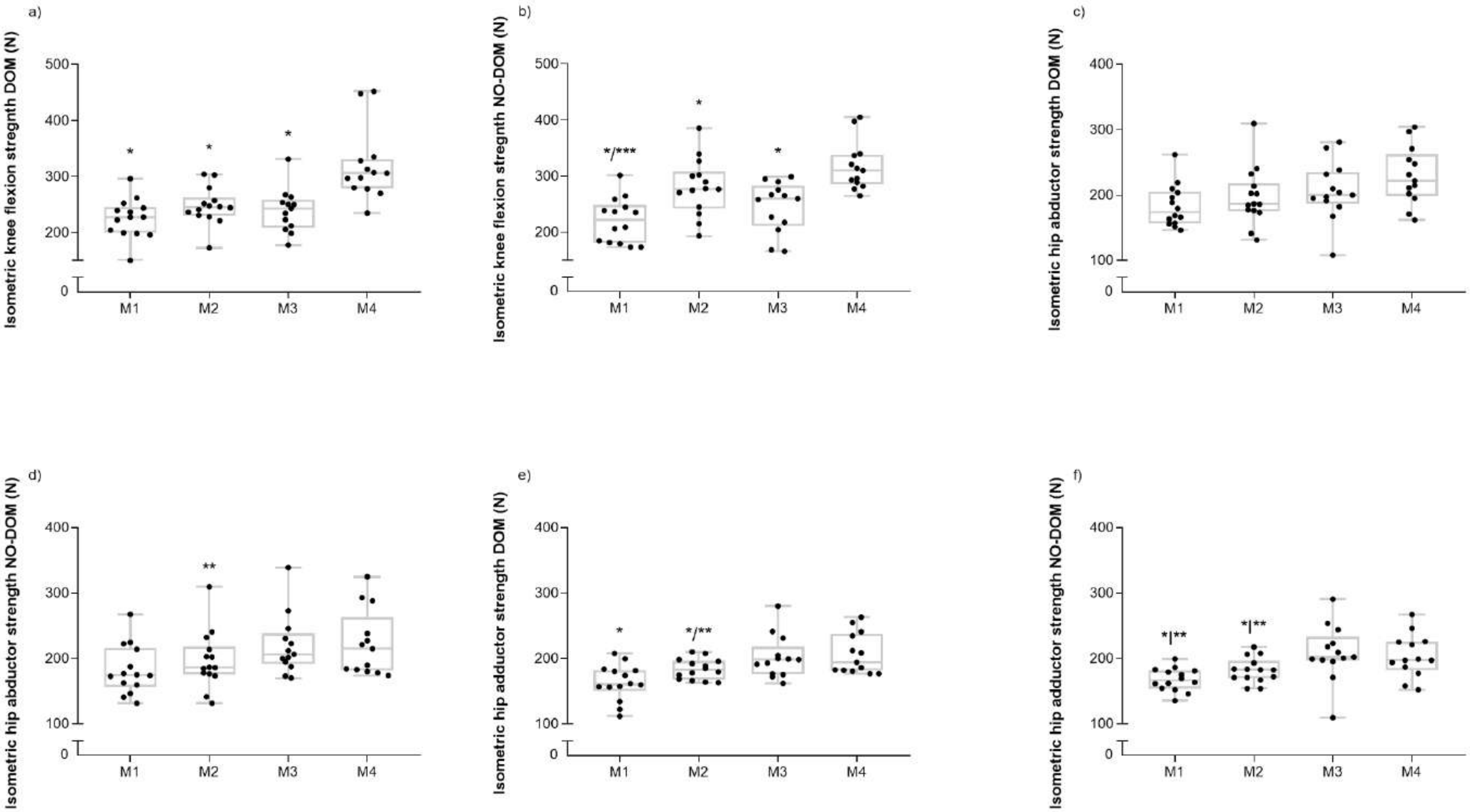
Figure 1. Experimental design.

Figure 2. Isometric strength values in female field hockey players. N=newton;kg=kilograms; DOM= Dominant; NO-DOM=non-dominant. *Statistical differences comparing M4 ($p<0.05$). ** Statistical differences comparing M2. ($p<0.05$).*** Statistical differences comparing M2. ($p<0.05$).

Figure 3. ROM values in female field hockey players. N=newton; kg=kilograms; DOM= Dominant; NO-DOM=non-dominant. *Statistical differences comparing M4 ($p<0.05$).

Table 1: Items obtained in the subjective wellness questionnaire (5-WQ) in female field hockey players


EVERY TRAINING FOR 4 MONTHS
WELLNESS QUESTIONNAIRE
INTERNAL MATCH LOAD
PRE TRAINING
POST TRAINING
ONE PER MONTH (M1;M2;M3;M4)
ISOMETRIC HIP ADDUCTORS AND ABDUCTORS STRENGTH
ISOMETRIC KNEE FLEXION STRENGTH
HIP FLEXION RANGE OF MOTION
ANKLE DORSIFLEXION RANGE OF MOTION
VERTICAL JUMP WITH COUNTERMOVEMENT
ANTHROPOMETRIC DATA
INJURY REGISTRY


a)
Isometric knee flexion stregnth DOM (N)
b)
Isometric knee flexion stregnth NO-DOM (N)
c)
Isometric hip abductor strength DOM (N)
d)
Isometric hip abductor strength NO-DOM (N)
e)
Isometric hip adductor strength DOM (N)
f)
Isometric hip adductor strength NO-DOM (N)
M1
M2
M3
M4

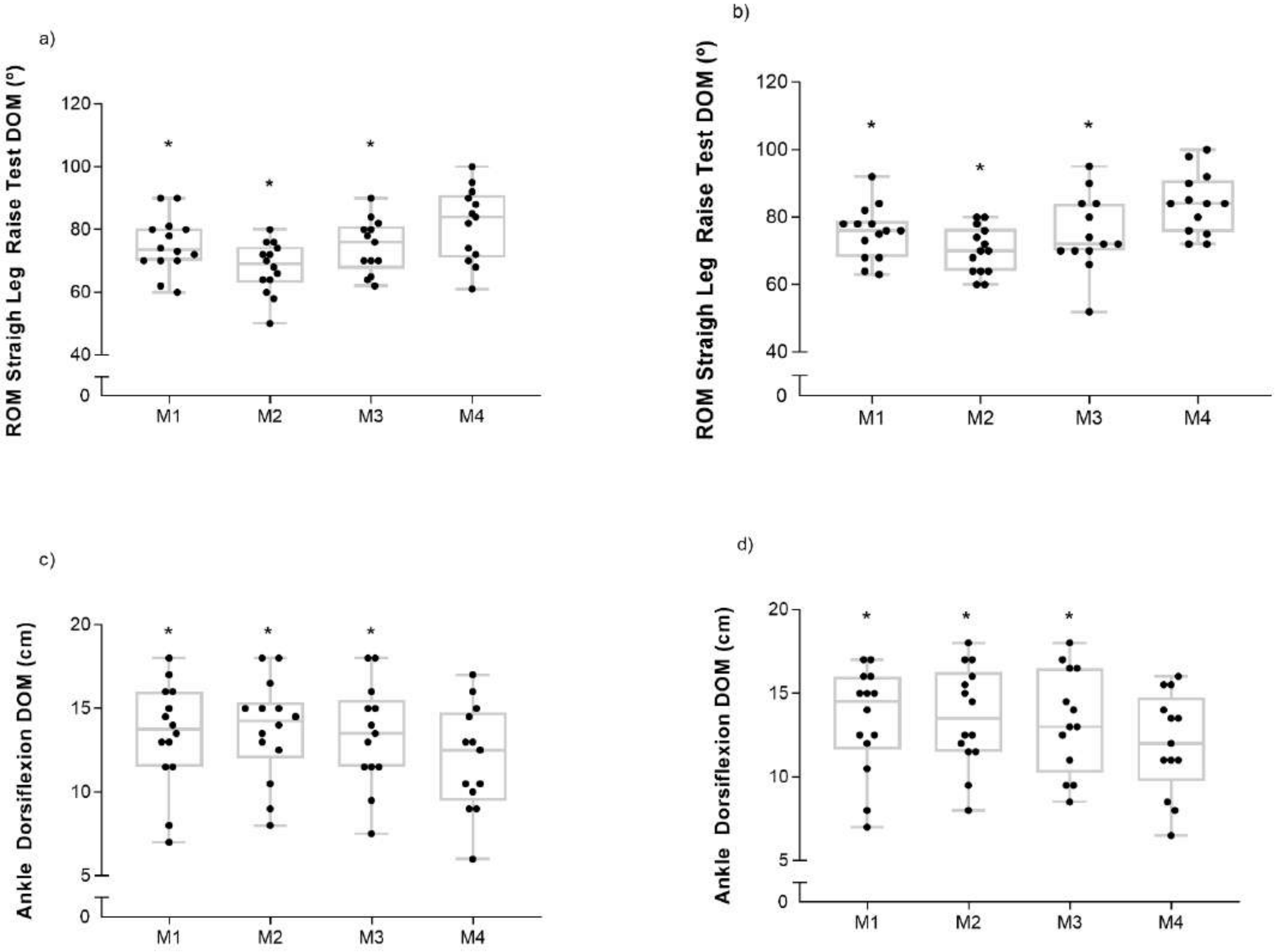

a)
ROM Straigh Leg Raise Test DOM (°)
120
100
80
60
40
0
M1
M2
M3
M4
b)
ROM Straigh Leg Raise Test DOM (°)
120
100
80
60
40
0
M1
M2
M3
M4
c)
Ankle Dorsiflexion DOM (cm)
20
15
10
5
0
M1
M2
M3
M4
d)
Ankle Dorsiflexion DOM (cm)
20
15
10
5
0
M1
M2
M3
M4

Table 1: Items obtained in the subjective wellness questionnaire (5-WQ) in female field hockey players

Variable (Arbitrary Units)	M1	M2	M3	M4	*p-value*	Kendall's W
Fatigue	3.43±0.85	3.59±0.53	3.51±0.55	3.70±0.89	0.459	0.066
Sleep	3.61±0.59	3.71±0.68	3.39±0.33	3.58±0.70	0.331	0.087
Soreness	3.32±0.80	3.54±0.67	3.23±0.55	3.26±0.72	0.261	0.103
Stress	3.46±1.26	3.10±0.94	3.08±0.64	3.41±1.24	0.426	0.071
Mood	3.32±1.10	3.67±0.58	3.59±0.40	4.00±0.74	0.089	0.167
Total Wellness	3.43±0.54	3.52±0.48	3.36±0.35	3.59±0.66	0.183	0.124

4. RESULTADOS DISCUSIÓN

4. RESULTADOS Y DISCUSIÓN

A través de los diferentes estudios realizados en esta Tesis Doctoral, se han analizado los efectos provocados en diferentes periodos de carga competitiva (*i.e.,* efecto agudo, periodo de congestión y mesociclo competitivo) sobre los factores de riesgo intrínsecos modificables en jugadoras de hockey hierba femenino.

4.1. Efectos agudos de un partido de hockey hierba femenino

Los resultados obtenidos en el estudio 1 de esta Tesis Doctoral, en el que se analizaron los efectos agudos provocados por la realización de un partido simulado, reportaron un aumento significativo post partido en la fuerza isométrica los músculos flexores de la rodilla en la extremidad no dominante (7.0%), en el ROM de la flexión de la cadera en el miembro no dominante (4.4%) y un descenso de los valores de CMJ (-11.1%), mientras que no se reportaron diferencias en la fuerza isométrica de los músculos abductores y aductores de la cadera y la ratio de aductores/abductores de la cadera así como del ROM de la flexión de la cadera y ROM de la dorsiflexión del tobillo en el lado dominante. De acuerdo al conocimiento previo de los autores, no existen estudios que hayan analizado cambios en la fuerza isométrica de los músculos flexores de la rodilla en jugadores/as de hockey hierba. Los resultados obtenidos difieren de estudios anteriores realizados en otros deportes de carácter intermitente (*e.g.,* fútbol, fútbol australiano) que reportaron una disminución en los valores post partido (84,118). Estas diferencias entre estudios pueden ser debidas a las diferentes demandas a nivel físico-fisiológicas que se producen entre los diferentes deportes de equipo, ya que mientras que en los datos obtenidos en este estudio a nivel agudo en hockey hierba, las jugadoras reportaron una distancia total recorrida alrededor de 5500 metros, mientras que otros estudios realizados en deportes como el fútbol reportan distancias recorridas alrededor de los 10000 metros durante el transcurso de un partido de 90 minutos de duración (119). Por otra parte, el CMJ es una de las pruebas neuromusculares más utilizadas (*i.e.,* debido a su fácil implementación y bajo coste) para poder determinar la fatiga neuromuscular en la musculatura del miembro inferior (113,120). Por ello, la reducción de manera significativa de la capacidad de salto con contramovimiento (CMJ) (-11.1%) por parte de las jugadoras de hockey femenino tras la disputa de un partido simulado parece indicar que la realización de un solo partido simulado es suficiente para inducir fatiga neuromuscular en las jugadoras que disputen esta modalidad deportiva, por tanto, es necesario establecer estrategias desde el ámbito de la medicina deportiva que permitan a las jugadoras de hockey hierba recuperarse lo antes posible para el siguiente evento competitivo. Por otra parte, de acuerdo a la literatura existente, se sabe que un ROM reducido de la dorsiflexión del tobillo y de los flexores de la cadera pueden estar asociados a un aumento de la incidencia lesional de la musculatura isquiosural (38,71), no dándose este fenómeno a nivel agudo en jugadoras de hockey hierba como es reportado en el estudio 1, donde no se encontraron diferencias ni en el miembro dominante ni en el no dominante en los valores de ROM de la dorsiflexion del tobillo y de la flexión de la cadera (*i.e.,* lado dominante). Esto es respaldado por otros estudios realizados en deportes de equipo que no reportaron diferencias tras la realización de un partido simulado o competitivo (*e.g.,* fútbol, baloncesto) (84,121).

4.2. Efectos en un periodo de congestión competitiva de hockey hierba femenino

En los estudios 2 y 3 de la presente Tesis Doctoral se examinó el efecto que conlleva una congestión competitiva, jugando dos partidos consecutivos con menos de 48 horas de diferencia y evaluando variables de fuerza isométrica, ROM, además de monitorizar la fatiga neuromuscular (*i.e.,* CMJ) y la utilización de herramientas de evaluación de la carga interna (*e.g.,* s-RPE, 5-WQ). Referente a los efectos provocados en la fuerza isométrica de los músculos flexores de la rodilla durante este periodo de congestión (estudio 2), se registró un aumento significativo en la extremidad no dominante 48 horas después de la realización del partido 2, lo que podría sugerir que no se reportó fatiga acumulada después de una comgestión competitiva y esto se podría hipotetizar que es debido a que los músculos isquiosurales no acumulan una fatiga excesiva entre partidos, dado que las distancias recorridas a intensidades muy altas y velocidades de sprint son bajas en hockey hierba (122), si se comparan con las distancias recorridas en otros deportes intermitentes como el fútbol (123), donde los jugadores cubren mayores distancias a intensidades y velocidades de sprint elevadas. Esto está basado en investigaciones anteriores que los músculos isquiosurales son más activos a estas altas velocidades (124) no teniendo un papel predominante a velocidades más bajas (125).

Referente a los efectos provocados por una congestión competitiva en hockey hierba sobre la fuerza isométrica de los músculos abductores y aductores de la cadera (estudio 3), nuestros hallazgos mostraron que la fuerza isométrica del aductor de la cadera disminuyó significativamente (-10.6%) de forma aguda después del partido 1 en la extremidad no dominante y después del partido 2 disminuyó también en la extremidad no dominante (-17.5%) como en la dominante (-13.4%) en comparación con los niveles reportados previos al partido 1. Previas investigaciones han demostrado que los valores de fuerza de la musculatura aductora de la cadera se ven reducidos significativamente después de partidos de fútbol jugados consecutivamente con una recuperación insuficiente (*i.e.,* ≤ 96 h de descanso entre partidos) en comparación con los niveles pre competitivos (90,126). Estas disminuciones de la fuerza isométrica de los abductores y aductores de la cadera observados tras el partido podrían explicarse por la aparición de la fatiga neuromuscular (80) impuesta por las exigencias físicas específicas del hockey hierba. Esto puede ser debido a que las jugadores de hockey hierba realizan una gran cantidad de cambios de dirección durante la disputa de un partido competitivo (73), que probablemente requieran altos niveles de fuerza en los músculos aductores de la cadera a nivel concéntrico/excéntrico. Las reducciones agudas y sostenidas de la fuerza isométrica de los músculos aductores de la cadera que se observan actualmente en el lado no dominante (10.6-17.5%) tras una congestión competitiva podrían representar un aumento del riesgo de la probabilidad de desarrollo de lesiones inguinales (89). Por otro lado, tras una congestión competitiva, se observó que la fuerza isométrica de los músculos abductores de la cadera disminuyó de manera significativa en la extremidad no dominante al comparar los niveles pre partido 1 (-11.1%), al partido 2 (-14.9%) y a las 48 horas del partido 2 (-17.0%) con los niveles basales (pre partido 1). Dado que ningún estudio anterior ha analizado la fuerza muscular isométrica de los músculos abductores de la cadera en jugadores de hockey hierba, no es posible realizar comparaciones con la literatura. Sin embargo, es sabido que los patrones de movimiento en hockey hierba requieren una fuerte implicación tanto del miembro inferior como del miembro superior (*e.g.,* movimientos pivotantes unidireccionales repetitivos que se realizan durante los golpes de derecha y los golpes de arrastre) (127).

Los efectos provocados por un periodo de congestión competitiva sobre el ROM de la flexión de la cadera (estudio 2), no mostraron diferencias significativas ni en el miembro dominante ni en el no dominante. Estos resultados coinciden con protocolos similares realizados en tenis (83) en el que se comparó el ROM de la flexión de la cadera antes y después de un partido. En cuanto al ROM de la dorsiflexión del tobillo (reportado en el estudio 2), no se reportaron diferencias significativas (*i.e.,* pierna dominante y no dominante). Estos resultados coinciden con los previamente encontrados por Wollin et al. (2018) donde el ROM de la dorsiflexión del tobillo no se vio afectada por la disputa de dos partidos en jugadores de élite de fútbol (*i.e.,* periodo congestivo) (89). Debido a que es difícil comparar los datos entre estudios por las diferentes características físicas de los participantes (*i.e.*, jugadoras de hockey hierba senior vs jugadores de fútbol jóvenes) se requiere la realización de futuros estudios que analicen periodos de congestión competitiva en deportes de equipo para poder aumentar la evidencia en este campo de investigación.

Referente al CMJ (estudio 2), su respuesta se caracterizó por un aumento de los valores lo largo de los partidos. Esto es contrario a lo publicado anteriormente en diferentes deportes (*e.g.,* fútbol, hockey hielo) (88,128,129). Estas diferencias podrían ser debidas a diferentes razones: a) en primer lugar, previo al partido 1 se realizó un calentamiento de solamente cinco minutos de duración, centrado principalmente en ejercicios de movilidad articular del miembro inferior, posteriormente a este calentamiento, las jugadoras pasaron a realizar el calentamiento específico del partido, por lo que la intensidad del calentamiento podría haber sido insuficiente para poder una activación correcta a nivel neuromuscular. b) en segundo lugar, el aumento de la altura del CMJ podría estar relacionado con una mayor activación de los músculos del tibial anterior, gastrocnemio y sóleo como resultado de carreras de intensidad media realizadas durante el partido (130), ya que estos músculos desempeñan un papel importante en la determinación del rendimiento del salto con contramovimiento (CMJ) (131) y una mayor activación, podría dar lugar a un mejor rendimiento.

Respecto a el 5-WQ tras un periodo de congestión competitiva (estudio 3), las jugadoras de hockey hierba mostraron elevados índices de fatiga y dolor muscular 48 horas después de la disputa del partido 2 en comparación con los niveles pre competición (*i.e.*, pre partido 1). Además, no se observaron cambios en el resto de variables incluidas en el cuestionario 5-WQ. Referente a las variables de fatiga y el dolor muscular acumulados, así como los signos de deterioro del bienestar subjetivo, los hallazgos encontrados pueden explicarse en general por las acciones repetidas y alta exigencia provocada por la disputa de dos partidos con un tiempo inadecuado de recuperación (126). Los presentes resultados apoyan la necesidad de monitorizar variables de carga interna (*e.g.,* bienestar subjetivo a través de herramienta 5-WQ), para evaluar la recuperación físico-fisiológica durante los períodos de alta densidad competitiva (*i.e.,* periodos de congestión), ya que podría proporcionar información de gran relevancia a los entrenadores para poder establecer e individualizar estrategias de recuperación y con ello, poder gestionar una preparación adecuada para los siguientes eventos competitivos.

No se encontraron diferencias significativas en el TQR tras una congestión competitiva (estudio 3). De acuerdo a nuestro conocimiento, no existen estudios previos en jugadoras de hockey hierba que analicen la recuperación percibida a través del TQR, por ello, no fue posible realizar comparaciones con la literatura. La presente falta de cambios en el TQR está parcialmente respaldada por Gjaka et al. (2016), que no observaron cambios en otros deportes de equipo de carácter intermitente (*i.e.,* fútbol) en jugadores que participan en uno o dos partidos por semana durante un período de 4 semanas (132). En conjunto, los datos disponibles sugieren que el TQR es menos sensible que las medidas de bienestar en el seguimiento de los jugadores de hockey hierba durante el transcurso de partidos consecutivos y/o periodos de congestión competitiva.

En cuanto a los valores de s-RPE reportados durante el estudio 3 no se encontraron diferencias significativas entre en los datos reportados tras la disputa del partido 1 (346 ± 231 UA)) en comparativa con la reportada tras el partido 2 (392 ± 203 UA). Esto, difiere de los hallazgos encontrados por el grupo de McGuinness et al. (2020) (2) que reportaron diferencias significativos en el s-RPE entre el partido 1 y el partido 2 (*i.e.,* 348.0 ± 61 vs 436 vs 85 UA) (133). Las diferencias entre estudios pueden ser atribuidas a los diferentes niveles competitivos (*i.e.*, élite vs semiprofesionales), sabiendo que el aumento del nivel competitivo conlleva un incremento de las demandas físico-fisiológicas en el hockey hierba. Finalmente, teniendo en cuenta que es habitual que los jugadores profesionales de hockey disputen partidos consecutivos como parte de su calendario de competición, podría ser útil realizar más investigaciones para identificar la relación entre las exigencias físicas impuestas durante los partidos consecutivos en los jugadores de hockey hierba y los cambios resultantes en el s-RPE (132).

4.3. Efectos en un mesociclo competitivo de hockey hierba femenino

El estudio 4 de las presente Tesis Doctoral se caracteriza por la monitorización de los factores de riesgo intrínsecos modificables en jugadoras de hockey femenino durante un mesociclo competitivo (*i.e.,* 16 semanas).

Referente a los resultados obtenidos se reportó un aumento de los valores de la fuerza isométrica de los músculos flexores de la rodilla tras 4 meses en comparación con los valores de pretemporada (M4) (*i.e.,* durante el primer mes de competición (M1)) tanto en la extremidades dominante como en la no dominante (39.0-43.1%) respectivamente. Estos hallazgos están en concordancia con un estudio previo desarrollado por Moreno-Pérez et al. (2022) donde reportaron un incremento (12.3%) de la fuerza isométrica de los músculos flexores de la rodilla en futbolistas semiprofesionales tras 18 semanas de competición (*i.e.,* comparando los valores obtenidos a mitad de la temporada con respecto a los valores obtenidos durante la pretemporada) (117). Una posible explicación del incremento observado en la fuerza isométrica de los músculos flexores de la rodilla tras los 4 meses de seguimiento podría atribuirse a que los jugadores comenzaron la pretemporada en septiembre (*i.e.*, primer mes de medición) tras un periodo de 3 meses de periodo de transición caracterizado por una reducción de la carga de entrenamiento y del calendario competitivo, que podría haber provocado una disminución de las adaptaciones fisiológicas y de rendimiento (134).

Respecto a las variaciones de fuerza isométrica de los músculos abductores y aductores de la cadera durante un mesociclo competitivo, se observó un aumento de los valores en la musculatura aductora tanto de la pierna dominante como no dominante presentando diferencias significativas comparando el tercer (M3) y cuarto mes (M4) de competición con respecto al primer (M1) y segundo mes de competición (M2), mientras que referente a la musculatura abductora, solamente se encontraron diferencias significativas en el miembro no dominante en el tercer mes de competición (M3) versus al segundo mes de competición (M2). Los datos mencionados anteriormente permiten suponer que un aumento de la carga de entrenamiento (*i.e.,* acumulación de entrenamientos y competiciones) durante el periodo de un mesociclo competitivo puede aumentar los niveles de fuerza isométrica de los músculos flexores de la rodilla y de la musculatura abductora (*i.e.,* dominante y no dominante) y aductora de la cadera (*i.e.,* no dominante). Como ya hemos mencionado previamente, las diferencias obtenidas podrían estar influenciadas por un volumen de entrenamiento durante el periodo previo al primer mes de medición pudiendo influir en una disminución de las adaptaciones fisiológicas y de rendimiento mostradas en ese primer mes de medición (M1) (134). Estos resultados relativos a la fuerza isométrica de los músculos abductores y aductores de la cadera difieren con un estudio previo realizado por Moreno-Pérez et al. (2022) en futbolistas masculinos semiprofesionales donde informaron de cambios en la fuerza isométrica de los músculos abductores de la cadera entre la pretemporada y la mitad de la temporada (*i.e.,* comparativa realizada entre los meses de julio (pretemporada) en comparativa con enero) tanto en el miembro dominante como en el no dominante frente a los datos que nuestro estudio que solo reportamos cambios en el miembro no dominante. Además, los citados autores no reportaron diferencias en la fuerza isométrica de los músculos aductores de la cadera (99) frente a la diferencias significativas que reportamos nosotros en nuestro estudio. Estas diferencias de hallazgos pueden deberse a los diferentes patrones de movimiento y a las diferentes demandas a nivel fisiológico que se reportan en hockey hierba femenino frente al fútbol competitivo.

Acerca de los valores del ROM de la flexión de cadera durante 4 meses de competición, estos mostraron diferencias estadísticamente significativas para la extremidad dominante y no dominante después de 4 meses de competición (M4) en comparación con los tres meses de competición anteriores (M1,M2,M3). Estos hallazgos se encuentran en contraposición al estudio previo de Moreno-Pérez et al. (2022) que no reportaron diferencias a lo largo de la temporada en jugadores de fútbol semiprofesionales (117). En cuanto a los valores del ROM de la dorsiflexión del tobillo, durante un mesociclo competitivo (16 semanas), se observó un descenso estadísticamente significativo al comparar el cuarto mes de competición (M4) con los meses anteriores (M1, M2, M3), lo que concuerda con el estudio de Moreno Pérez et al. (2020) en futbolistas semiprofesionales que reportaron un descenso de entre (8.9-9.6%) de los valores de ROM de la dorsiflexión del tobillo (miembro dominante y no dominante) respectivamente (121). Una posible razón de estas disminuciones en el ROM de la dorsiflexión del tobillo podría atribuirse a las adaptaciones crónicas derivadas de la disputa de una la temporada competitiva que se caracteriza por la realización de un elevado número de acciones de alta intensidad (*i.e.,* aceleraciones/desaceleraciones, cambios de dirección y saltos repetidos) con una alto componente excéntrico que pueden conllevar un aumento de la rigidez de de la unión músculo-tendinosa (135) conllevando una disminución del ROM de la dorsiflexión del tobillo (136).

Referente al CMJ sabemos que es una prueba que nos permite valorar tanto el rendimiento físico (137) como la presencia de fatiga neuromuscular (113). Además, de acuerdo a los datos presentados podemos establecer que tras la realización un mesociclo de competitivo, se observó que los valores encontrados presentaban diferencias estadísticamente significativas durante el tercer mes (M3) en comparación con los del primer (M1), segundo (M2) y cuarto (M4) mes. Este hallazgo podría estar relacionado con una mayor densidad competitiva durante el M3 en comparación con los otros meses. Estos resultados contradicen estudios anteriores que examinaron otras disciplinas deportivas de equipo (*e.g.,* fútbol) donde no mostraron cambios en la capacidad de salto durante la temporada (138). Estas diferencias podrían deberse a que Malone et al. (2015) solamente analizaron los cambios producidos durante un microciclo competitivo (*i.e.,* 1 semana) a diferencia del estudio 4 de la presente Tesis Doctoral en el que se analizaron los cambios que se produjeron durante 4 meses de competición (*i.e.,* 16 semanas). Debido a lo mencionado con anterioridad, parece necesario monitorizar los cambios en la fuerza/potencia muscular a lo largo de la temporada para poder controlar el rendimiento neuromuscular en las jugadoras de deportes de equipo (137) y poder así, detectar de manera anticipada la aparición de la fatiga neuromuscular a través de test fáciles y sencillos de implementar como puede ser el CMJ (113).

Finalmente, se valoró la carga interna a través de la implementación del 5-WQ durante todo el mesociclo competitivo, no encontrándose cambios significativos en las variables de fatiga, sueño, dolor muscular, estrés y estado de ánimo. Estos hallazgos están en consonancia con estudios previos que no informaron cambios a nivel de carga interna (*i.e.,* 5-WQ) a largo plazo durante un mesociclo en jugadores de rugby y fútbol (139,140).

4.4. Limitaciones y futuras líneas de investigación

Esta Tesis Doctoral, aunque presenta nuevos hallazgos en la literatura referente a varios factores de riesgo intrínsecos modificables en mujeres en el hockey hierba y que espera que pueda ser utilizada por los cuerpos técnicos de los diferentes cuerpos técnicos, tiene sin embargo varias limitaciones que deben ser reseñadas.

- En primer lugar, la muestra de los cuatro estudios está formado por jugadoras de hockey hierba de nivel semiprofesional, por tanto, nuestros resultados no puedan ser extrapolables a jugadoras de categoría profesional o jugadores de categoría masculina. Futuros estudios que se centren en el estudio de factores de riesgo modificables deberían ser realizados en diferentes edades, niveles de rendimiento, y sexo.

- En segundo lugar, solamente se han analizado los momentos pre y post de un partido, el pre, post y 48 horas de dos partidos consecutivos, por lo que es posible que los resultados encontrados no se extiendan a otros escenarios competitivos con una congestión mayor de partidos. Por ello, futuros estudios deberían centrarse en los efectos ocurridos durante la participación en torneos congestionados con un mayor número de partidos.

- En tercer lugar, referente al estudio 4 de esta Tesis Doctoral, solo se analizó un mesociclo competitivo (16 semanas) debido a la aparición de la pandemia (SARS-CoV-19) en marzo de 2020, por tanto, futuros estudios deberían analizar el efecto que puede tener una o varias temporadas competitivas sobre estos factores de riesgo intrínsecos modificables.

- En cuarto lugar, no se valoró la influencia del ciclo menstrual, por tanto, futuros estudios deberían determinar la importancia que puede tener esta variable fisiológica en parámetros de riesgo intrínsecos modificables en mujeres.

5. CONCLUSIONES

5. CONCLUSIONES

Tras la realización de esta Tesis Doctoral sobre la monitorización de los efectos agudos, crónicos y de congestión sobre factores de riesgo de lesión modificables en jugadoras de hockey hierba femenino se extraen las siguientes conclusiones:

5.1. Conclusiones estudio 1

Un partido de hockey hierba simulado aumenta la fuerza isométrica de la flexión de la rodilla y el ROM de la flexión de la cadera en la pierna no dominante y disminuye la capacidad de salto con contramovimiento (CMJ).

5.2. Conclusiones estudio 2

Una congestión competitiva en hockey hierba femenino no produce diferencias significativas sobre las variables de fuerza isométrica de flexión de rodilla, ROM de la flexión de la cadera y ROM de dorsiflexión del tobillo.

5.3. Conclusiones estudio 3

Una congestión competitiva en hockey hierba femenino produce una reducción de los valores de fuerza isométrica de los músculos abductores y aductores de la cadera.

5.4. Conclusiones estudio 4

Un mesociclo competitivo (16 semanas) en hockey hierba femenino provoca un aumento de la fuerza isométrica en los músculos abductores y aductores de la cadera y un aumento en la fuerza isométrica de los flexores de la rodilla aumentando progresivamente a medida que aumenta la actividad competitiva, además de reportar un aumento de la capacidad de salto al aumentar los valores de CMJ.

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