DOCTORAL THESIS

Recovery in soccer

Post-game recovery strategies in elite male soccer players

Albert Altarriba Bartés

ESCOLA
DE DOCTORAT
UVIC·UCC

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Thesis to obtain the degree of:
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Doctorat
Cures Integrals i Serveis de Salut
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"Dimidium facti, qui coepit, habet: sapere aude, incipe"

"He who has begun has half done. Dare to be wise; begin"

Quintus Horatius Flaccus "Horace"

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Thesis supervision certificate

Professor Javier Peña López, of University of Vic-Central University of Catalonia.

I DECLARE:

That the present thesis, entitled **"Recovery in soccer. Post-game recovery strategies in elite male soccer players"** and presented by Albert Altarriba Bartés to obtain a doctoral degree, is a compendium of publications, and has been completed under my supervision.

For all intents and purposes, I hereby sign this document.

Javier Peña López
PhD Supervisor

Vic, 9 March 2023

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Thesis supervision certificate

Professor Julio Calleja González, of University of the Basque Country-Euskal Herriko Unibertsitatea.

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Prof. Julio Calleja González
PhD Supervisor

Vitoria-Gasteiz, 9 March 2023

List of publications

The present Doctoral Thesis is based on the following article publications, which are detailed below and referred to in the text with their Roman numerals:

I. **Post-competition recovery strategies in elite male soccer players. Effects on performance: A systematic review and meta-analysis.**
Altarriba-Bartes A, Pena J, Vicens-Bordas J, Mila-Villaroel R, Calleja-González J.
PloS One. 2020 Oct 2;*15*(10), e0240135. doi: 10.1371/journal.pone.0240135.
Journal Impact Factor (2020) – 3.240

II. **The use of recovery strategies by Spanish first division soccer teams: a cross-sectional survey.**
Altarriba-Bartes A, Pena J, Vicens-Bordas J, Casals M, Peirau X, Calleja-González J.
Phys Sportsmed. 2021 Sep; 49(3): 297-307. doi:10.1080/00913847.2020.1819150
Journal Impact Factor (2021) – 2.758

III. **The effectiveness of two comprehensive recovery protocols on performance and physiological measures in elite soccer players: A parallel group-randomized trial.**
Altarriba-Bartes A, Vicens-Bordas J, Pena J, Alarcón-Palacios F, Sixtos-Meliton LA, Matabosch-Pijuan M, Giménez-Martínez E, Beato M, Calleja-González J.
Int J Sports Sci Coach. 2023. doi:10.1177/17479541231155585
Journal Impact Factor (2021) – 2.029

List of figures

List of abbreviations

Acc: accelerations
AEMEF: Asociación Española de Médicos de Equipos de Futbol
ALB: active-land-based
AWB: active-water-based
BAM+: brief assessment of mood
BC: Before Christ
BFQ: belief questionnaire
CG: compression garments
CG: control group
CHP: carbohydrate and protein
CI: confidence interval
CJ: tart cherry juice concentrate
CK: creatine kinase
CK-III: creatine kinase muscular isoenzyme
CK-MM: creatine kinase muscular isoenzyme
CMJ: countermovement jump
CONSORT: consolidated standards of reporting trials
CRP: C-reactive protein
CS: calf
CV: coefficient of variation
CWI: cold-water immersion
Dec: decelerations
DOMS: delayed onset muscle soreness
EG: experimental group
EIMD: exercise-induced muscle damage
ES: effect size
FA: English Football Association
FIFA: Féderation Internationale de Football Association
FLG: tights group
FR: foam roller
GAS: general adaptation syndrome
GLMM: generalized linear mixed model
GOT: glutamic oxaloacetic
GPS: global positioning system
GPT: glutamic pyruvic
HAMS: hamstrings
HMVC: hamstring maximal voluntary contraction
HS: hamstrings
HSR: high-speed running
ICC: intraclass correlation coefficient
ICWI: intermittent cold-water immersion
IG: intervention Group
[La-]: lactate concentration
LDH: lactate
LMM: linear mixed model
MAs: national members associations
Mb: myoglobin

MD: matchday
MD: mean difference
MeSH: medical subject headings
MIVC: maximal isometric voluntary contraction
MS: muscle soreness
MVC: maximal voluntary contraction
NSHS: normal post-game sleep hygiene strategy
PCM: cooled phase change material
PICOS: population, intervention, comparison, outcomes, and study design
PRISMA: preferred reporting items for systematic reviews and meta-analyses
QG: shorts group
QS: quadriceps
QUAD: quadriceps
RCT: randomized controlled trial
RPE: rate of perceived exertion
SaO2 (%): arterial oxygen saturation of hemoglobin
SD: standard deviation
SE: standard error
SG: stockings group
SHS: sleep hygiene strategy
SJ: squat jump
SMD: standardized mean difference
STR: stretching
TQR: perceived recovery
TQRper: total quality recovery perceived
TWI: thermoneutral water immersion
WBV: whole-body vibration
YYIR2: Yo-Yo intermittent recovery level 2

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Abstract

It is challenging for elite soccer players and staff to achieve peak performance. Recovering as quickly as possible from a training or competitive effort (load) and restoring pre-performance levels are crucial elements of success. Thus, an adequate balance between load management and recovery will be necessary, and the proper choice of recovery strategies may be decisive. Therefore, the present thesis' main aim is to gain insight into the use of recovery strategies among elite male soccer players.
Three publications: a systematic review with meta-analysis (Article-I), an observational cross-sectional descriptive study (Article-II), and a randomized parallel-group trial (Article-III) were developed as the main body of this thesis.

Article-I aimed to provide an overview of available evidence on post-game performance and physiological and wellness outcomes in elite soccer players after using different recovery strategies. Five randomized controlled trials that analyzed the effects of using different post-game recovery strategies and interventions, such as compression garments (n = 3), cold-water immersion (n = 1) and acute sleep hygiene strategy (n = 1), by elite male soccer players, on post-game performance outcomes (countermovement jump; CMJ, twenty-meter sprint; 20-m sprint and maximal voluntary contraction; MVC), physiological markers (creatine-kinase; CK and C-reactive protein; CRP), and wellness indicators (delayed onset muscle soreness; DOMS) were included. The results for the primary outcomes showed greater CMJ values at 48 hours for the intervention group (SMD = 0.70; 95% CI 0.14 to 1.25; p = 0.001). However, no differences were found at 24 and 48 hours for the 20-m sprint and MVC. For the secondary outcomes, in physiological markers (CK and CRP) and wellness indicators (DOMS), small to large standardized mean difference (SMD) were present in favor of the intervention group at 24 and 48 hours (-0.12 to -1.86 and -0.21 to -0.85, respectively). Thus, the use of post-game recovery strategies in elite soccer players is highly recommended as it offers greater positive effects on performance and physiological and wellness outcomes than a control group.

In **Article-II**, the purpose was to identify the use of recovery strategies by professional soccer teams. In this study, all "LaLiga" teams (n=23) during the seasons 2018-2019 and 2019-2020 were included. They all admitted to using recovery strategies at some point during the season. The most utilized (>90%) were natural (active field or gym-based cooldowns, active or passive stretching, sleep/nap, food/fluid replacement and supplement use) and physical (cold/ice bath/shower/immersion, massage, and foam rolling) ones. Three physical recovery strategies showed a higher presence after competition: cold/ice bath/shower/immersion, massage, and foam rolling, always used by seventeen (74%), sixteen (70%) and thirteen (57%) teams, respectively. Moreover, a multidisciplinary staff designed and supervised recovery strategies in 87% of the teams (n = 20). Nevertheless, there was no general agreement between them on the ones employed nor the moments where they applied them. Most teams (n = 15) admitted using scientific evidence parameters to prescribe it, while the other eight (35%) followed expert opinion. However, a gap between theory and practice exists when the information the team's staff reported regarding the use of recovery strategies was contrasted with scientific research available on the matter. Furthermore, all of them (100%) combined (using more than one) different recovery strategies.

Article-III main aim was to compare the effectiveness of two comprehensive recovery protocols on physiological, neuromuscular, and perceptual outcomes after a soccer game. Eighteen elite under twenty-one (U-21) Mexican National Team soccer players were divided into two intervention groups: carbohydrate and protein shake, foam-roller, cold-water immersion, and tart cherry juice concentrate (CHP+FR+CWI+CJ [n = 9]) or carbohydrate and protein shake, stretching and intermittent cold-water immersion (CHP+STR+ICWI [n = 9]) protocols. Both included a combination of natural and physical recovery methods and were performed twice, immediately after the game and the day after (21-hours post-game). Players were assessed before, immediately after, and 20-44-68 hours post-game for physiological (muscular creatine-kinase; CK-III), neuromuscular (hamstring maximal voluntary contraction; HMVC and CMJ), and perceptual (total quality recovery perceived; TQRper and muscle soreness; MS) outcomes. The main effect of time was large ($p < 0.001$, $F > 6.99$ and $\chi^2 > 46.49$) for all the outcomes. However, no significant effects between protocols were found ($p > 0.05$), but the interaction effects (group * time) showed changes in the CHP+FR+CWI+CJ group at post-game and MD+1 in neuromuscular (CMJ, HMVC) and TQRper outcomes. Moreover, neuromuscular, and perceptual outcomes were normalized at MD+2. In contrast, CK-III was completely normalized at MD+3 in both groups, and changes in this physiological marker, immediately post-game, were correlated to the number of accelerations ($p < 0.001$; very large effect) and decelerations ($p = 0.003$; large effect), High Speed Running (HSR) distance ($p = 0.007$; large effect) and sprinting distance ($p = 0.04$; large effect). Both interventions were equally effective in improving physiological, neuromuscular, and perceptual outcomes.

Based on the findings in this thesis and although evidence tells us that some methods, used isolated, have a more significant effect on recovery than others, this superiority effect can be minimized when a combination of methods is used. Thus, elite soccer players could combine different recovery methods after practices or games, and natural and physical methods positively affect recovery. However, a balance between scientific evidence criteria and players' perceptions or preferences should be found for optimal performance. Therefore, adequate communication between staff members and players is crucial to design and individualizing appropriate recovery protocols. Moreover, these protocols should also be designed according to ecological parameters such as the game venue (home or away), human and economic resources, or the logistics available.

Keywords: football, recovery methods, physiology, performance, wellness

Resum

Pels jugadors i cossos tècnics dels equips de futbol d'elit, és un desafiament aconseguir el màxim rendiment. Recuperar-se tan ràpid com sigui possible d'un entrenament o d'un partit (càrrega), restablint els nivells previs de rendiment es considera un element crucial per aconseguir l'èxit. Així, un equilibri adequat entre la gestió de la càrrega i de la recuperació serà necessari per aconseguir-ho, i l'apropiada elecció de les estratègies de recuperació pot ser decisiva. L'objectiu principal de la present tesi és, per tant, aprofundir en l'ús d'estratègies de recuperació en futbolistes d'elit de gènere masculí .
Tres publicacions: una revisió sistemàtica amb metaanàlisi (Article-I), un estudi observacional descriptiu transversal (Article-II) i un assaig aleatoritzat de grups paral·lels (Article-III) s'han desenvolupat com a cos principal d'aquesta tesi.

L'**Article-I** va tenir com a principal objectiu proporcionar una visió general de l'evidència existent sobre resultats en paràmetres de rendiment físic, fisiològic i de benestar post-partit en jugadors de futbol d'elit després de fer servir diferents estratègies de recuperació. Van ser inclosos un total de cinc assajos de controlats aleatoritzats que van analitzar els efectes de l'ús de diferents estratègies i intervencions de recuperació, com ara peces de compressió (n = 3), immersió en aigua freda (n = 1) i estratègies d'higiene aguda del son (n = 1) en els paràmetres de rendiment físic (salt amb contra moviment; CMJ, esprint de vint metres; 20-m esprint i contracció voluntària màxima; MVC), marcadors fisiològics (creatina-quinasa; CK i proteïna C reactiva; CRP), i indicadors de benestar (dolor muscular d'aparició tardana; DOMS) post-partit. Els resultats primaris van mostrar valors més grans de CMJ a les 48 hores per al grup d'intervenció (SMD = 0.70; IC del 95%: 0.14 a 1.25; p = 0.001). Tot i això, no es van trobar diferències a les 24 i 48 hores ni pels 20-m esprint ni per la MVC. Pel què fa referència a resultats secundaris, en els marcadors fisiològics (CK i CRP) i en els indicadors de benestar (DOMS), petites a grans diferències de mitjana estandarditzada (SMD) estaven presents a favor del grup d'intervenció a les 24 i 48 hores (-0.12 a -1.86 i -0.21 a -0.85 respectivament). Per tant, l'ús d'estratègies de recuperació post-partit en jugadors de futbol d'elit és molt recomanable, ja que ofereix més efectes positius en paràmetres de rendiment, fisiològics i de benestar en comparació amb un grup control.

En l'**Article-II**, el propòsit va ser identificar l'ús d'estratègies de recuperació per part d'equips de futbol professional. En aquest estudi es van incloure tots els equips de "LaLiga" (n=23) durant les temporades 2018-2019 i 2019-2020. Tots ells van admetre haver utilitzat estratègies de recuperació en algun moment de la temporada i les més utilitzades (>90%) van ser les naturals (tornada a la calma activa al camp o al gimnàs, estiraments actius o passius, dormir/migdiada, reposició d'aliments/líquids i ús de suplements) i físics (bany/dutxa/immersió en fred/gel, massatge i rodets d'escuma o "foam roller"). Tres estratègies de recuperació física van mostrar més presència després de la competició: bany/dutxa/immersió en fred/gel, massatge i "foam roller"; utilitzats sempre per disset (74%), setze (70%) i tretze (57%) equips respectivament. A més, en el 87% dels equips (n = 20), les estratègies de recuperació van ser dissenyades i supervisades per un equip multidisciplinari. Tot i això, no hi va haver acord general entre ells sobre les estratègies emprades ni els moments en què les van aplicar. La majoria dels equips (n = 15) van admetre utilitzar paràmetres reportats per l'evidència científica en el moment de prescriure les estratègies, mentre que els altres vuit equips restants (35%) van seguir l'opinió d'experts. No obstant això, hi ha una escletxa entre la teoria i la pràctica quan es contrasta i compara la informació reportada pels cossos tècnics dels equips en relació a l'ús d'estratègies de recuperació amb l'evidència i la investigació científica disponible al respecte. Tots els equips (100%) van combinar (utilitzant més d'una) diferents estratègies de recuperació.

L'objectiu principal de l'**Article-III** va ser comparar l'efectivitat de dos protocols integrals de recuperació sobre paràmetres fisiològics, neuromusculars i de percepció després d'un partit de futbol. Divuit futbolistes d'elit menors de 21 anys (U-21) de la Selecció Nacional de Mèxic van ser dividits en dos grups d'intervenció: batut de carbohidrats i proteïna, "foam roller", immersió en aigua freda i concentrat de suc de cirera àcida (CHP+FR+CWI+CJ [n = 9]) o batut de carbohidrats i proteïna, estirament i immersió intermitent en aigua freda (CHP+STR+ICWI [n = 9]). Tots dos van incloure una combinació de mètodes de recuperació natural i física i es van fer dues vegades, immediatament post-partit i l'endemà (21 hores post-partit). Es van avaluar els jugadors abans, immediatament després i 20-44-68 hores post-partit per determinar paràmetres fisiològics (creatina-quinasa muscular; CK-III), neuromusculars (contracció voluntària màxima dels isquiotibials; HMVC i CMJ) i perceptius (qualitat total de la recuperació percebuda; TQRper i dolor muscular; MS). L'efecte principal del temps va ser gran ($p < 0.001$, $F > 6.99$ i $\chi 2 > 46.49$) per a tots els resultats. No obstant això, no es van trobar efectes significatius entre protocols ($p > 0.05$), però els efectes d'interacció (grup * temps) van mostrar canvis al grup CHP+FR+CWI+CJ en el post-partit i en el MD+1 en paràmetres neuromusculars (CMJ , HMVC) i de TQRper. A més, els paràmetres neuromusculars i perceptius es van normalitzar en el MD+2 mentre que la CK-III es va normalitzar per complet en el MD+3 en ambdós grups, i els canvis en aquest marcador fisiològic, immediatament després del partit, es van correlacionar amb el nombre d'acceleracions ($p < 0.001$; efecte molt gran) i desacceleracions ($p = 0.003$; efecte gran), distància a alta intensitat (HSR) ($p = 0.007$; efecte gran) i distància en esprint ($p = 0.04$; efecte gran). Totes dues intervencions van ser igualment efectives per millorar els resultats a nivell fisiològic, neuromuscular i de percepció.

En base a les troballes d'aquesta tesi i encara que l'evidència ens diu que alguns mètodes, usats de manera aïllada, tenen un efecte més significatiu en la recuperació que altres, aquest efecte de superioritat es pot minimitzar quan es fa servir una combinació de mètodes. Així, els futbolistes d'elit podrien combinar diferents mètodes de recuperació després dels entrenaments i partits, ja que l'ús de mètodes naturals i físics mostra un efecte positiu en la recuperació. No obstant això, per a un assoliment òptim, cal trobar un equilibri entre els criteris d'evidència científica i les percepcions i/o preferències dels jugadors. Per això, la comunicació adequada entre els membres del cos tècnic i els jugadors és crucial per dissenyar i individualitzar els protocols de recuperació apropiats. A més, aquests protocols també s'han de dissenyar segons paràmetres ecològics com el lloc on es juga el partit (local o visitant), els recursos econòmics i humans i/o la logística disponible.

Paraules clau: futbol, mètodes de recuperació, fisiologia, rendiment, benestar

Resumen

Para los jugadores y los cuerpos técnicos de los equipos de fútbol de élite, es un desafío lograr el máximo rendimiento. Recuperarse lo más rápido posible de un entrenamiento o de un partido (carga), restableciendo los niveles previos de rendimiento se considera un elemento crucial para conseguir el éxito. Así, un adecuado equilibrio entre la gestión de la carga y de la recuperación será necesario para lograrlo, y la apropiada elección de las estrategias de recuperación puede ser decisiva. Por lo tanto, el objetivo principal de la presente tesis es profundizar en el uso de estrategias de recuperación en futbolistas de élite de género masculino.
Tres publicaciones: una revisión sistemática con metaanálisis (Artículo-I), un estudio observacional descriptivo transversal (Artículo-II) y un ensayo aleatorizado de grupos paralelos (Artículo-III) se han desarrollado como cuerpo principal de esta tesis.

El **Artículo-I** tuvo como objetivo principal proporcionar una visión general de la evidencia existente sobre resultados en parámetros de rendimiento físico, fisiológico y de bienestar postpartido en jugadores de fútbol de élite después de usar diferentes estrategias de recuperación. Fueron incluidos un total de cinco ensayos controlados aleatorizados que analizaron los efectos del uso de diferentes estrategias e intervenciones de recuperación, como prendas de compresión (n = 3), inmersión en agua fría (n = 1) y estrategias de higiene aguda del sueño (n = 1) en los parámetros de rendimiento físico (salto con contra movimiento; CMJ, sprint de veinte metros; 20-m sprint y contracción voluntaria máxima; MVC), marcadores fisiológicos (creatina-quinasa; CK y proteína C reactiva; CRP), e indicadores de bienestar (dolor muscular de aparición tardía; DOMS) postpartido. Los resultados primarios mostraron mayores valores de CMJ a las 48 horas para el grupo de intervención (SMD = 0.70; IC del 95%: 0.14 a 1.25; p = 0.001). Sin embargo, no se encontraron diferencias a las 24 y 48 horas ni para el 20-m sprint ni para la MVC. Para los resultados secundarios, en los marcadores fisiológicos (CK y CRP) y los indicadores de bienestar (DOMS), pequeñas a grandes diferencias de promedio estandardizado (SMD) estaban presentes a favor del grupo de intervención a las 24 y 48 horas (-0.12 a -1.86 y -0.21 a -0.85 respectivamente). Por lo tanto, el uso de estrategias de recuperación postpartido en jugadores de fútbol de élite es muy recomendable, ya que ofrece mayores efectos positivos en parámetros de rendimiento, fisiológicos y de bienestar en comparación con un grupo control.

En el **Artículo-II**, el propósito fue identificar el uso de estrategias de recuperación por parte de equipos de fútbol profesional. En este estudio se incluyeron todos los equipos de "LaLiga" (n=23) durante las temporadas 2018-2019 y 2019-2020. Todos ellos admitieron haber utilizado estrategias de recuperación en algún momento de la temporada y las más utilizadas (>90%) fueron las naturales (vueltas a la calma activa en el campo o en gimnasio, estiramientos activos o pasivos, dormir/siesta, reposición de alimentos/líquidos y uso de suplementos) y físicos (baño/ducha/inmersión en frio/hielo, masaje y rodillos de espuma o "foam roller"). Tres estrategias de recuperación física mostraron una mayor presencia después de la competición: baño/ducha/inmersión en frio/hielo, masaje y "foam roller"; utilizados siempre por diecisiete (74%), dieciséis (70%) y trece (57%) equipos respectivamente. Además, en el 87% de los equipos (n = 20), las estrategias de recuperación fueron diseñadas y supervisadas por un equipo multidisciplinario. Sin embargo, no hubo acuerdo general entre ellos sobre las estrategias empleadas ni los momentos en que las aplicaron. La mayoría de los equipos (n = 15) admitió utilizar parámetros reportados por la evidencia científica en el momento de prescribir las estrategias, mientras que los otros ocho equipos restantes (35%) siguieron la opinión de expertos. Sin embargo, existe una brecha entre la teoría y la práctica cuando se contrasta y compara la información reportada por los cuerpos técnicos de los equipos en relación con el uso de estrategias de recuperación con la evidencia e investigación científica disponible al respecto. Además, todos los equipos (100%) combinaron (utilizando más de una) diferentes estrategias de recuperación.

El objetivo principal del **Artículo-III** fue comparar la efectividad de dos protocolos integrales de recuperación sobre parámetros fisiológicos, neuromusculares y de percepción después de un partido de fútbol. Dieciocho futbolistas de élite menores de 21 años (U-21) de la Selección Nacional de México fueron divididos en dos grupos de intervención: batido de carbohidratos y proteína, "foam roller", inmersión en agua fría y concentrado de jugo de cereza ácida (CHP+FR+CWI+CJ [n = 9]) o batido de carbohidratos y proteína, estiramiento e inmersión intermitente en agua fría (CHP+STR+ICWI [n = 9]). Ambos incluyeron una combinación de métodos de recuperación natural y física y se realizaron dos veces, inmediatamente postpartido y al día siguiente (21 horas postpartido). Se evaluó a los jugadores antes, inmediatamente después y 20-44-68 horas postpartido para determinar parámetros fisiológicos (creatina-quinasa muscular; CK-III), neuromusculares (contracción voluntaria máxima de los isquiotibiales; HMVC y CMJ) y perceptuales (calidad total de la recuperación percibida; TQRper y dolor muscular; MS). El efecto principal del tiempo fue grande ($p < 0.001$, $F > 6.99$ y $\chi 2 > 46.49$) para todos los resultados. Sin embargo, no se encontraron efectos significativos entre protocolos ($p > 0.05$), pero los efectos de interacción (grupo * tiempo) mostraron cambios en el grupo CHP+FR+CWI+CJ en el postpartido y en el MD+1 en parámetros neuromusculares (CMJ, HMVC) y de TQRper. Además, los parámetros neuromusculares y perceptuales se normalizaron en el MD+2 mientras que la CK-III se normalizó por completo en el MD+3 en ambos grupos, y los cambios en este marcador fisiológico, inmediatamente después del partido, se correlacionaron con el número de aceleraciones ($p < 0.001$; efecto muy grande) y desaceleraciones ($p = 0.003$; efecto grande), distancia a alta intensidad (HSR) ($p = 0.007$; efecto grande) y distancia en sprint ($p = 0.04$; efecto grande). Ambas intervenciones fueron igualmente efectivas para mejorar los resultados a nivel fisiológico, neuromuscular y de percepción.

En base a los hallazgos de esta tesis y aunque la evidencia nos dice que algunos métodos, usados de forma aislada, tienen un efecto más significativo en la recuperación que otros, este efecto de superioridad puede minimizarse cuando se usa una combinación de métodos. Así, los futbolistas de élite podrían combinar diferentes métodos de recuperación después de los entrenamientos y/o partidos, dado que el uso de métodos naturales y físicos muestra un efecto positivo en la recuperación. Sin embargo, para un desempeño óptimo, se debe encontrar un equilibrio entre los criterios de evidencia científica y las percepciones y/o preferencias de los jugadores. Por esa razón, la comunicación adecuada entre los miembros del cuerpo técnico y los jugadores es crucial para diseñar e individualizar los protocolos de recuperación apropiados. Además, estos protocolos también deben diseñarse de acuerdo con parámetros ecológicos como el lugar dónde se juega el partido (local o visitante), los recursos económicos y humanos y/o la logística disponible.

Palabras clave: futbol, métodos de recuperación, fisiología, rendimiento, bienestar

Preface

The motivation for the study

To understand the end of the journey, you should focus on how it began and how it evolved. I have loved practicing sports since I was a kid. My mum always tells me that I learnt how to kick a ball before taking my first steps. However, it was only when I was seventeen that I decided what to study at the University. Surprisingly, I decided after breaking my femur during a soccer game, the sport that I had practiced since I was six and going into surgery. At this point, I started wondering which was the best way to recover and be in shape as soon as possible. One year later, in 2002, I was at the University of Vic starting Sports Sciences and Physical Activity. During the degree, I developed many skills and acquired knowledge. However, I wanted to deal with injured players and become an excellent sports rehabilitation specialist, so I started physiotherapy in 2005.

My childhood dream to become a professional soccer player was never achieved, but I signed up for "my team", Futbol Club Barcelona, in 2006, and I worked there for seven seasons. I learned from the best medical and strength and conditioning professionals during this period. I also shared locker room and life experiences with recognized soccer coaches and players, who taught me things you cannot find in any book or University. However, I realized that it was not enough, and to develop myself and keep growing, I needed to improve my research skills. So, I decided to perform a postgraduate course in Injury Rehabilitation (2007), the MSc in Team Sports Training at INEFC Barcelona (2011-2013), and I started my PhD at the Olympic Training Center in Sant Cugat del Vallès (2009). In March 2013, my "American dream" began. I joined NY Red Bulls as one of the two first-team fitness coaches. I had my first opportunity to be involved in a professional soccer team staff dynamics and the privilege to meet and work with players like Thierry Henry (what a legend and a real human being). I also started working under the supervision of David Álvarez, who became my "old brother" and my best friend. In 2014, I presented my thesis project about "Taekwondo risk factors detection, analysis and evaluation in Olympic athletes".

Back to Vic (2015), I started working at the University of Vic-Central University of Catalonia, where I started to share office and work meetings with my former teachers (what an honor). A close relationship with one of them, Dr Javier Peña, began. After knowing each other better and better every day, he realized that my thesis topic related to Taekwondo, a sport that I had never practiced nor followed, had not motivated me enough while doing it. So, he proposed to do a second PhD (what a crazy idea) about soccer under his supervision, and I accepted immediately. Let us get this party started! I used my 2017-2018 leave of absence at the University to work as First Team Strength and Conditioning Coach with Birmingham City Football Club and to start with the PhD project. After a year, in September 2018, I moved back to Vic, where I am still working and living.

This thesis that you are about to read pretends to fill the gap in knowledge about recovery strategies used in soccer, but it must be highlighted that even if some answers have been given, more will be needed from now on.

Chapter 1 –

Introduction

The conditioning procedure

In their search for excellence, athletes must cope with demanding training and perform well in competitions [1]. Therefore, traditional competition and training methods have revolved around work-based training, with challenges in performance solved by training more [1]. The main purpose of training is to optimize performance and reduce injuries and illnesses [2,3] by displacing or upsetting, stressing, athletes' functional systems' homeostasis. The natural consequence derived from it is some degree of fatigue, which is essential for improvement but also requires a proper recovery to complete the developmental cycle [1]. Thus, the residual effects on performance capacities and readiness are determined by the interaction between recovery and stress [4] and the individual's capacity to manage this last one [5]. These interactive effects of stress and recovery form a continuum among positive change, adaptation, and negative change, maladaptation, in performance capacities [2]. Adaptation to maintain homeostasis is stimulated by stressors and, depending on the type of stressors applied, will condition recovery and adaptation [6]. Therefore, specificity can be considered a fundamental training principle for condition-specific capacities. An acute physical activity's mode, intensity, and duration will show unique residual and immediate stress effects [7]. (See Figure 1).

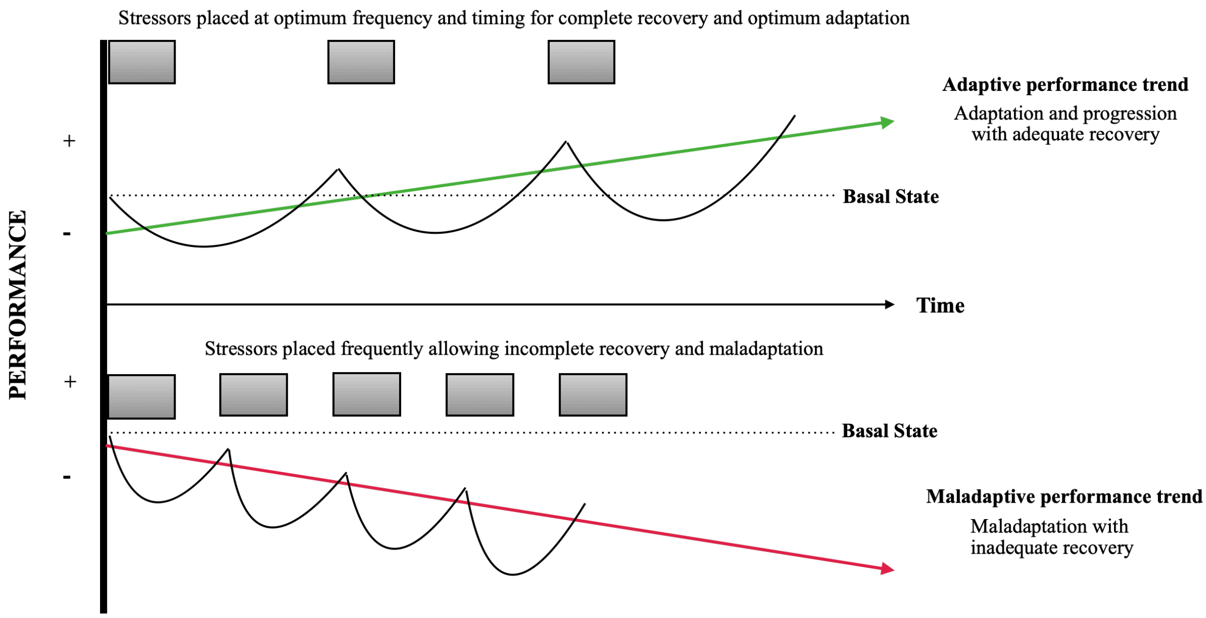

Figure 1. Schematic overview of performance and recovery over time. Adapted from West [7].

The physical capacity improvement due to adaptation following acute stress and fatigue (the alarm phase) is known as supercompensation [8] and is consistent with Selye's general adaption syndrome (GAS). Banister [9] proposed a model where the immediate effects of acute physical stressors consisted of both positive (fitness) and negative (fatigue) physiological responses. Fitness and fatigue were considered inputs, and performance was the output [10]. Consequently, and depending on the application of the inputs, the output was beneficial or harmful. The point where accumulated fitness and fatigue coupled with optimal recovery leads to maximum adaptation and supercompensation (See Figure 2). Nevertheless, if recovery is insufficient or fatigue too high, maladaptation, the exhaustion stage of Selye's GAS, occurs [3]. Under-recovery and performance maladaptation can be considered similar concepts with similar outcomes [11]. Hence, training and recovery should be programmed and planned according to periodization principles [8] to avoid adverse affectations for the athlete.

To sum up, Selye's GAS theory used to explain athlete's conditioning is holistic in its approach towards cumulative adaptation and psycho-socio-physiological stressors [7].

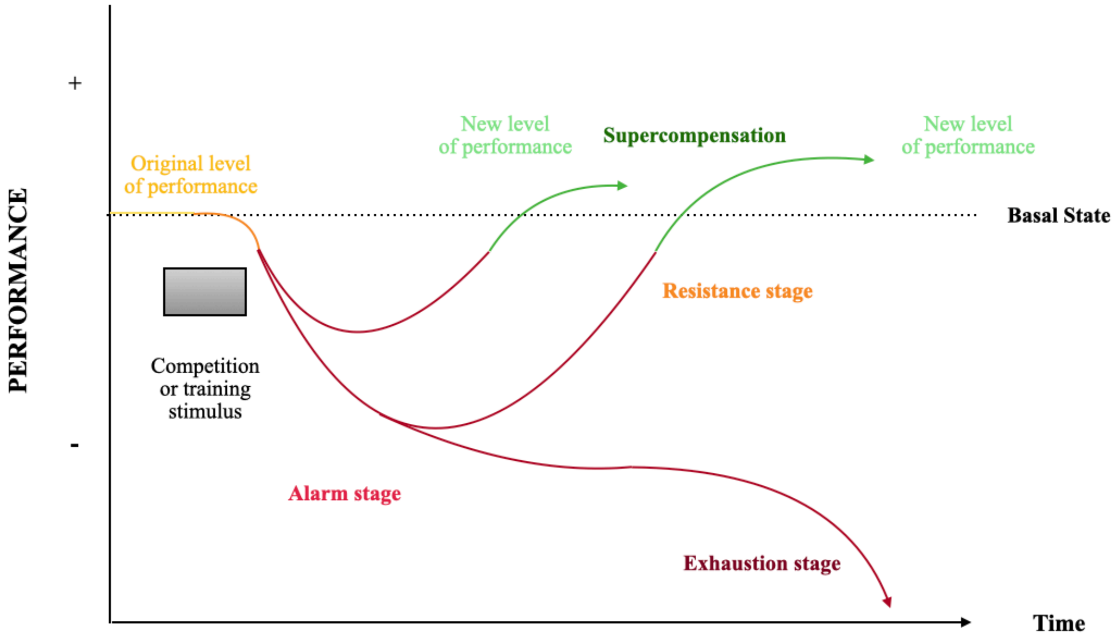

Figure 2. General adaptation syndrome regarding to performance supercompensation and timeline of stress-recovery-adaptation continuum. Adapted from West [7].

Monitoring the conditioning procedure

According to West [7] the athletic conditioning process is a psycho-socio-physiological interaction of stress and recovery events, inputs, which stimulate changes in performance capacities and outputs. Kinugasa [4] proposed a model to monitor elite athletes' conditioning, considering the conditioning process as one system, with allostatic load and recovery as inputs, doses, and performance and performance readiness, or athlete's potential state to perform, as outputs, responses. (See Figure 3).

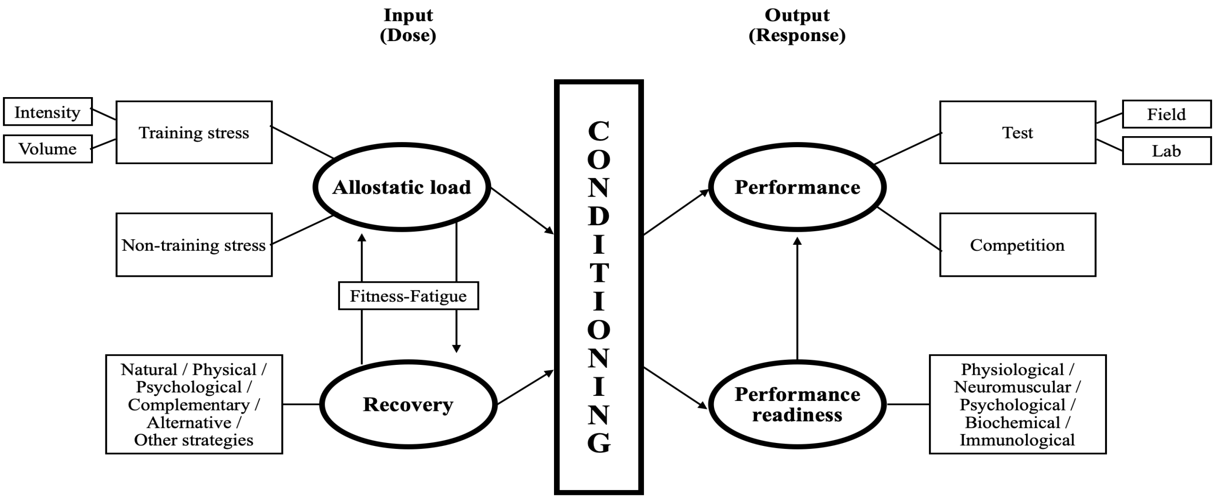

Figure 3. The conditioning process for the athlete monitoring. Adapted from West [7].

West [7] summarizes that a valid and reliable assessment of training stress in athletes may be achieved using the product of the session duration and session RPE (Rate of Perceived Exertion). In contrast, the assessment of major non-training stressors may be achieved with the periodic assessment of the Life Event Survey for Collegiate Athletes (LESCA) and the perceived stress using weekly or monthly (Perceived Stress Scale (PSS-10) assessments. A valid and reliable system of measuring recovery activities is absent. The same happens with physiological, biochemical, and immunological measures subject to various confounding variables. Perceived stress, recovery and performance readiness may be achieved using the RESTQ-Sport (Recovery-Stress Questionnaire for Athletes) [12,13]. Even if situational variables and assessment opportunities limit competition, competition performance is a valid measure [7].

Recovery in sport

Maximizing the performance capacity of an athlete is not only a matter of training. However, it results from a synergistic interaction of complex social, physical, and mental factors nets with an external environment [14] affected by a wide array of intrinsic and extrinsic parameters [15,16]. This continuous high-level sports peak performance is only sustainable if the stress and fatigue produced by training and competition loads and other personal life demands are appropriately balanced with an adequate recovery time [2,17] given that it is emphasized that adaptation occurs during regeneration phases [18]. Thus, the interaction between training load, fatigue (physical, mental, and emotional), adaptation, and recovery is an extreme complexity element that comprises various factors of a very different nature [16,19]. For this reason, the recovery process is regarded as an inter- and intra-individual multi-level and multifaceted (physiological and psychological) performance abilities restorative process relative to time [2]. Moreover, current studies highlight that optimal, sufficient, and proper choice of recovery strategies by coaches and athletes may be crucial to prevent athletes' health problems [20,21] as well as to lead them to better performances, helping to feel more rested and healthier [2,22].

However, we should consider that high-performance athletes face a wide array of daily training stimuli that may not allow complete recoveries [23], emphasizing the need for optimal recovery strategies based on individual fatigue thresholds [20,24]. In conclusion, defining the concept of "recovery from exercise" is challenging due to the number of variables affecting an optimal recovery [25]. Furthermore, recovery and fatigue can be seen on a continuum, and the assessment should be relative to the demands of the sport and the athlete [26], and in case of insufficient recovery, it could initiate a cascade of disadvantageous conditions such as non-functional overreaching, under-recovery, or overtraining syndrome [2,27]. So, recovery is related to previous loads, depending on the individual capacities of players, but also on time between sessions or games and the activities (strategies) undertaken in that time frame. (See Figure 4).

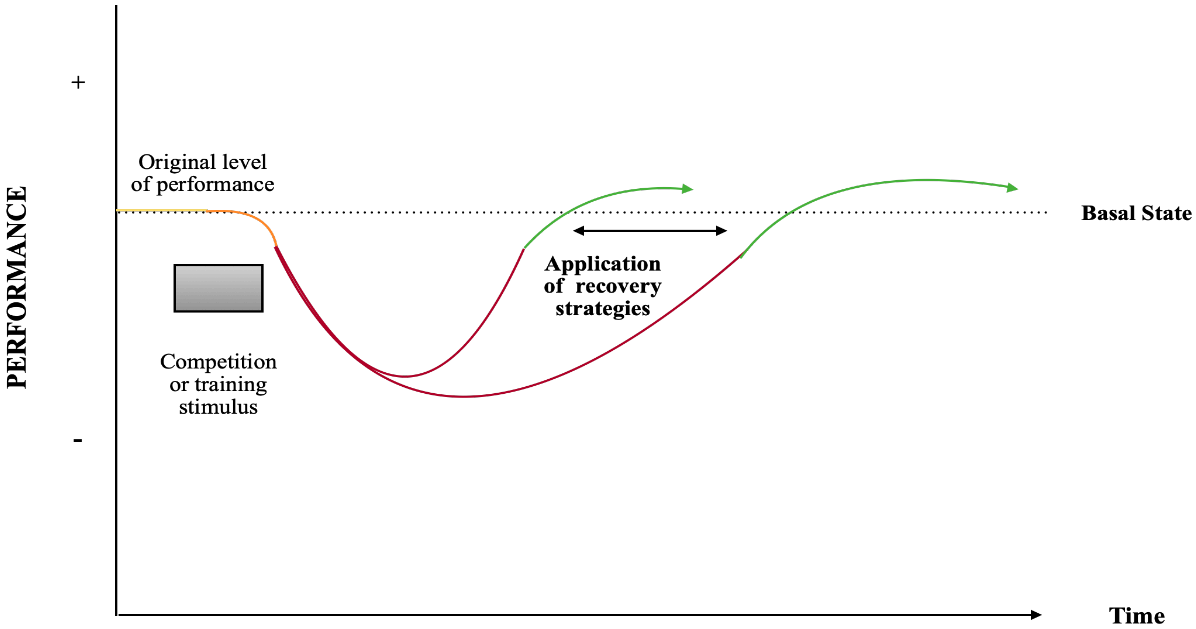

Figure 4. Potential performance supercompensation applying recovery strategies. Adapted from West [7].

The use of recovery strategies

Generally, recovery strategies aim to "shift from stress to recovery" [23]. For this reason, different post-exercise recovery techniques and modalities are increasingly used among elite sports athletes [28]. They should understand the importance of recovery for performance and implement them as part of an effective regeneration strategy [14,29–31] involving active processes with the main aim of re-establishing multiple components (psychological, physiological, emotional, social, and behavioral) and trying to compensate internal and external loads mismatches. Achieving it will allow them to train and perform again faster [2,11,31]. Thus, restoring pre-performance levels as quickly as possible is considered crucial to success in every sport [32–34]. Teams' staff members and athletes continuously search for the most effective strategies to accelerate post-exercise recovery processes [16,26,32,35].

Moreover, performance improvement is not achieved through a high quantity of recovery activities but through a high-quality, well-matched, and individualized approach to recovery according to athlete's situation-specific needs [2,36]. Furthermore, recovery should be programmed as an integral component of training via the implementation of recovery microcycles and recovery strategies [8] and prescribed by taking the current period of the season, the level of participation and the training stimulus nature into account [2,37,38]. However, further research is needed to determine the proper prescription and periodization of recovery modalities in elite sport and their potential impact on training adaptations [39].

Nevertheless, many practitioners apply it according to their coaching experiences or what they have observed at higher levels [28,40] and need to follow scientific recommendations. Also, the choice of recovery modalities may be influenced by support staff and coaches' preferences and orders [41], existing a major disconnect amongst athlete's belief in particular strategies and their real behaviors [42]. In many cases, eliminating non-desirable behaviors in athletes is not easy, even when there is a clear understanding that poor habits are detrimental [43]. For different reasons, scientific evidence is not always considered before implementing recovery strategies, showing the inadequate translation of sports science knowledge to day-to-day practice [20,28]. As Haller and colleagues concluded [44], the optimal enhancing recovery intervention should combine good scientific evidence that matches teams' or players' preferences and practitioners' expertise.

Thus, the proper choice of these strategies and the cooperation of a multidisciplinary team should be promoted and considered when designing recovery interventions and before their implementation [20,28]. Besides, taking a scientific approach to design and adjust individual training programs and monitoring the recovery-fatigue continuum, to assess an athlete's adaptation and ensure an adequate recovery-stress balance represents the first step toward performance enhancement [2,39,45]. However, sometimes there is a disconnect between research and practice and monitoring of recovery is often through informal observation rather than formal investigation [28,46]. Practicality, validity, reliability, accessibility, and acceptance are some of the aspects to consider when choosing the proper monitoring tools to use [2,28]. After this election, criteria to determine changes in recovery, performance and load need to be established to build a reliable decision-making process [46]. Monitoring systems should provide scientifically valid feedback to researchers and practitioners [47]; that way, the perceived effectiveness of recovery modalities commonly reported to be impacted by coaches' or athletes' feelings [28] could be avoided or minimized.

Recovery strategies

Many post-exercise recovery options are available for athletes to enhance recovery processes [48]; some of the most used ones in elite sports include hydrotherapy, sleep, stretching, compression garments (CG), massage, contrast and/or cold-water immersion (CWI) and ergogenic aids [24,28,34,39,40,49–52]. Moreover, besides sleep and fluid replacement, socializing with friends was one of the elite athletes' most popular recovery strategies [14].

Furthermore, active, passive, and proactive approaches to recovery can be differentiated [11]. While active recovery is characterized by involving physical activities and generally refers to the idea of "warming-down" or "cooling-down" after exercise, passive modalities generally refer to all non-exercise therapies. They may implement a state of rest or inactivity or apply external methods [53,54]. Proactive recovery needs a high level of self-determination by picking out personalized and individualized activities [14,30,36]. In practice, active and passive recovery are the two most used categories [55].

Following Reilly's categorization [52] there are three active, cool-down, recovery strategies: low-intensity aerobic activity (jogging, cycling, pool-running), stretching and muscle relaxation. Moreover, Crowther [40] subdivided low-intensity aerobic activities in active-land-based (ALB) and active-water-based (AWB).

Another classification for the recovery strategies following different authors' proposals [14,40] is to divide them into four main groups and another extra or other strategies:

- Natural strategies or those recovery methods that do not require special devices or modalities. It includes active field or gym-based, active pool-based, active, or passive stretching, sleep/nap, food and/or fluid replacement, supplement use.
- Physical strategies, which include various forms of cold, heat and contrast temperatures administration: cryotherapy or cooling methods (cold/ice bath/shower/immersion and ice pack/vest application), contrast temperature therapy (contrast bath/shower/immersion and sauna) heat methods (heat pack application), CG, massage, foam rolling (FR), liniment or gel/cream application.
- Psychological strategies: progressive muscle relaxation, imagery/prayer/music.
- Complementary/alternative strategies: reflexology or acupuncture, medication use.
- Other strategies.

Although there is some evidence of positive effects on some physiological (lactate removal or delayed onset muscle soreness recovery) and neural aspects, West [7] concludes that the mechanisms and effectiveness of many passive and active recovery strategies is anecdotal and speculative [23,56]. Specifically, passive recovery modalities lack consistent empirical evidence on its effectiveness, mainly using elite athletes [7]. Considering active recovery and despite unclear mechanisms and the role of lactate in fatigue, research indicated that it was generally effective, beneficial [7] and enhanced perceived wellbeing [57]. Moreover, some benefits were derived from its use compared with passive ones [58,59]. Nevertheless, although static stretching is commonly proposed to help the recovery process, more research needs to be published [7].

Soccer history

Modern soccer, or football as it is most known in Europe, was born in 1863 when the English Football Association (FA) was founded, and the first basic rules were established [60].. However, there is evidence during the 2nd and 3rd centuries BC that Chinese soldiers played "Tsu' Chu, which consisted of hitting a leather ball full of feathers and fur towards a net fixed in some bamboo canes without using upper extremities [60,61].

Soccer worldwide

Since it became a ruled sport on 26th October 1863 by the FA, soccer has evolved fast, and it is the most popular sport worldwide nowadays [62]. In 2006, according to the last *BigCount* of FIFA, soccer had over 265 million players playing for 301000 clubs and 1.7 million teams all over the world [63].

In 1872, the first national teams' game between England and Scotland was played. Since then, different countries adopted the British love for soccer, and leagues started to emerge; Netherlands and Denmark in 1889, Argentina in 1893; Switzerland and Belgium in 1895; Italy in 1898, Germany and Uruguay in 1900, Hungary in 1901 and France in 1903. However, it was not until 1904 in Paris that FIFA (*Fédération Internationale de Football Association*) was formed with seven members. This included Belgium, Denmark, France, the Netherlands, Spain, Sweden, Switzerland, and Germany. In 1930, the first-ever FIFA World Cup was held in Uruguay. There were 41 members at that time [60]. Today, FIFA membership comprises 211 national member associations (MAs), and it is the highest governing body of soccer [64].

Soccer professionalism

Soccer professionalization started in 1878 when John Love and Fergus Suter became the first soccer players to get paid for playing. Nevertheless, it was not until 1885 when the FA officially regulated it [65]. These numbers vastly differ from the ones provided by the FIFA Professional Football Report 2019, where there were at least 128983 professional soccer players and 3903 professional clubs over their 211 MAs worldwide. Mexico led the way on this score, and on the other hand, soccer was still considered completely amateur in 43 countries, with no professional players reported [64]. However, becoming a professional soccer player is difficult, and less than 1% of all practitioners achieve this goal [63].

Soccer physical demands and performance

Soccer is a complex team sport with unpredictable activity patterns that intersperses high and low-intensity intermittent efforts with active or passive recovery [55,66–68]. These efforts include ball contact actions such as dribbling, heading, kicking, or tackling, and no ball contact actions such as walking, running, turning, changing direction, accelerating, or decelerating among others [69,70]. Consequently, a vast majority of physiological systems are demanded and stressed, either mechanically or metabolically, during and after the game, leading to muscle soreness, muscle damage and reduced functional capacity [70–74]. Hence, coaches frequently searched for mimicry and prepared players to keep high-performance levels during the whole season by intensifying the demands of the training session [75].

Monitoring load is essential to understand individual responses to training sessions or games and to assess fatigue and the associated need for recovery [76]. Global Positioning System technology (GPS) provides comprehensive information about players' external load during games and training sessions, allowing the staff members to make informed decisions regarding their performance and trying to prevent increased levels of fatigue and minimizing the injury risk [77,78]. Elite soccer players could cover 10-12 km at an average intensity close to 80-90% of maximal heart rate and 70-80% of maximal oxygen uptake during a competitive game [79]. At the same time, the mean energy expenditure has been estimated to be approximately 1107 Kcal [80]. Moreover, soccer physical and technical demands have increased considerably in the last decade [67,68,81], with players performing approximately 200 high-intensity actions from a total of 1300, such as accelerating, decelerating, changing direction, or sprinting [82–85], which supposes to change activity every 5 seconds on average [79]. However, playing position impact physical demands and performance; consequently, physical profiles could differ substantially [66,85–87]. Wide-midfielders and second strikers travel the greatest total distance, sprint the most and repeated-sprint sequences are greater than any other group [85,86,88]. In contrast, central defenders have shown to have more time to recover between efforts [89], complete the least total distance, the shortest distance at high intensity and combined high-intensity and sprinting [90,91]. This monitoring approach enables the staff to understand the conditioning and recovery needs of each player in the team. It facilitates training' periodization throughout the week, administrating sessions with appropriate, individual, intensities and volumes (load) according to personal characteristics and trying to prevent high levels of fatigue, enhance performance and reduce the injury risk [92–97]. Nevertheless, a player's performance, also shows dependency on situational and contextual game factors or variables such as the venue, the result of the game, score, opponent level, playing style, or competition period, among others [82,98–101]. Thus, a holistic team performance analysis would be helpful since a decrease in it may respond to physiological fatigue but situational variables [102].
Moreover, heart rate and perceived exertion ratings (RPE) are frequently used to assess internal load. The advantage of using both, external and internal load measures, is that it helps assessing whether a player is fit or fatigued [47].

Fatigue in soccer

As mentioned before, a crucial factor in team sports performance is properly recovering from fatigue caused by games or training sessions. According to Terrados [103], sports fatigue can be defined as "the state in which the athlete is unable to maintain the expected level of performance or training". It will be essential to differentiate between central fatigue (the nervous system blocks muscles to protect them from injury, even if they can generate high power outputs) and peripheral fatigue (muscle is biomechanically or biochemically unable to respond effectively to an effort due to a homeostasis perturbation) [104] in order to know which one we are facing off and support proper recovery strategies [34].

Focusing on fatigue in elite competitive soccer, the average player is exposed to high-congested fixture periods with a mean of 60 competitive games per season, equating 5.5 games per month [105], 1-3 games per week [106] or one game every 4.3 days [107]. Moreover, it may be further complicated by national team fixtures and or European/World travel issues derived from them [108]. Therefore, much psychophysiological stress is endured by professional soccer players [32,38], predisposing them to non-contact and overuse injuries [109–111]. It is known that playing two games per week and having less than or equal to four days to recover, leads to a low-performance state and increases the risk of sustaining an injury substantially, being more than six times higher compared to having a recovery time of six days or more between competitive events and only one game per week [71,112,113]. Furthermore, adding load without sufficient recovery might lead to a low-performance state and increase injury and illness risk [111,112,114,115]. According to several authors, recovery occurs when players can reach or exceed benchmarks related to physiological, physical and/or perceptual states following trainings or games [97,116,117]. Dupont and colleagues [71] stated that soccer-related physical performance was immediately impaired after a game and recovered gradually to pre-game levels.

Based on different authors, it is typical to experience transition residual fatigue over the season, causing adverse effects on different performance factors [71,89]. Among others, repeated sprint and jumping abilities and maximal strength seem to be reduced immediately after the completion of a game; and the time needed for its normalization from a single game could not be observed until at least, 72 hours [71,118–120], even with signs of biochemical and physiological stress [121]. Furthermore, some external load parameters of the game such as high-intensity distance covered (total and per minute), high-speed running distance (HSR), and the number of sprints were significantly correlated to a creatine kinase (CK) increase, muscle damage, at 24-h post-game [97,122] . Nevertheless, when playing two games per week, the three-day period may not be sufficient to achieve a full recovery [71,123] and evidence showed that subjective markers, such as wellness and perceived recovery, exercise-induced inflammation, and performance parameters such as sprint, jump and strength, could take longer, 96 hours, to be normalized [34,116,118,124] which increases the need for recovery strategies [44]. However, there is a lack of consistency between studies when measuring the impact of fixture congestion on performance [125]. While some performed with professional soccer players showed that they were able to cope with the physical demands of consecutive venues [89,101,126,127] and non-significant differences in running performance, injury risk or pace in technical activities were significant [123,126,128], others demonstrated a negative impact on variables, such as low- and moderate- intensity distance covered during congested competitive periods [129,130]. Moreover, minimizing travel fatigue effects should be considered [131], given that traveling long distances by plane significantly affects the subjective ratings of jetlag, neurological fatigue, and sleepiness [33].

Recovery strategies in soccer

Having vast knowledge about physical performance profiles, players management, time courses, and recovery strategies parameters is fundamental to obtaining a realistic approach to optimize players' readiness for the upcoming games, helping them to feel healthier and more rested, establish an ideal periodization season design and to enhance the recovery process, [38,111,132–135]. According to the literature, professional soccer players' three essential recovery objectives are: alleviating muscle damage/fatigue, minimizing injury risk and optimizing performance [135]. There are many recovery strategies and options to choose from. However, the most common with a better subjective perception among professional soccer practitioners include active recovery, structured recovery day, extra rest day, sleep, massage, cold-water therapy, hydrotherapy, CG, nutrition, and carbohydrate supplementation [34,135]. All of them, most frequently employed around the game day [135], are not applied uniformly along post-game periods, differ depending on the location (home or away) of the game, and are used combining some of them [136]. Nevertheless, some of these strategies are considered inappropriate, detrimental for optimizing recovery [135], its recovery and performance benefits are not supported by scientific evidence [118,137–139] or even harmful to players, impairing the adaptation of a training stimulus [140] or a recovery intervention leading to potential damage in bones and tissues [141].

For this reason, with the primary objective to help soccer players and technical staff to educate, choose and implement the use of the most appropriate recovery techniques, some practical recovery guides based on extensive scientific evidence revisions have been published recently [44,55,71,137]. Some of these authors [55,71,137] found a high grade of recommendation for several recovery strategies such as nutrition, hydration, CWI, whole-body cryotherapy, and CG. At the same time, sleep, massage, FR, and electrical stimulation were considered inappropriate, or their benefits in physical performance and recovery were unclear. However, a recent publication [142] concluded that CWI and massage could be recommended to recover up to 72 post-game at a perceptive level. Furthermore, Haller and colleagues [44] rated nutrition and rehydration with the best evidence. Yet, CWI, CG, FR, and sleep were classified with moderate evidence and stretching, active and psychological recovery showed weak evidence. More high-quality research identifying effective strategies to enhance physical, physiological, and psychological recovery is still needed [142,143].

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Chapter 2 –

Aims and hypothesis

This thesis aims to gain insight into using recovery strategies and their effects on post-game neuromuscular, physiological, and perceptual outcomes within elite soccer players. The obtained knowledge has the purpose of helping players and staff to understand how to improve recovery strategies to enhance performance outcomes.

The objectives for each publication and hypothesis were:

- **Article-I**
  The study's main aim was to review the available evidence on the value of post-game recovery strategies and interventions in male professional or semi-professional soccer players to determine its effect on post-game performance outcomes, physiological markers, and wellness indicators. It was hypothesized that using recovery strategies after a soccer game would offer higher positive effects on all performance, physiological and wellness outcomes than not using them.

- **Article-II**
  The study focused on describing and reporting the use of recovery strategies by "LaLiga" (Spanish first division) teams, considered one of the best soccer leagues in the world, during the whole season. It was hypothesized that most clubs used various recovery strategies, with the physical ones likely being the most popular ones, and that professional players tended to use recovery strategies based on their preferences and beliefs, not scientific evidence. It was also hypothesized that different professionals and multidisciplinary teams designed and supervised recovery protocols.

- **Article-III**
  A parallel group-randomized trial was set up to compare the effectiveness of two comprehensive recovery protocols, including and combining different natural and physical recovery strategies, on physiological, neuromuscular, and perceptual outcomes after a soccer game in elite players. First, it was hypothesized that a comprehensive recovery protocol combining more methods could speed up and be more effective in enhancing objective and subjective players' recovery parameters. In addition, as a secondary aim hypothesis, the acute changes of muscular CK (CK-III) correlate with GPS external load variables recorded during the game.

Chapter 3 –

Material and methods

Three articles are included in the main body of this thesis. All the manuscripts are presented in the following sections, including a copy of the actual publications. The articles are presented chronologically in which they were written, published, and accepted.

The first article is a systematic review with a meta-analysis of randomized controlled trials. The following article is an observational cross-sectional descriptive study that reports the use of recovery strategies by "LaLiga" teams. The last article is a parallel-group randomized trial designed to compare the effectiveness of two recovery protocols on physiological, neuromuscular and perceptual outcomes in elite soccer players.

Readers are referred to the specific methods section of each article for further information.

Chapter 4 –

Articles

Article-I

Post-competition recovery strategies in elite male soccer players. Effects on performance: A systematic review and meta-analysis

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PLOS ONE

RESEARCH ARTICLE

Post-competition recovery strategies in elite male soccer players. Effects on performance: A systematic review and meta-analysis

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Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Abstract

Aims

The main aim of the present review was to update the available evidence on the value interest of post-competition recovery strategies in male professional or semi-professional soccer players to determine its effect on post-game performance outcomes, physiological markers, and wellness indicators.

Methods

A structured search was carried out following the PRISMA guidelines using six online databases: Pubmed, Scopus, SPORTDiscus, Web of Science, CINAHL and Cochrane Central Register of Controlled Trials. The risk of bias was completed following the Cochrane Collaboration Guidelines. Meta-analyses of randomized controlled trials were conducted to determine the between and within-group effects of different recovery strategies on performance, physiological markers and wellness data. Final meta-analyses were performed using the random-effects model and pooled standardized mean differences (SMD).

Results

Five randomized controlled trials that used Compression Garments (n = 3), Cold Water Immersion (n = 1), and acute Sleep Hygiene Strategy (n = 1) were included. Greater CMJ values at 48h for the intervention group (SMD = 0.70; 95% CI 0.14 to 1.25; p = 0.001; I^2 = 10.4%) were found. For the 20-m sprint and MVC, the results showed no difference either at 24h or 48h. For physiological markers (CK and CRP) and wellness data (DOMS), small to large SMD were present in favor of the intervention group both at 24h (-0.12 to -1.86) and

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48h (-0.21 to -0.85). No heterogeneity was present, except for MVC at 24h (I^2 = 90.4%; p = 0.0012) and CALF DOMS at 48h (I^2 = 93.7%; p = 0.013).

Conclusion

The use of recovery strategies offers significant positive effects only in jumping performance (CMJ), with no effects on the 20-m sprint or MVC. Also, the use of recovery strategies offers greater positive effects on muscle damage (physiological markers and wellness data), highlighting the importance of post-match recovery strategies in soccer.

Introduction

The interaction between training load, fatigue, adaptation, and recovery is an element of extreme complexity comprising factors of a very different nature [1, 2]. According to the literature, maximizing the performance of an athlete is not only a matter of training, but it is also affected by a wide array of intrinsic and extrinsic elements [2, 3]. Current evidence highlights that enough and optimal recovery is necessary to prevent health problems and to achieve peak performance and the choice of recovery strategies by coaches and athletes may be crucial [4, 5]. Proper recovery strategies can lead athletes to better performances, helping them to feel more rested and healthy [6]. However, high-performance athletes face a wide array of daily training stimuli that may not allow complete recoveries [7], emphasizing the need for optimal recovery strategies based on individual fatigue thresholds [4, 8].

Recovering as quickly as possible, restoring pre-performance levels is considered a crucial element of success in almost every athletic discipline [9]. For this reason, coaches and athletes are always in a continuous search for the most effective strategies to speed up post-exercise recovery [2, 9–11]. However, precisely defining the concept of "recovery from exercise" is a challenging mission due to the number of variables affecting an optimal recovery [12]. This pioneering idea has inspired a multi-factorial approach to the "physiology of recovery," evidencing the need for more conclusive research [13].

Placing the focus on fatigue in elite competitive soccer, we observe that the average player at this level is exposed to high-congested game schedules with a mean of 60 competitive games played per season, equating 5.5 games per month [14] or one game every 4.3 days [15]. Consequently, a lot of physical and psychological stress is imposed on professional soccer players [9, 16]. Players participating in two games per week and less than or equal to four recovery days are under a substantial risk of sustaining an injury. It is estimated that it is more than six times higher, compared to having only one game per week and a recovery time of six days or more between competitions [17–19]. Imposing load without enough recovery might also be an essential factor leading to illnesses or injuries [20, 21].

Among other performance factors in soccer, repeated sprint ability, jumping ability, maximal strength seem to be reduced immediately after a game; and the time needed to recover from training sessions or competitive events fully may vary between 48 hours and 96 hours depending on the authors and the physical fitness values analyzed [18, 22–30]. Besides, biochemical markers in team sports are also altered inconsistently after training or competition, showing relevant differences in the recovery profile of every sport [31]. Particularly in soccer, CK and hormonal parameters seem the most relevant biomarkers of the recovery process [32].

Establishing the importance of recovery, several studies show non-significant differences in injury risk, running performances, or pace in technical activities during congested competitive periods in professional soccer players [33, 34]. Soccer players seem to be able to cope with the physical demands of consecutive games [34–37]. Thus, the decline in performance can be attributed to an increase in game interruptions and not to the effect of physical fatigue, and it may be a common trend to overestimate fatigue-induced performance declines [35]. Player's covered distances and velocities also show dependency on contextual game factors such as the venue and the result of the game [36]. To experience transient residual fatigue over the games and the season is something common in professional soccer players, causing adverse effects on the on-field physical performance and predisposing to overuse and non-contact injuries [18, 37–40]. Minimizing the effects of travel fatigue should also be taken into account [41], given that traveling long distances by plane has a significant effect on the subjective ratings of jet-lag, neurological fatigue, and sleepiness [42].

The knowledge about physical performance profiles, players management (squad rotation) recovery strategies, and time courses seems to be an essential factor in getting a realistic approach to recovery, establishing an optimal periodization design for the season, and optimizing players' readiness for the upcoming competitions. [16, 33, 38, 43–46].

To enhance the recovery process, the more common strategies employed by athletes include ergogenic aids, hydrotherapy, active recovery, stretching, compression garments, and massage [47, 48]. These methods are frequently used by professional soccer players, being nutrition, sleep, compression garments, cold-water immersion, and contrast water therapy, the ones with a better subjective perception [49]. However, in many cases, scientific evidence is not taken into account before implementing these strategies, showing inadequacies of sports science knowledge translation to the day-to-day practice [4]. Abaïdia and Dupont [50] proposed a practical recovery protocol based on an extensive scientific revision, finding a high grade of recommendation for several nutritional strategies and hydration, cold water immersion, whole-body cryotherapy, and compression garments. In this proposal, other recovery strategies such as sleep, massage, foam rolling, electrical stimulation, and massage were considered inappropriate, or its benefits in physical performance and recovery were not clear. Moreover, other authors concluded that even active strategies were largely ineffective for improving post-exercise recovery, offered some benefits compared with passive ones [51, 52].

Specifically, in soccer, some studies show that active recovery neither has effects on neuromuscular recovery nor in antioxidant response to competitive games and muscle soreness [27, 45, 53]. Others found it useful, reducing muscle pain, concluding that it may help to restore performance abilities such as vertical jump [54]. Cold-water immersion is another of the most common strategies employed and has been reported as effective improving muscular damage and discomfort and overall fatigue perception after training and competition, but not having a definite positive effect on physical performance [55–58]. Modern techniques, such as electrostimulation and foam roller, have also shown a significant effect on the recovery in agility and perceived muscle soreness [59, 60] while compression garments have reduced histological damage in some experimental studies [61]. However, the studies with professional or semi-professional soccer players are scarce, and consequently, decision making very complex.

Several authors have tried to find pooled positive effects of using combinations of different recovery strategies. Kinugasa & Kilding [62] observed higher positive effects on perceived recovery after combining cold-water immersion and active recovery. In another study, whole-body vibration (WBV), in combination with a traditional cool-down reduced perceived muscle pain and enhanced recovery faster than the protocols without WBV after a soccer-specific drill [10]. Other authors have demonstrated that no recovery strategy is more effective than the others. However, the use of combined strategies tended to be more effective than a simple strategy [63]. To the best of our knowledge, no systematic review has analyzed the empiric use of these strategies in professional soccer settings previously.

Therefore, the main aim of the present study is to review the available evidence on the value of post-match recovery strategies and interventions in male professional or semi-professional soccer players in order to determine its effect on post-match performance outcomes, physiological markers, and wellness indicators.

Materials and methods

Design

A systematic review and meta-analysis focusing on the effects of different recovery strategies in professional soccer contexts were reported following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-analyses statement (PRISMA) [64]. Before the search, a review protocol based on PRISMA-P [65] was completed (S1 File) and registered at PROSPERO (ID = CRD42018094854). The review protocol was updated during the review process and is available at http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42018094854 (07 November 2019)

Search strategy and study selection

A systematic computerized literature search was performed using six online databases: Medline (PubMed), Scopus, SPORTDiscus, WOS (Web of Science), CINAHL, and Cochrane Central Register of Controlled Trials (CENTRAL). The search included articles published before May 20th, 2020. All databases were searched using Boolean operators with the following medical subject headings (MeSH) and free text words for critical concepts related to recovery and soccer performance: "Athletes," "Sport," "Recovery," "Match," "Performance," "Feeling perception." The eligibility of the studies was formulated according to the following PICOS criteria, which returned relevant articles in the field using a snowballing approach:

- Population: elite professional or semi-professional male football or soccer players.
- Intervention: structured interventions comparing methods and control groups.
- Comparison: studies that compare different recovery modalities or between a modality and control group.
- Outcomes: physical performance was taken into account as a primary outcome. Subjective perception, wellness, technical, tactical, and physiological performance were considered as secondary outcomes.
- Study design: randomized clinical trials were included.

Studies were included if 1) were randomized controlled trials (RCTs) with participants randomly separated into equal groups (control group and intervention group); 2) participants were semi-professional or professional adult football/soccer players; 3) recovery strategies were performed after a competition. Studies were excluded if: 1) female players were taken into account. Only full-text publications in English were considered.

The complete search strategy for each database can be found in the S2 File. The searches were customized to accommodate the layout and characteristics of each search tool. The reference sections of all identified articles were examined, and a hand-search of it was also conducted for other potentially relevant references.

One author selected papers for inclusion (AAB). Titles and abstracts obtained by the search were screened and downloaded into Mendeley Desktop (Glyph & Cog) for a subsequent full-text review. Cross-references and duplicates were removed. All publications potentially relevant for inclusion in the meta-analysis were independently assessed by two reviewers (AAB and JVB). Any discrepancies at this stage were resolved during a consensus meeting, and a third (JP) reviewer was available if needed.

Outcome variables

For the primary outcome, changes in muscle strength, sprint and jump performance values obtained from different tests after using recovery modalities were considered.

For the secondary outcomes, changes in psychological, wellness, and physiological data were considered.

Data extraction

General study information, participants, intervention characteristics, and outcome measures were extracted independently by two reviewers (AAB and JVB) using a specific standardized data extraction form (S3 File). When studies provided insufficient data for inclusion in the meta-analysis, the first author of the study made contact with the corresponding author(s) to determine whether additional data could be provided; in other cases, data was extracted from graphs using Digitizeit digitizer software (https://www.digitizeit.de).

Risk of bias

Methodological quality was not implemented, as no evidence for such appraisals and judgments exists and, therefore, can be confusing when interpreting results [66].

A bias is a systematic error, or deviation from the actual effect, in results or inferences. The authors assessed the risk of bias in RCTs following the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials [67]. The items on the list were divided into six domains: selection bias (random sequence generation, allocation concealment); performance bias (blinding of participants and researchers); detection bias (blinding of outcome assessment); attrition bias (incomplete outcome data); reporting bias (selective reporting); and other bias. For each study, bias domain was judged by consensus (AAB and JVB), or third-party adjudication (JPL) and was characterized as "high" (a plausible bias that severely weakens confidence in the results); "low" (a plausible bias unlikely to seriously alter the results); or "unclear" (plausible bias that raises some doubt about the results). A quote from the study report, together with a justification for the judgment, was provided.

Statistical analysis

Descriptive data of the participants' characteristics were reported as mean (SD). All meta-analyses calculations were conducted with the R software with meta and metafor packages for met-analysis (Version 3.5.1.). Descriptive analyses and figures of risk of bias were performed using Microsoft Excel for MAC, version 16.29.1 (Microsoft, USA). Mean and standardized mean differences (Hedges' g) and 95% CI for each group were calculated. The analysis of pooled data was conducted using a random-effect model [68] to estimate the change for each group at the same measurement time on primary and secondary outcomes. For the secondary meta-analysis, the mean difference between primary and secondary outcomes was collected to estimate the change from baseline to each time measurement for each group (control and experimental groups). Standardized mean differences were weighted by the inverse of the variance to calculate the size of the effect and 95% confidence interval. Cohen's criteria were used to interpret the magnitude of the effect: $<|0.50|$: small; $|0.50|$ to $|0.80|$: moderate; and $>|0.80|$: large [69]. Heterogeneity was assessed using Cochran's Q statistics and its corresponding p-value as well as the I^2 statistic, which describes the percentage of variability in effect estimates attributable to heterogeneity rather than chance when I^2 was >30% (30–60% representing moderate heterogeneity) [66]. Publication bias was assessed with funnel plots and Begg's test. Significance was set at $p<0.05$.

In the case of studies reporting recovery at different time frames such as 20h and 44h, those values were assimilated to the ones reported in the literature, 24h and 48h.

Results

The initial search identified 4184 references (Fig 1). No other references were identified through the examination of reference lists and citations of relevant articles. After the identification of duplicates, 3402 titles and abstracts were screened. Seven studies remained for further full-text analysis. Subsequently, 2 studies were excluded. The reasons for exclusion were that participants were not football or soccer players; or data on primary outcomes (performance) was not assessed in the study. In the end, five studies were included in the final review process.

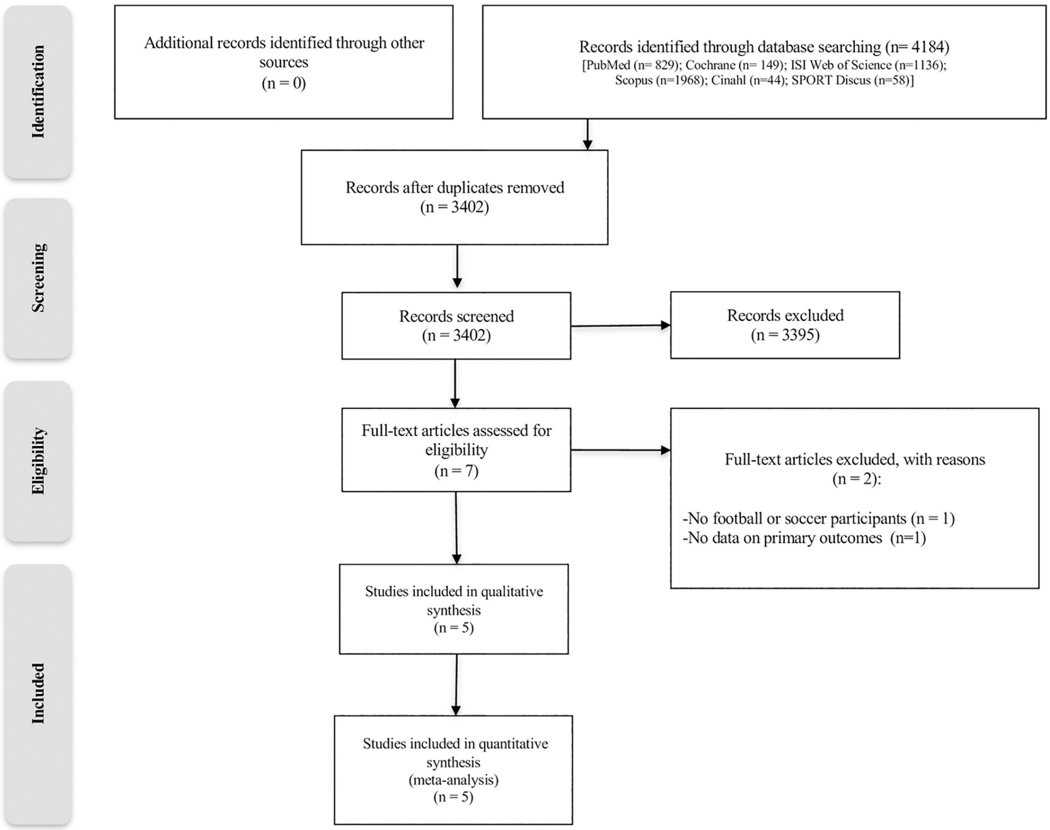

Fig 1. Eligibility flow diagram showing the selection process for the inclusion studies in this meta-analysis. n: sample size.

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Description of studies

Five RCTs [57, 70–73] were included in this review, with their most relevant characteristics being summarized in Table 1. A total of 69 participants were included in the review, with a mean age of 20.8 ± 1.3 years with a range of 18 to 28 years The competitive level of the soccer players in the studies was semi-professional [57, 71–73], and elite or professional [70]. From the included studies, three assessed the effects of wearing lower-body compression garments

Table 1. Characteristics of the included randomised controlled trials.

Study	Population and level N (male); age ± SD	Intervention description	Group: Intervention and Control characteristics	Primary Outcome	Secondary outcomes	Results, conclusions and intervention effect
Ascensão et al. [57].	20 junior soccer players National team leagues IG (10); 18.1 ± 1.8 years CG (10); 18.3 ± 0.8 years	Effect of immediate post-exercise CWI single session on soccer players	After match for 10 minutes IG: CWI 10ºC CG: TWI 35ºC	SJ (cm) CMJ (cm) 20-m sprint (sec) MVIC (Kg)	DOMS Muscle damage: CK (U/L), Mb (μg/L) Inflammation CRP (mg/L)	Decrease in SJ at 24h and CMJ at 24h and 48h in the TWI group[b] Decrease in CMJ at 24h in the CWI group[b] Decreases in peak quadriceps strength in the TWI group at 24h and 48h and in CWI at 48h[b] Quadriceps strength greater at 24h in CWI group[a] CWI more effective than TWI at 24h for quadriceps and calf DOMS and at 30min for hip adductors[a] CK increased in both groups at 30min, 24h and 48h[b] and more in the TWI at 24h and 48h[a] Mb increased in both groups at 30min[b], more in the TWI[a] CRP concentrations increased in both groups at 30min and 24h[b], but again more in the TWI than in CWI[a]
Clifford et al. [70].	11 elite professional soccer players 19.0 ± 1.0 years	Effect of wearing lower body garments fitted with cooled phase changed material (PCM) on accelerating functional and perceived recovery after a game	45 min after match for 3 hours. 5 mmHg IG: PCMcold 15ºC CG: PCMwarm 22ºC	CMJ (cm) MVIC (N)	BAM+ MS BFQ	MVIC at 36 h and 60 h post was greater with PCMcold than PCMwarm[a] MS post 36 h and 60 h was lower with PCMcold than PCMwarm[a] No differences in CMJ or BAM + between groups. PCMcold was more effective than the PCMwarm after the intervention according to BFQ[a]
Fullagar et al. [71].	20 highly trained semi-professional soccer players 25.5 ± 4.6 years	Effect of an acute sleep hygiene strategy (SHS) on physical and perceptual recovery of players after a late-night game.	IG: SHS lights dimmed, eye-masks and ear plugs, cool temperature rooms (~17˚C). No technological or light stimulation ~15–30 min prior to bedtime. 7h 30 min in bed. CG: NSHS allowed to use mobile phones and TV. 5 h 30 min in bed.	External load Internal load CMJ (cm) YYIR2 (m)	Objective and subjective sleep data General recovery state Sleep chronotype RPE Psychological recovery Physiological recovery Muscle damage: CK (mg/ml) and urea(mg/dl) Inflammation: CRP (mg/dl)	Greater sleep duration in SHS compared to NSHS on match night[a] Less sleep duration with NSHS[b]Greater wake episodes on match night for SHS[a] No differences between conditions for any physical performance or venous blood marker. Maximum heart rate during YYR2 higher in NSHS than SHS at 36h[a] No differences between conditions for perceptual "overall recovery" or "overall stress.

(*Continued*)

Table 1. (Continued)

Study	Population and level N (male); age ± SD	Intervention description	Group: Intervention and Control characteristics	Primary Outcome	Secondary outcomes	Results, conclusions and intervention effect
Marqués-Jiménez et al. [72].	18 semi-professional soccer players 24.0 ± 4.07 years	Evaluate physiological and physical responses to wearing compression garments during soccer matches and during recovery	During game and during 3 days after for 7 h/day. SG: 20–25 mmHg ankle / 15–20 mmHg calf FLG: 25–30 mmHg calf / 15–20 mmHg thigh QG: 15–20 mmHg thigh CG: no compression garments	CMJ (cm) 10–20 m sprint (sec) T-Test (sec) YYIR2 (m)	[La-] mmol/L SaO_2 (%) RPE TQR	There are significant correlations, immediately post-match, between 10-m sprint and 20-m sprint in the CG, 10-m sprint and 20-m sprint and 10-m sprint and T-Test in the SG, and [La-] and 10-m sprint in the QG. At 48 h post-match, there are significant correlations between 10-m sprint and 20-m sprint in the EG, 10-m sprint and 20-m sprint in the SG, 10-m sprint and 20-m sprint in the FLG. At 72 h post-match there are significant correlations between 10-m sprint and 20-m sprint in the CG.
Marqués-Jiménez et al. [73].	18 semi-professional soccer players 24.0 ± 4.07 years	Evaluate the influence of different types of compression garments in reducing exercise-induced muscle damage (EIMD) during recovery after a friendly soccer match	During game and during 3 days after for 7 h/day. SG: 20–25 mmHg ankle / 15–20 mmHg calf FLG: 25–30 mmHg calf / 15–20 mmHg thigh QG: 15–20 mmHg thigh CG: no compression garments		EIMD biomarkers DOMS Swelling	In CG, most biomarkers, including CK, LDH, GOT and GPT, were greater at 72-h post-match compared to pre-match. In EG, increases[a] between pre- and 72-h post-match were observed only in CK and LDH. Thigh swelling increases[a] with time were present in CG. Differences in calf swelling were observed between CG, EG, SG and FLG[a] DOMS differences between groups were only observed between CG, SG and QG in tibialis soreness, between CG and FLG in quadriceps soreness, between CG, EG, SG and QG in calf soreness and between SG and QG in hamstring soreness

IG: intervention Group; CG: control group; EG: Experimental group; CWI: cold water immersion; TWI: thermoneutral water immersion; SJ: squat jump; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; Mb: myoglobin; CRP: C-reactive protein; PCM: cooled phase change material; MIVC: maximal isometric voluntary contraction; BAM+: brief assessment of mood; MS: muscle soreness; BFQ: belief questionnaire; SHS: sleep hygiene strategy; NSHS: normal post-game sleep hygiene strategy; YYIR2: Yo-Yo intermittent recovery level 2; RPE: rate perceived exertion; SG: stockings group; FLG: tights group; QG: shorts group; TQR: perceived recovery; [La-]: lactate concentration; SaO_2 (%): Arterial oxygen saturation of hemoglobin; EIMD: exercise-induced muscle damage; LDH: lactate; GOT: glutamic oxaloacetic; GPT: glutamic pyruvic

[a] Significance at $p<0.05$

[b]Significant differences at baseline level ($p<0.05$)

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[70, 72, 73], one assessed the effects of cold-water immersion [57] and one assessed the effects of an acute sleep hygiene strategy [71] on performance outcomes. One of the compression garments interventions [70] combined compression with cold, using specific garments with cooled phase changed material (PCM) at 15º. All the studies assessed the effects of recovery strategies at 24 hours and 48 hours post-match. Since only one of the authors [72, 73] reported the effects of recovery strategies at 72 hours, those values could not be included in the analyses.

Some authors were contacted to provide extra information about the studies. Data from three authors could be obtained [70, 72, 73], two were extracted from the tables and graphs

Table 2. Risk of bias (RCTs).

Study	Domain						
	Random sequence generation	Allocation concealment	Blinding of participants and researchers	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias
Ascensão et al. [57].	Low	Unclear	High	Unclear	Low	Low	-
Clifford et al.[70].	Low	Low	Low	Unclear	Low	Low	Low
Fullagar et al. [71].	Low	Unclear	High	Unclear	Low	Low	Low
Marqués-Jiménez et al. [72].	Low	Unclear	High	Low	Low	Low	Low
Marqués- Jiménez et al. [73].	Low	Unclear	High	Unclear	Low	Low	Low

https://doi.org/10.1371/journal.pone.0240135.t002

[57, 71]. Results of the RCTs risk of bias assessment are presented in Table 2 and Fig 2. The primary source of bias was the blinding of participants and outcome assessors.

Total estimate

Primary analyses. Four RCTs [57, 70–72] were included in the primary analyses for primary outcomes. In total, six analyses were performed: two for CMJ (24h and 48h), two for the 20-m sprint (24h and 48h), and two for MVC (24h and 48h), are shown in Table 3 and Fig 3.

For the CMJ, the results showed no difference at 24h (MD = 1.26; 95% CI: -0.92 to 3.44; p = 0.2575; I^2 = 0.0%; SMD = 0.14; 95% CI: -0.31 to 0.59), but greater CMJ values at 48h for the intervention group (MD = 3.01; 95% CI: 1.21 to 4.80; p = 0.001; I^2 = 10.4%; SMD = 0.69; 95% CI: 0.14 to 1.25). For the 20-m sprint, the results showed no difference either at 24h (MD = -0.05; 95% CI: -0.14 to 0.04; p = 0.311; I^2 = 0%; SMD = -0.28; 95% CI: -0.81 to 0.24), or 48h (MD = -0.02; 95% CI: -0.10 to 0.06; p = 0.592; I^2 = 28.1%; SMD = -0.21; 95% CI: -0.74 to 0.31). For the MVC, the results showed no difference either at 24h (MD = -105.41; 95% CI: -189.14 to 399.97; p = 0.483; I^2 = 90.4%; SMD = 0.57; 95% CI: -1.10 to 2.25), or 48h for the intervention group (MD = 36.21; 95% CI: -42.58 to 115.01; p = 0.3677; I^2 = 0%; SMD = 0.23; 95% CI: -0.38 to 0.84). No heterogeneity was present (I^2 range from 0 to 28.1%) in all the analyses, except for MVC at 24h (I^2 = 90.4%). Finally, analyses on aerobic capacity (YYIR2) could not be performed due to lack of available data.

Secondary analyses. Three RCTs [57, 71, 73] were included in the secondary analyses for the secondary outcomes (physiological markers and wellness data). In total, nine analyses were performed: one for CK, two for CRP (at 24h and 48h), two for quadriceps (QUAD), hamstrings (HAMS), and calf (CALF) DOMS (at 24h and 48h) are shown in Table 3.

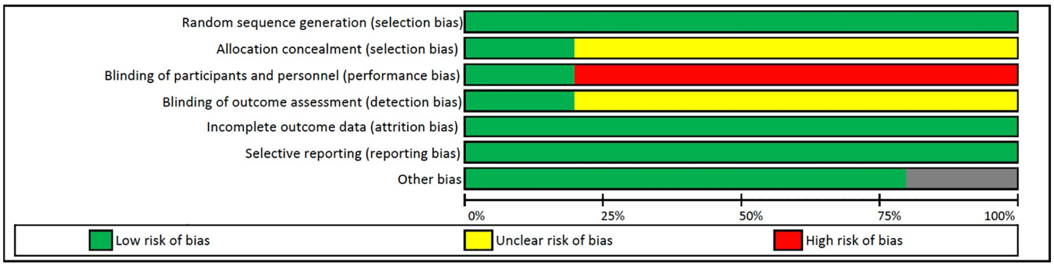

Fig 2. Risk of bias (RCTs).

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Table 3. Results from primary and secondary analyses.

Variable		Study	Mean Difference [95% CI]	Random effects model	P-value	SMD [95% CI]
Primary outcomes	CMJ 24h	Ascensão et al. 2011	4.40 [-1.65; 10.45]	1.26 [-0.92; 3.44]	0.2575	0.14 [-0.31;0.59]
		Marqués-Jiménez (a) et al. 2018	1.04 [-2.84; 4.92]			
		Clifford et al. 2018	0.65 [-2.27; 3.57]			
	CMJ 48 h	Ascensão et al. 2011	5.90 [1.54; 10.25]	3.01 [1.21; 4.80]	0.001	0.69 [0.14; 1.25]
		Marqués-Jiménez (a) et al. 2018	1.45 [-2.50; 5.40]			
		Clifford et al. 2018	3.12 [0.99; 5.25]			
	20-m sprint 24 h	Ascensão et al. 2011	-0.40 [-0.19; 0.04]	-0.05 [-0.14; 0.04]	0.311	-0.28 [-0.81; 0.24]
		Marqués-Jiménez (a) et al. 2018	-0.05 [-0.15; 0.05]			
	20-m sprint 48 h	Ascensão et al. 2011	-0.13 [-0.31; 0.05]	-0.02 [-0.10; 0.06]	0.592	-0.21 [-0.74; 0.31]
		Marqués-Jiménez (a) et al. 2018	-0.01 [-0.09; 0.07]			
	MVC 24 h	Ascensão et al. 2011	251.00 [145.62; 356.37]	-105.41 [-189.14; 399.97]	0.483	0.57 [-1.10; 2.25]
		Clifford et al. 2018	-49.73 [-198.54; 99.08]			
	MVC 48 h	Ascensão et al. 2011	37.00 [-97.17; 171.17]	36.21 [-42.58; 115.01]	0.3677	0.23 [-0.38; 0.84]
		Clifford et al. 2018	34.46 [-107.02; 175.94]			
Secondary outcomes	QS DOMS 24 h	Ascensão et al. 2011	-2.39 [-3.45; -1.32]	-2.37 [-3.51; -1.22]	<0.0001	-1.08 [-1.69; -0.48]
		Marqués-Jiménez (b) et al. 2018	-2.34 [-4.11; -0.57]			
	QS DOMS 48 h	Ascensão et al. 2011	-1.56 [-2.46; -0.66]	-1.66 [-2.73; -0.59]	0.0024	-0.85 [-1.40; -0.30]
		Marqués-Jiménez (b) et al. 2018	-1.91 [-3.90; 0.08]			
	HS DOMS 24 h	Ascensão et al. 2011	-2.42 [-3.40; -1.45]	-1.95 [-3.17; 0.66]	0.169	-0.54 [-2.45; 1.37]
		Marqués-Jiménez (b) et al. 2018	-0.07 [-2.81; 2.66]			
	HS DOMS 48 h	Ascensão et al. 2011	-1.60 [-2.26; -0.93]	-1.46 [-2.34; -0.59]	<0.0001	-0.50 [-0.89; -0.11]
		Marqués-Jiménez (b) et al. 2018	-0.61 [-2.98; 1.76]			
	CS DOMS 24 h	Ascensão et al. 2011	-3.29 [-3.97; -2.60]	-3.20 [-4.06; -2.35]	<0.0001	-1.86 [-3.27; -0.45]
		Marqués-Jiménez (b) et al. 2018	-2.87 [-4.72; -1.01]			
	CS DOMS 48 h	Ascensão et al. 2011	0.89 [0.19; 1.60]	-0.45 [-3.37; 2.48]	0.7619	-0.03 [-1.54; 1.50]
		Marqués-Jiménez (b) et al. 2018	-2.11 [-4.26; 0.04]			
	CK 24 h[a]	Ascensão et al. 2011	-168.00 [-225.21; -110.78]	-165.82 [-222.81; -108.83]	<0.0001	-0.59 [-1.13; -0.08]
		Fullagar et al. 2016	112.00 [-534.71; 758.71]			
	CK 48 h[a]	Ascensão et al. 2011	-96.00 [-47.60; -44.40]	-93.97 [-145.30; -42.64]	0.0003	-0.56 [-1.10; -0.03]
		Fullagar et al. 2016	101.00 [-405.11; 607.11]			
	CRP 24 h[a]	Ascensão et al. 2011	-0.23 [-0.39; -0.06]	-0.22 [-0.38; -0.06]	0.0084	-0.72 [-1.19; -0.24]
		Fullagar et al. 2016	0.10 [-0.91; 1.11]			
	CRP 48 h[a]	Ascensão et al. 2011	-0.20 [-0.36; -0.05]	-0.21 [-0.35; -0.05]	0.01	-0.69 [-1.23; -0.15]
		Fullagar et al. 2016	-0.60 [-2.40; 1.19]			

SMD: Standardized Mean Difference; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; CRP: C-reactive protein; QS: quadriceps; HS: hamstrings; CS: calf.

[a]Ascensão evaluated at 24-hours and 48-hours, while Fullagar evaluated at 20-hours and 44-hours post-match.

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For the QUAD DOMS, the results showed greater values for the intervention group both at 24h (MD = -2.37; 95% CI: -3.51 to -1.22; $p<0.0001$; $I^2 = 0.0\%$; SMD = -1.08; 95% CI: -1.69 to -0.48) and 48h (MD = -1.66; 95% CI: -2.73 to -0.59; p = 0.0024; $I^2 = 0.0\%$; SMD = -0.85; 95% CI: -1.40 to -0.30). For the HAMS DOMS, the results showed no difference at 24h (MD = -1.95; 95% CI: -3.17 to 0.66; p = 0.169; $I^2 = 55.9\%$; SMD = -0.54; 95% CI: -2.45 to 1.37), but greater values for the intervention group at 48h (MD = -1.46; 95% CI: -2.34 to -0.59; $p<0.0001$; $I^2 = 0.0\%$; SMD = -0.50; 95% CI: -0.89 to -0.11). For the CALF DOMS, the results only showed greater values for the intervention group at 24h (MD = -3.20; 95% CI: -4.06 to -2.35; $p<0.0001$;

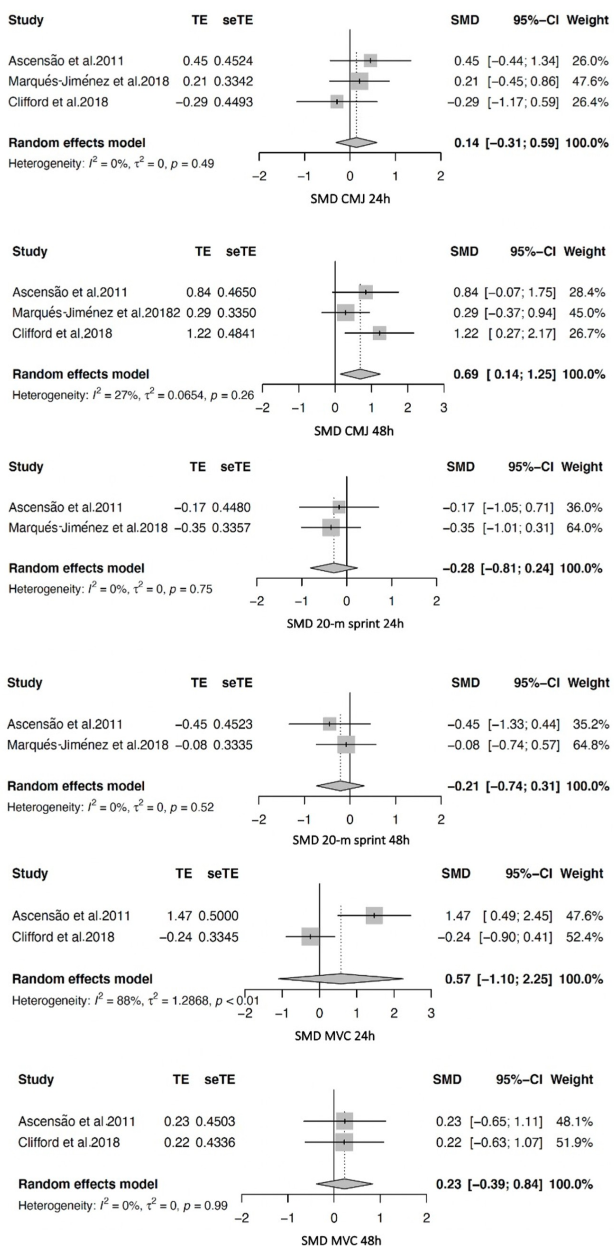
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 0.45 0.4524 0.45 [−0.44; 1.34] 26.0%
Marqués-Jiménez et al.2018 0.21 0.3342 0.21 [−0.45; 0.86] 47.6%
Clifford et al.2018 −0.29 0.4493 −0.29 [−1.17; 0.59] 26.4%
Random effects model 0.14 [−0.31; 0.59] 100.0%
Heterogeneity: I^2 = 0%, τ^2 = 0, p = 0.49
SMD CMJ 24h
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 0.84 0.4650 0.84 [−0.07; 1.75] 28.4%
Marqués-Jiménez et al.20182 0.29 0.3350 0.29 [−0.37; 0.94] 45.0%
Clifford et al.2018 1.22 0.4841 1.22 [0.27; 2.17] 26.7%
Random effects model 0.69 [0.14; 1.25] 100.0%
Heterogeneity: I^2 = 27%, τ^2 = 0.0654, p = 0.26
SMD CMJ 48h
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 −0.17 0.4480 −0.17 [−1.05; 0.71] 36.0%
Marqués-Jiménez et al.2018 −0.35 0.3357 −0.35 [−1.01; 0.31] 64.0%
Random effects model −0.28 [−0.81; 0.24] 100.0%
Heterogeneity: I^2 = 0%, τ^2 = 0, p = 0.75
SMD 20-m sprint 24h
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 −0.45 0.4523 −0.45 [−1.33; 0.44] 35.2%
Marqués-Jiménez et al.2018 −0.08 0.3335 −0.08 [−0.74; 0.57] 64.8%
Random effects model −0.21 [−0.74; 0.31] 100.0%
Heterogeneity: I^2 = 0%, τ^2 = 0, p = 0.52
SMD 20-m sprint 48h
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 1.47 0.5000 1.47 [0.49; 2.45] 47.6%
Clifford et al.2018 −0.24 0.3345 −0.24 [−0.90; 0.41] 52.4%
Random effects model 0.57 [−1.10; 2.25] 100.0%
Heterogeneity: I^2 = 88%, τ^2 = 1.2868, p < 0.01
SMD MVC 24h
Study TE seTE SMD 95%–CI Weight
Ascensão et al.2011 0.23 0.4503 0.23 [−0.65; 1.11] 48.1%
Clifford et al.2018 0.22 0.4336 0.22 [−0.63; 1.07] 51.9%
Random effects model 0.23 [−0.39; 0.84] 100.0%
Heterogeneity: I^2 = 0%, τ^2 = 0, p = 0.99
SMD MVC 48h

Fig 3. Meta-analysis of primary outcomes (counter movement jump; 20-m sprint and maximal voluntary contraction) at 24 hours and 48 hours.

https://doi.org/10.1371/journal.pone.0240135.g003

I^2 = 0.0%; SMD = -1.86; 95% CI: -3.27 to -0.45), but no difference at 48h (MD = -0.45; 95% CI: -3.37 to 2.48; p = 0.7619; I^2 = 83.7%; SMD = -0.03; 95%CI: -1.54 to 1.50). For the CK variables, the results showed greater values for the intervention group both at 24h (MD = -165.82; 95% CI: -222.81 to -108.83; p<0.0001; I^2 = 0.0%; SMD = -0.59; 95%CI: -1.13 to -0.08) and 48h (MD = -93.97; 95% CI: -145.30 to -42.64; p = 0.0003; I^2 = 0.0%; SMD = -0.56 CI: -1.10 to -0.03). For the CRP, the results showed greater values for the intervention group both at 24h (MD = -0.22; 95% CI: -0.38 to -0.06; p = 0.0084; I^2 = 0.0%; SMD = -0.72 CI: -1.19 to -0.24) and 48h (MD = -0.21; 95% CI: -0.35 to -0.05; p = 0.01; I^2 = 0.0%; SMD = -0.69; 95% CI: -1.23 to -0.15).

Post-hoc analyses. On primary outcomes (Fig 4 and S1 and S2 Tables), neither the intervention nor the control group showed changes in CMJ or 20-m sprint performance at 24h nor 48h compared to baseline, with a trend of decreased performance in both groups. MVC is decreased at 24h and 48h for the control group, and a trend of decreased performance in the intervention group was present.

On secondary outcomes (Fig 4 and S1 and S2 Tables), the intervention group showed no changes for QUAD (24h and 48h), HAMS DOMS (24h and 48h), and CALF DOMS (24h), but decreased CALF DOMS (48h) compared to post-match values. Instead, the control group showed no changes for QUAD DOMS (48h) and HAMS DOMS (24h and 48h), increased QUAD DOMS (24h), and CALF DOMS (24h), but decreased CALF DOMS (48h) compared to post-match values. For CK, both groups showed increased muscle damage at 24h and 48h

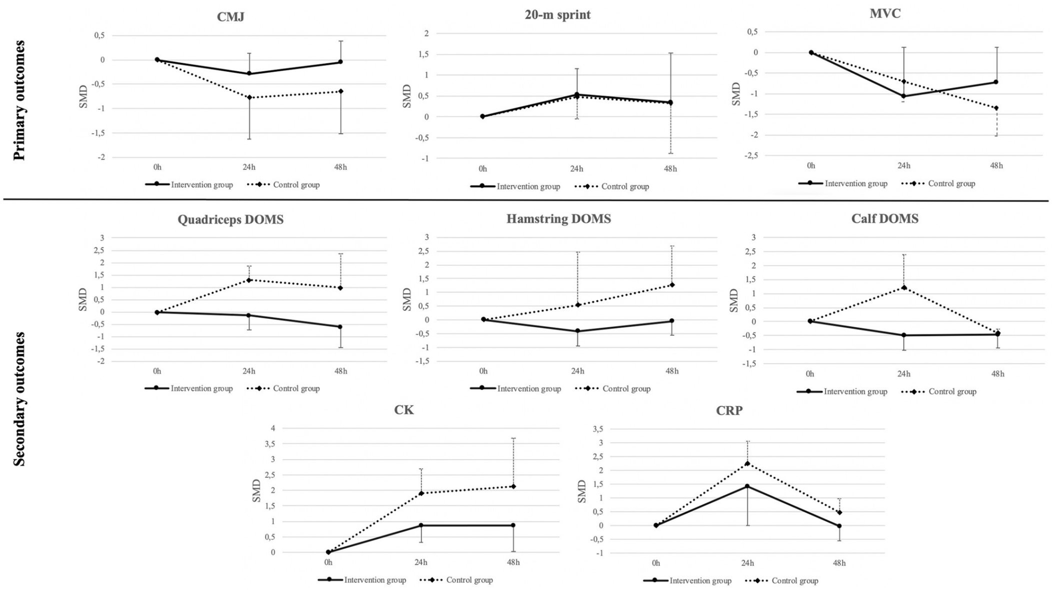

Fig 4. Time trends for primary and secondary outcomes from the experimental and control group.

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compared to baseline. For CRP, both groups showed increased muscle damage at 24h, but no difference at 48h compared to baseline.

Discussion

In this systematic review and meta-analyses, where the primary aim was to determine the effects of recovery strategies on post-match performance outcomes, these only provided larger effects on jumping performance at 48h compared to the control group.

Primary outcome: Jump performance, sprint, and muscle strength

Between groups. Our study reveals that for jump performance (CMJ), no significant differences are present in the RCT's at 24h. However, at 48h, there exists a moderate difference (SMD = 0.69) in favor of the intervention group using compression garments or cold-water immersion [57, 70, 72]. This outcome is contrary to that of Rey, Lago-Peñas, Casáis, & Lago-Ballesteros [54] who found that CMJ values in professional soccer players were significantly higher 24h after using an active recovery strategy (12 minutes of submaximal running and 8 minutes of static stretching) after a training session, simulating the demands of a soccer game. The study mentioned earlier could not be included in our meta-analysis due to limitations in its design (performed after training sessions; does not evaluate post-competition recovery effects). However, their findings show that the differences in the benefits arising from the use of single-method recovery strategies and their combinations could be notorious, and should be considered, and more so as was pointed by other authors in their investigations [63].

On the other hand, when analyzing the 20-m sprint and muscle strength (MVC) outcomes, small to moderate non-significant effects are present to enhance recovery when using cold-water immersion and compression garments, at 24h for sprint performance (SMD = -0.28) and after 48h for MVC (SMD = -0.21). Not reaching statistical significance, we cannot confirm that these recovery strategies (cold-water immersion and compression garments) may provide positive sprint performance changes. However, given that a 0.05s difference in 20-m sprint is a meaningful change [74], this could be a relevant trend for future research that can more accurately determine that these strategies have positive effects. These findings do not align with previous studies such as De Nardi, Torre, Barassi, Ricci, & Banfi, [58] or Rowsell, Coutts, Reaburn, & Hill-Haas [55] that found cold-water immersion not to affect physical performance tests. However, the mentioned studies had young players in their samples, and this fact may play an essential role in the differences found between them and those included in our analyzes. This lower effect may exist because young athletes recover faster than adults from strenuous exercise mainly due to lower relative power capabilities, relatively larger flexibility, and enhanced muscle compliance, making them less susceptible to muscle damage [75].

Within groups. When looking at time trends, similar trends are present for CMJ and 20-m sprint performance in both the experimental and control group, which tend to decrease at 24h. Then, CMJ seems to remain altered at 48h in the control group but restoring baseline levels in the intervention group. Instead, the 20m-sprint performance seems to remain altered at 48h in both groups. MVC is negatively affected at 24h (SMD = -0.70) and 48h (SMD = -1.34) for the control group. However, for the intervention group, MVC was not affected at any time-point but seemed to follow a similar negative trend (decreased performance). This finding agrees with Thomas, Dent, Howatson & Goodall [76] that found unsolved decrements in MVC in fifteen semiprofessional players 72 hours after a simulated soccer game. The present findings of the within-group analysis need to be taken in caution due to the wide confidence intervals of the outcomes, probably due to the small sample from the analyses.

Secondary outcome: Psychological, wellness and muscle damage

Between groups. Our study reveals medium to large effects (SMD = -0.50 to -1.86) in favor to the intervention group when analyzing DOMS at 24h and 48h in all muscle groups (quadriceps, hamstrings and calf), except for hamstring at 24h, and calf at 48h, where a similar trend occurs.

For CK and CRP, medium effects (SMD = -0.56 to -0.72) were found in favor of the intervention group at 24h and 48h. This effect may be provided by the reduction in histological damage shown by some studies using different recovery methods [61], or in perceived muscle soreness argued by some others [53].

Within groups. When looking at time trends for each group, an interesting finding arises. The intervention group shows no differences in DOMS perception at 24h and 48h, for any muscle group compared to post-match values but improved DOMS perception in CALF DOMS at 48h. Surprisingly, the intervention group had greater feelings on DOMS after the intervention than in the baseline. However, for the control group, the most significant difference for all muscle groups is at 24h, when an increase in DOMS perception at the QUAD and CALF (SMD = 1.20 to 1.29) exists, and there was no difference for QUAD and HAMS compared to baseline at 48h. Moreover, CALF DOMS showed an improvement compared to baseline (SMD = -0.40) when baseline values were reestablished at 48h, showing that time trends on DOMS are different depending on the muscle group analyzed, especially for QUAD and HAMS which better responses seem to be induced after using recovery strategies. Considering many professional teams compete twice a week, improving the recovery perception may help overall team performance.

When analyzing muscle damage, there is an increase in damage for CK and CRP at 24h compared to baseline in both groups. Moreover, after 48h, CRP returns to the baseline values while CK keeps elevated in both groups. This finding agrees with some authors [32], stating that these biomarkers are sensitive to recovery time.

Although many coaches and practitioners are trying to design and implement protocols based on scientific evidence, we cannot forget the perception of the players regarding this matter. Some studies clearly show that athletes' preferences and scientific evidence do not always agree [77], with perceptual recovery not matching the recovery of performance variables [78]. More than likely, this effect occurs because when professional athletes use recovery strategies, not only are we promoting physical and physiological changes in their bodies, but we are also influencing perceptions and favoring mental well-being from a psychological point of view [53, 60].

Limitations of the study

One of the most important limitations of this study is the lack of research available in the literature meeting the inclusion criteria. The difficulty of implementing RCT's in team sport environments with competitive settings, truly significant in professional sports, hinders the possibility of providing more evidence to our findings. This gap is significant, and a critical constraint to establishing evidence-based recovery protocols in professional soccer.

Another substantial handicap in our proposal is related to the time frames used by some of the studies included in the sample. The majority of studies used times equal to one day (24h) and two days (48h) for the evaluation of acute recovery. However, some studies used time-frames of 20 and 44 hours that had to be assimilated for performing all our analyses.

Our research group requested all the original datasets to the corresponding authors of the studies included in our final analyses.

Conclusions

This systematic review and meta-analysis demonstrated that the use of recovery strategies in soccer players such as compression garments, cold water immersion, and sleep hygiene strategy offers greater positive effects only on one of the physical performance tests (CMJ), but no effects on the 20-m sprint or MVC compared to a control group. On top of that, these recovery strategies offer greater positive effects on muscle damage (physiological markers and wellness data) compared to a control group.

The conclusion is based upon the currently available literature where only five RCTs qualified for meta-analysis. We encourage professional practitioners and medical or technical staff teams to implement new RCTs in order to increase current evidence, helping the understanding on how the different recovery interventions and strategies affect physical, physiological and wellness parameters. Another relevant field for future research should aim at investigating the use of recovery strategies specifically by professional teams, as these studies are scarce. Additionally, new protocols based on how these strategies interact, assessing their effectiveness if they are used combined should be implemented and evaluated using the scientific method.

Supporting information

S1 File. PRISMA checklist.
(PDF)

S2 File. Search strategy.
(PDF)

S3 File. Data extraction form for randomised controlled trials.
(PDF)

S1 Table. Primary and secondary outcomes for the experimental group relative to the baseline data. SMD: Standardized Mean Difference; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; CRP: C-reactive protein; QS: quadriceps; HS: hamstrings; CS: calf. [a]Ascensão evaluated at 24-hours and 48-hours, while Fullagar evaluated at 20-hours and 44-hours post-match.
(DOCX)

S2 Table. Primary and secondary outcomes for the control group relative to baseline data. SMD: Standardized Mean Difference; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; CRP: C-reactive protein; QS: quadriceps; HS: hamstrings; CS: calf. [a]Ascensão evaluated at 24-hours and 48-hours, while Fullagar evaluated at 20-hours and 44-hours post-match.
(DOCX)

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Article-II

The use of recovery strategies by Spanish first division soccer teams: a cross sectional survey

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ORIGINAL RESEARCH

The use of recovery strategies by Spanish first division soccer teams: a cross-sectional survey

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ABSTRACT

Objectives: different active and passive post-exercise recovery techniques such as massage, foam rolling, stretching or ice baths among others, are used by elite athletes to promote effective physiological, physical, and mental restoration. However, limited research is available investigating the use of recovery strategies in professional soccer. As such, we aimed to explore and describe the use of strategies by professional teams throughout the season, describing competitive and preparatory phases.
Methods: the present study collected data from all professional Spanish soccer teams who played in 'LaLiga' (The Spanish first division), during the season 2018–2019 (n = 20) and the ones promoted for the season 2019–2020 (n = 3). A six-section online survey was responded once.
Results: teams used different recovery protocols and combinations, although natural and physical strategies such as sleep/nap, food/fluid replacement, cold/ice bath/shower/immersion, and massage were always present. However, there is no agreement in the protocols and timings employed. Three physical strategies showed a higher presence in the recovery protocols after competition: cold/ice bath/shower/immersion, massage and foam rolling; always used by seventeen teams (74%), sixteen (70%) and thirteen (57%) respectively. The design and supervision of recovery are multidisciplinary tasks in 87% of the teams. Our findings also demonstrate that although there is a body of scientific evidence on recovery, a gap between theory and practice exists with 13% of the teams acknowledging that insufficient logistics and economic resources limit the use of some strategies, and two teams (9%) not periodizing or individualizing recovery.
Conclusion: the investigation provided insight into the current use of recovery strategies by 'LaLiga' teams, highlighting that all clubs used them to one extent or another, but also that significant variability responding to individualized perceptions exists. Moreover, this study provides relevant contextual information that may be useful for professional soccer staff concerning the use of recovery strategies.

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Introduction

Athlete performance is the result of synergistic interaction among physical, mental, and social factors [1] affected by intrinsic and extrinsic parameters [2,3]. Production in high-level sports is only sustainable if the stress and fatigue produced by practice, competition, and personal life are balanced with adequate time for recovery [4,5]. Thus, the recovery process is regarded as a multifaceted, physiological, and psychological, restorative process relative to time [5]. A recovery and fatigue continuum, relative to the specific demands of each sport, also exists [6]. So if recovery is insufficient, it could initiate a cascade of disadvantageous conditions such as under-recovery, overtraining syndrome, or nonfunctional overreaching [5,7].

Post-exercise recovery techniques are used among elite sports athletes as part of an effective regeneration strategy [1,8–10]. Recovery practices aim at compensating from internal and external loads, allowing the athletes to train and perform again faster [5,10,11]. Restoring pre-performance levels as quickly as possible is essential in every athletic discipline, and that is the reason why coaches are continuously searching for the most effective strategies [3,6,12,13]. However, many practitioners turn to past experiences when implementing them [14,15], not following evidence-based recommendations [16]. Perceived effectiveness of recovery modalities impacted by feelings [14] should be avoided or minimized. Additionally, a potential disconnection amongst athlete's beliefs and their real behaviors toward recovery exists [17]. As it has been demonstrated by previous research,

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soccer players, rate recovery methods differently just because of their subjective perception [18].

Many post-exercise recovery options validated by scientific research are available for their use in professional sport [19]. Thus hydrotherapy, active recovery, sleep, stretching, compression garments, massage, contrast, cold water immersion, and ergogenic aids are among the most commonly used in these professional settings [14,15,18,20–25].

The active, passive, and proactive approaches to recovery may also be differentiated [1,8,11,26]. According to Reilly and Ekblom [21], three active, cool-down, recovery strategies are commonly applied in soccer: low-intensity aerobic activity (jogging, cycling, running-pool), stretching, massage, and muscle relaxation. Moreover, Crowther [15] subdivided low-intensity aerobic activities in active-land-based (ALB) and active-water-based (AWB).

The cooperation of a multidisciplinary team is crucial to choose the proper strategies, especially when scientific evidence is not always taken into account before implementing them [14,27]. Thus, the improvement of performance is not achieved through a high amount of recovery activities but, instead, through a high-quality, well-matched, and personalized approach to recovery adjusted to situation-specific needs [5,26]. Furthermore, recovery should be programmed as an integral component of training via the implementation of recovery microcycles [28] prescribed considering the period of the season, the level of participation in the team and the nature of the training stimuli [5,29,30]. However, further research is needed to determine proper prescription and designing tailored periodization in elite sport [25].

Placing the focus on fatigue in competitive soccer, the average elite soccer player is exposed to high-congested game schedules [31]. Consequently, experiencing transient residual fatigue over the games and the season is typical in professional players, causing adverse effects on the physical performance and predisposing them to non-contact and overuse injuries [32–36]. Hence, the knowledge about player management (squad rotation), physical performance profiles, and recovery strategies parameters are essential factors to get a realistic approach to recovery, optimizing players' readiness for the upcoming competitions [29,32,37–39].

Although there exist many post-exercise recovery methods available to soccer players and it is generally accepted that they are using them, to the authors' knowledge, there is currently no research available to describe which ones and how are they are used by professional soccer teams. Therefore, the main aim of the current study was to describe and report the use of recovery strategies by 'LaLiga' (Spanish first division) teams, considered as one of the best soccer leagues in the world, during the whole season. It was hypothesized that most clubs use a wide variety of recovery strategies, with the physical ones likely being the most popular ones. It was also hypothesized that a multidisciplinary teams design and supervise recovery protocols.

Materials and methods

Participants

All twenty professional Spanish teams who played in 'LaLiga' (The Spanish first division), during the season 2018–2019 and the three ones who were promoted for the season 2019–2020, were included. Teams were contacted (via e-mail or phone) to participate in this study and responded to the survey once. Medical or technical staff members (fitness coaches or strength and conditioning coaches) contacts were obtained via 'Asociación Española de Médicos de Equipos de Futbol' (AEMEF) or by personal contacts.

Ethics approval and consent to participate

The study was approved by a local Research Ethics Committee (registration number 78/2019) and was designed according to the Declaration of Helsinki [40]. Participants received all the information detailing the study aims in advance. Participants' rights were preserved, asking for voluntary participation, and giving the possibility to withdraw at any moment.

Study design

An online Ad-hoc survey was specifically deployed to determine the use of recovery strategies by Spanish professional soccer teams, consisting of a combination of questions using checkboxes, Likert scales and open-ended, free-text responses. The authors designed the first draft of the survey. A pilot test of the survey was performed by two semiprofessional soccer teams not included in the study who volunteered to participate.

The design was based on previously published surveys on recovery strategies [1,14,15,17,24]. The survey was available online (https://forms.gle/6NyZtkyxehedLJao6) from 19/06/2019 to 24/09/2019 when the last team answered. It comprises the six sections described in the following paragraph, and it took a maximum time of 15 minutes to be completed.

Data collection method

The survey considered six sections, the first section consisted of the demographics of the teams (team name and number of players per team) and their level of participation (number and duration of weekly training sessions and games). The following sections consisted of specific questions regarding the use of recovery strategies after games (second section), after pre-season training sessions (third section), and after in-season training sessions (fourth section). In each of these sections, participants had to indicate how many players used each strategy ('all of them,' 'more than 50%', or 'less than 50%' of the total of the team) and its frequency (always, sometimes, rarely, never, depending on the player). The list of strategies was elaborated following two proposals [1,15], included:

- **Natural strategies**: active field or gym based, active pool-based, active or passive stretching, sleep/nap, food or fluid replacement and supplement use.
- **Physical strategies**: cryotherapy or cooling methods (cold/ice bath/shower/immersion and ice pack/vest application), contrast temperature therapy (contrast bath/shower/immersion and sauna) heat methods (heat pack application), compression garments (CG), massage, foam rolling and liniment or gel/cream application.
- **Psychological strategies**: progressive muscle relaxation and imagery/prayer/music.
- **Complementary/alternative strategies**: reflexology or acupuncture and medication use.

Other strategies

In the last question of this section, participants were invited to add other strategies used but not mentioned in the survey, using an open category labeled 'other strategies.'

The fifth section provided a deeper understanding of the use of the recovery strategies in each team/club. Check listing was used to ask for the moment of the first use, the number of times that the strategy was performed from the end of a game/training session until the following one, periodization or planning, the combination of different recovery strategies and the obligation or non-obligation to use them. Furthermore, questions about preparation/design and supervision responsibility, personalization for players, the location where strategies took place, and the main reason for choice were asked using a checklist. However, in order to include all other options if they did not find the proper one, an open-labeled 'other' (specify) option was added.

The sixth section included questions complementary information about the use/or not of recovery strategies in the club youth teams and economic and logistic resources. Participants not using recovery strategies in their day-to-day practices in the previous sections were redirected straight to this section. After that, their participation in the survey concluded.

Statistical analysis

The present study follows an observational, cross-sectional descriptive design. Absolute and relative frequencies for the categorical variables, measures of central tendency (mean), and dispersion [standard deviation (SD), Range] for continuous variables were calculated. Qualitative terms were assigned to determine the observed frequencies' magnitude as follows: All = 100% of teams; Most = ≥75%; Majority = 55 to 75%; Approximately half = ~50%; Approximately a third = ~30%; Minority = <30% [41]. Data were extracted from the online survey (Google forms®) to a spreadsheet (Microsoft® Excel for Mac, version 16.40). After codifying all the responses, analyzes were performed using the R software. Quantitative, Likert, data were analyzed using the 'Likert' [42] package in R version 3.6.1 (R CoreTeam, 2019).

Results

All the teams contacted in the study completed the survey (100% response rate). Teams were composed by 24 ± 1 players (a total of 552 soccer players) who used to train between 4 and 6 (range) sessions per week (5.39 ± 0.66 sessions), with a total of 8.70 ± 3.23 hours on practice average per week and played 1–2 games per week (1.35 ± 0.49 games), with a total of 115.39 ± 39.45 minutes of competition on average every week.

All twenty-three teams used recovery strategies at some point during the season. After the competition, the majority of the teams (57%) used recovery strategies for all the players of the squad, and ten teams (43%) used recovery strategies by more than half of the players of the squad. After pre-season training, fifteen teams (65%) used recovery strategies for all

Table 1. Recovery strategies undertaken by all Spanish first division professional teams.

		Do you use these recovery strategies?			
		Yes		No	
Recovery strategy		n	%	n	%
Natural	Active field or gym based	22	96	1	4
	Active pool-based	11	48	12	52
	Active or passive stretching	21	91	2	9
	Sleep/Nap	23	100	0	0
	Food/Fluid replacement	23	100	0	0
	Supplement use	22	96	1	4
Physical	Cold/Ice Bath/Shower/Immersion	23	100	0	0
	Ice pack/vest application	12	52	11	48
	Contrast Bath/Shower/Immersion	17	74	6	26
	Sauna	8	35	15	65
	Heat pack application	2	9	21	91
	Compression garments	17	74	6	26
	Massage	23	100	0	0
	Foam rolling	21	91	2	9
	Liniment or gel/Cream application	19	83	4	1
Psychological	Progressive muscle relaxation	14	61	9	39
	Imagery/Prayer/Music	5	22	18	78
Complementary/Alternative	Reflexology/Acupuncture	5	22	18	78
	Medication use	13	57	10	43
Other	Other	-	-	-	-

the players of the squad, while the recovery strategies in the minority of the teams (30%) were used for more than half of the squad. Recovery strategies after in-season practices were more generalized, being used for all the players of the squad in eleven teams or half of the players of the squad in the other eleven teams (48%). There is only one team (4%) that did not propose any strategy after practices, neither pre-season nor in-season.

The use of recovery strategies differed among teams (Table 1). The most utilized recovery strategies (used by twenty-one teams or more) were sleep/nap, food/fluid replacement, cold/ice bath/shower/immersion, massage, active field, or gym-based cool-downs, use of supplementation, and active or passive stretching and foam rolling. Natural recovery strategies were the most popular among teams (>90%), apart from pool-based cool-downs (48%). Physical recovery strategies, such as cold/ice bath/shower/immersion, massage, and foam rolling, were also used by most of the teams (>90%). In contrast, psychological and alternative recovery strategies were less popular among the teams.

The use of recovery strategies after competition and after practice sessions, pre-season and in-season, are summarized in Figures 1–3, respectively.

Some of the other non-usual strategies, not mentioned in the survey but proposed by the teams were: cryosauna or cryo-chamber, vibration massage, use of vibration plates, cold compression wraps and ice compression therapy or manipulative manual techniques.

Periodization, individualization/personalization, frequency, time of first use and combination of recovery strategies after practice or competition during the season are summarized in Table 2.

Recovery strategies of most of the teams (87%), were designed and supervised by different professionals (members of the medical and technical staff) and not only by one specific profile. Three teams (13%) reported that a single person was

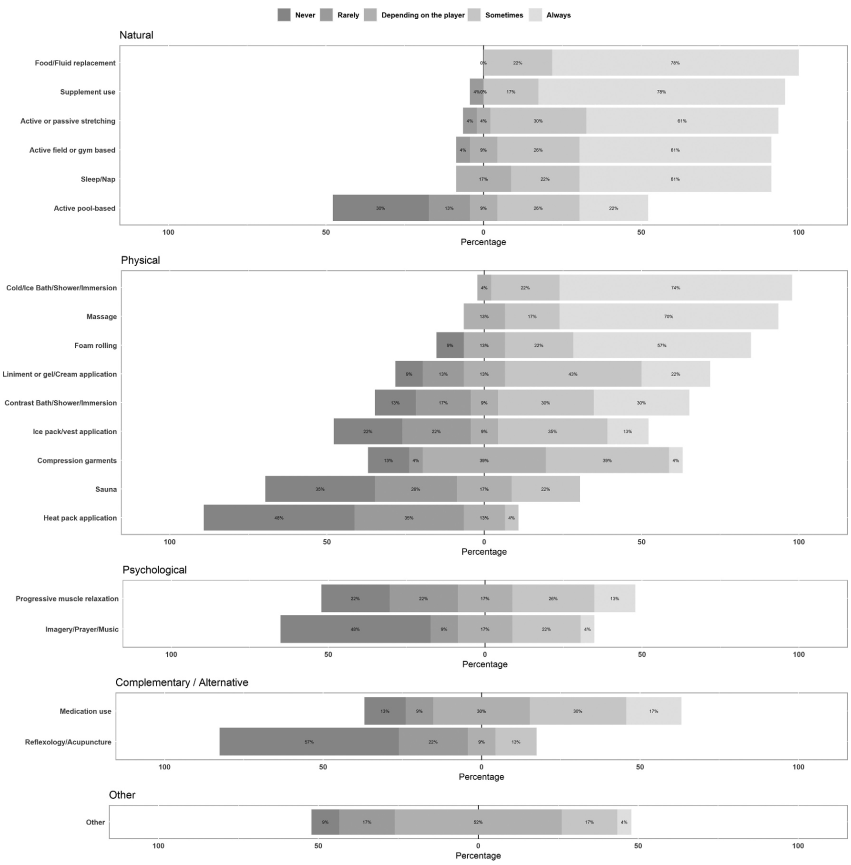

Figure 1. Recovery strategies undertaken by all Spanish first division professional teams after the competition.

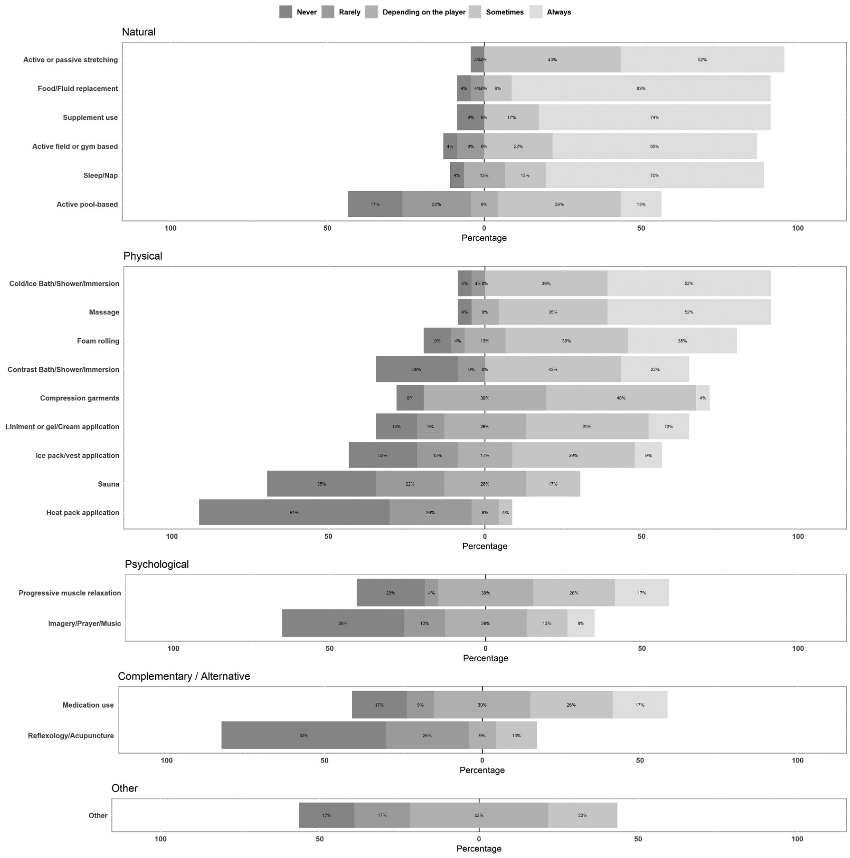

Figure 2. Recovery strategies undertaken by all Spanish first division professional teams after pre-season training sessions.

responsible for preparing/designing these protocols and supervising them. The physiotherapist was the main responsible in one of the teams (4%) and the fitness coach for the other two teams (9%).

The majority of the teams (65%) acknowledged that the prescribed parameters were based on scientific evidence about recovery, while approximately a third (35%) followed expert opinion.

Players' recovery strategies usage was optional in four teams (17%), while for the other nineteen (83%), it was mandatory. All twenty-three teams used their facilities to recover; the minority of them (13%) admitted that logistics and the economic resources of the club were not enough, which was the main reason not to use some or any of the strategies.

Twenty-one teams (91%) confirmed that their academy teams also used recovery strategies. From those, four teams (17%) used the same ones than the first team while the others (74%) opted for different protocols because of different reasons such as cost, logistics, resources, club structure, or schedule.

Discussion

This study aimed to identify the use of recovery strategies by the Spanish professional soccer teams from 'La Liga.' All twenty-three teams performed recovery strategies after competitions, and the majority of them (57%), the whole squad used at least one strategy.

Only one team reported not to use any recovery strategy after training, neither in pre-season nor in season. This finding supports previous Venter's hypothesis [1], explaining that most athletes use specific techniques to recover, although only one team reported not to use any recovery strategy after training, neither in pre-season nor in season.

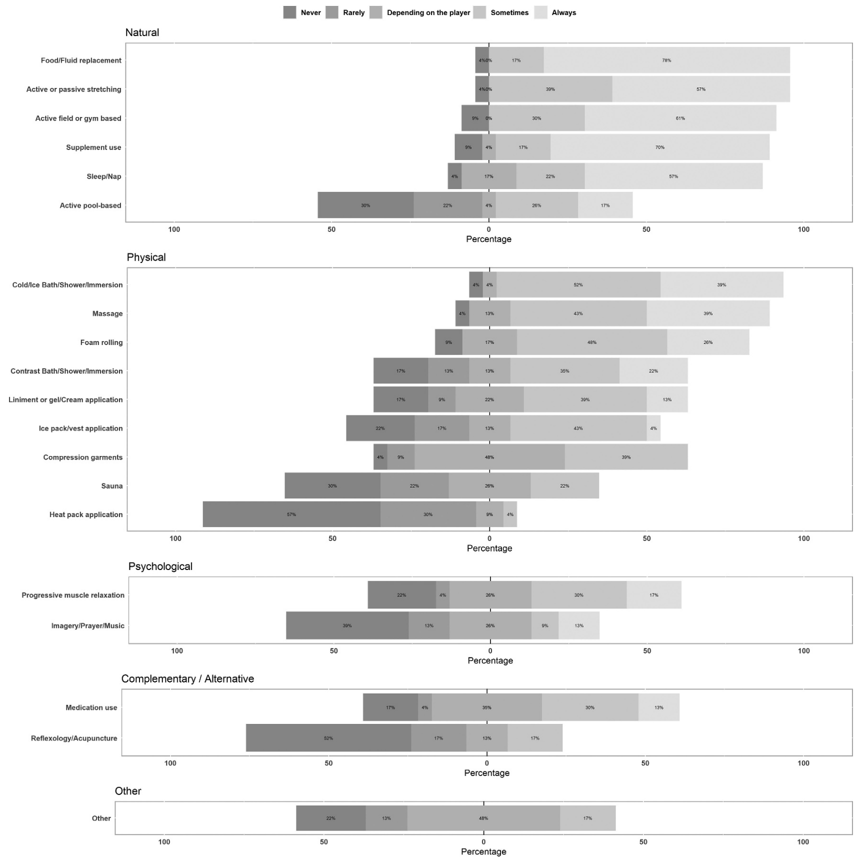

Figure 3. Recovery strategies undertaken by all Spanish first division professional teams after in-season training sessions.

Natural strategies

Natural strategies were used by most of the teams (88%). As these protocols do not require any equipment nor investment, except for the pool and supplements, it is then easy for these high-level teams to use these strategies [1]. Consistent with the literature, nutrition and sleep were adopted by all teams [15], confirming the idea that some of these strategies like taking a 'power nap' [7], seems to be critical for optimal recovery. Other natural strategies such as rehydration and refueling are more needed in high-performance competition, and they, generally, are well perceived by staff members [1].

Our findings support that active cool-down is one of the most used recovery modalities in soccer players either after training or competition [1,43]. Some of the benefits of using this strategy are a better perception of recovery and fatigue, faster blood lactate concentration clearance, sleep facilitation and increased muscle contraction restoration [21,44–48]. Data revealed that ALB usage (twenty-two teams; 96%) was higher than AWB (eleven teams; 48%), a fact that could be related to the need for specialized equipment and facilities to undertake these last ones. However, some studies showed significantly lower levels of adherence and better perception of ALB strategies compared to others, such as AWB or stretching [15].

Stretching is another active technique widely used by most of the professional Spanish soccer teams (twenty-one teams; 91%) either at the end of the games or the practices. The finding is consistent with previous investigations [43], and this technique was rated by athletes higher than ALB and AWB [15]. However, there is a lack of scientific evidence supporting its real physiological and muscular effectiveness [2,49,50]. Nevertheless, the minimal space and equipment needed to perform stretching protocols, and changes to parasympathetic dominance in the autonomic nerve activity after static stretching protocols [51] make it popular among players.

To summarize, and matching those results observed in [52], active recovery is one of the most used recovery modalities by

Table 2. Periodization, individualization, frequency, time of first use and combination of recovery strategies after practice or competition during the season.

	Yes, according to the microcycle (week)		Yes, according to the mesocycle		Yes, according to the period of the season		No	
Do you periodize the recovery strategies?	n	%	n	%	n	%	n	%
	11	53	2	9	8	38	2	9
Do you individualize the recovery strategies?	Yes, according to previous injuries		Yes, according to experience or age		Yes, according to other factors (sleep quality, wellness, training load, RPE)		No	
	n	%	n	%	n	%	n	%
	6	29	4	19	11	52	2	9
What is the frequency of use between efforts?	Once		Twice		>2 times		Based on players' perception	
	n	%	n	%	n	%	n	%
	9	39	5	22	1	4	8	35
When do you use the recovery strategies for the first time after an effort?	In less than 2 hours		Within 2–12 hours		Within 12–24 hours		After 24 hours	
	n	%	n	%	n	%	n	%
	20	87	1	4	2	9	0	0
Do you combine different recovery strategies?	Yes, following a specific order		Yes, not following a specific order		No			
	n	%	n	%	n	%		
	21	91	2	9	0	0		

RPE: Rate of Perceived Exertion

soccer players [18], even with few scientific pieces of evidence backing this strategy.

Physical strategies

Physical strategies were used by the majority (69%) of the teams. This investigation highlights the popularity of cold/ice bath/shower/immersion (CWI) as a post-match and post-training recovery modality [53]. Previous studies reported the same or similar results about the use and popularity of CWI among athletes [15,24,25] and soccer players [32]. Apart from different physiological and psychological benefits such as reduced blood flow, improved perception of muscle soreness and reduced fatigue feeling or analgesic effect [2,54–56] this recovery method also provided beneficial effects on strength performance [57]. On the other hand, massage is also a traditional way to try to improve recovery after practicing or competing in sports. However, the effect on recovery is rather small [12] and along with compression garments [58] and liniment or gel/cream application was ranked as one of the most frequently used modalities by all professional Spanish soccer teams. While some studies proved them efficient managing delayed onset muscle soreness, DOMS, and perceived fatigue [2], others suggested not to use it after a match or a training session because it may accentuate tissue damage caused by previous efforts [59] and showed lack or limited effectiveness enhancing performance [12,58,60].

The popularity of CG in sport is increasing rapidly [52]. Our findings show that CG usage by professional soccer players is slightly lower (seventeen teams; 74%) than other physical strategies such as CWI or massage (100%). However, similarly, the positive effects of CG on DOMS and perceived fatigue have been reported [2,58,61]. One potential explanation could be that the cost and ease of use of CG could increase players' and teams' adherence.

Related to foam rolling as one of the most used recovery strategies (91%) by soccer teams, similar conclusions were reported by other authors [62] who also found positive effects on performance recovery after using a structured session at the end of training or competition. If we add to these benefits, its price, portability, and user-friendliness make it an essential and indispensable tool for recovery sessions [63].

The adherence to the use of sauna was very low (eight teams; 35%). This outcome could be associated with a lack of evidence on its use in soccer [52] and also with the time, space, and cost, which makes it unaffordable for many clubs.

Contrast water therapy, consisting of a bath, a shower, or an immersion in warm and cold water alternatively, is often used by the majority of soccer teams (74%). This strategy showed benefits on DOMS, diminished muscle damage, and lowest perception of pain [2], being this last one the most important reasons for its use by athletes [15].

Psychological and complementary/alternative strategies

Psychological strategies showed different levels of adherence among players. While the majority of the teams (61%) reported the use of progressive muscle relaxation, only five used imagery/prayer or music. Some studies have reported that imagery is more used as the competitive level of the players increases [1]. However, we could not find a high number of users using this strategy or Prayer among Spanish teams. Although imagery/prayer and music are among the least used strategies in soccer players (five teams; 22%), to the best of the authors' knowledge, there is one study [64] reporting higher use of imagery by team contact-sports athletes than from non-contact sports. That is a clear example that sometimes, and even when the economic cost is minimal or even zero, players keep showing their personal perceptions in recovery.

Even some authors stated a substantial increase in the popularity of alternative medicine [65], only five teams (22%; minority) of the sample used reflexology or acupuncture as a recovery strategy. Similar rates in acupuncture usage (23%) were observed in previous studies [1]. These results could be linked to White's [66] statement, and athletes only use these strategies when conventional ones fail.

Other information

Three teams reported logistical or financial problems to establish recovery processes. This reason could explain the existing discrepancies between scientific recommendations and practice. The use of different recovery modalities seems to be strongly influenced by practicality and accessibility, time, and cost [1,14,52]. However, having access to vast economic and logistic resources cannot always be associated with better outputs from a performance or health point of view. In some cases, players have access to recovery strategies with low recommendation grades but available because of the club's budget. In this line, Crowther [15] reported that massage popularity among international-level athletes compared to lower levels was considerably higher because of its accessibility through massage therapists, support staff members only available at high levels. Another factor that should be considered is the venue [52] or the location of sports facilities. When teams play away during in-season games, they do not have their own proper spaces, material, or enough time to perform a particular recovery strategy. A similar situation occurs during pre-season when professional clubs use to travel around the world on team tours, or they establish their 'center of operation' away from their training facilities. That affects their logistics in many ways and also when planning recovery. However, and because they are on tour or at a training camp, time availability and player's predisposition could be slightly increased, compared to in-season, as it could be observed in the use of some strategies such as sleep/nap (83% vs. 78%), massage (87% vs. 83%) or supplementation intake (91% vs. 87%). Training camps, with more double sessions, also increase athletes' acute fatigue and may lead them to seek more ways to improve their readiness [67].

Most of the teams (87%) reported the first use of recovery strategies immediately after the competition. Similar results were published by Crowther and colleagues [15], who found that the hour after completion of the exercise was the most commonly used time frame for using recovery strategies. The main reason to do so was based on a belief of effectiveness. Still, and according to other authors [68], this may not be the case, because a recovery protocol the morning after seemed to be just as effective as a post-effort application.

Based on our research, the majority of the teams (65%) acknowledged that they follow scientific recommendations when choosing and prescribing recovery strategies while the other 35% followed expert opinion. According to these data, wrong parameters or non-effective strategies, traditionally induced by players' perceptions or beliefs seem to be mostly not considered by 'LaLiga' teams. This approach can eliminate relevant biases like leading players to make 'wrong' choices moved by a misunderstood authority principle, following the advice of more experienced or successful teammates [15]. Nevertheless, Kellmann [4] showed that although practitioners recognize recovery as crucial, they often have limited knowledge of what recovery strategies can be used with real effect. In our opinion, in this study, that limitation could not be observed. Teams reported designing recovery protocols on a multidisciplinary team setting, reducing this bias, and considering the microcycle (week) as the basic periodization unit and individual player needs.

We classified recovery strategies as physical, psychological, natural, complementary, or other. However, and considering the human being as a hyper-complex structure [69], all strategies may affect different systems and subsystems. Following this idea, some players use the strategies according to their perception, even when scientific evidence demonstrates the non-positive effects of some of them. Crowther and colleagues [15] have identified that some strategies were considered effective or ineffective due to psychological reasons, while others due to physical or physiological reasons. We cannot deny that when it comes to recovery, the right mind-set is also a powerful ally.

Limitations

This research has collected data from all twenty-three Spanish teams who played in 'LaLiga,' the Spanish first division, during the seasons 2018–2019 and 2019–2020. However, the instrument used for data collection, online survey, has some limitations. Interviewees may not be 100% truthful in their answers, mainly due to an attempt to protect club privacy or personal agendas. This situation was tackled by ensuring the anonymity of the data. This idea was reinforced in the participant information section of the survey.

Online questions can also be interpreted in different ways by different people. Although the survey was tested several times before sending it to the teams, some recovery techniques could be misunderstood if the person responding to the survey was not the one responsible for their application. To minimize the impact of wrong assumptions, we provided the contact of the lead researcher to every team just in case they had any questions regarding the survey.

Our survey was very detailed; some of the respondents may have experienced survey taking fatigue. Several previous tests tried to make it as less time-consuming as possible.

Although much effort has been devoted lately to research about recovery methods in sports, there is still a need for more conclusive studies with high levels of scientific evidence regarding the effect of the different protocols. With few exceptions, such as sleep, the use of every method in professional athletes can have different approaches without an evident detrimental effect on performance.

Future investigations

The daily use of recovery strategies in team sports settings is a reality, but it is essential to know the extent of these practices in every discipline and context. More studies like the present one is needed in other professional soccer leagues, as well as in other team sports. As educational backgrounds differ from country to country, and players' perceptions may vary according to their gender, age, or ethnicity and culture with different possibilities replicating the methodology used in the present study arise. The use of cross-sectional vs. longitudinal surveys or interviews can be alternatives to test in similar future studies.

The present study has used a purely quantitative research paradigm. However, this approach may miss some relevant information regarding the motivations leading coaches and practitioners to use one technique or another. These motivations may also be the object of future qualitative research in this area. Additionally, in those with high scientific evidence levels, such as cold-water immersion, it is important to individualize and set them on the proper moment according to the desired objectives. This manuscript also provides contextual information that may lead to design and perform more randomized control trials (RCT) in professional team settings and RCT's combining recovery methods to prove if those combinations display higher recovery power.

Conclusion

In summary, to the best of our knowledge, this is the first study to investigate post-exercise recovery techniques used by elite professional soccer teams in Spain. Natural strategies were more used than physical, psychological, or complementary ones. This finding may be due to the conditions to access to these strategies, and ease of use. Food and fluid replacement were regularly used by all teams and had the highest levels of adherence after competitions and practices. When training sessions were analyzed, more players used recovery strategies after pre-season practices than after the sessions conducted in-season.

This study highlights the recovery practices of some of the best soccer teams in the world. Nevertheless, a gap between theory and practice exists when the information reported by medical, technical, and performance staff regarding post-exercise recovery methods in professional team sports settings is contrasted with the scientific research available on the matter. All the Spanish first division soccer teams use some form of recovery protocol, however, there is no general agreement on the strategies employed nor the moments where they are applied.

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Declaration of interest

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The effectiveness of two comprehensive recovery protocols on performance and physiological measures in elite soccer players: A parallel group-randomized trial

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Abstract

Elite soccer players consistently report using several recovery methods after practices and games. However, it is unclear how their subsequent performance could be enhanced using broad protocols. The aim of this study was to compare the effectiveness of two different comprehensive recovery protocols in physiological, neuromuscular, and perceptual outcomes. Eighteen Mexican National Team players (19.56 ± 0.62 years) were recruited. Using a randomized parallel group design, players followed one of two recovery protocols: (a) carbohydrate and protein shake, foam roller, cold-water immersion, and tart cherry juice concentrate ($n = 9$) or (b) carbohydrate and protein shake, stretching, and intermittent cold-water immersion ($n = 9$) following the completion of an unofficial game and the day after. Muscular creatine kinase, countermovement jump, hamstring maximal voluntary contraction, perceived recovery, and muscle soreness were assessed before, immediately after, and 20-44-68 h post-game. Significant effects (set at $p \leq 0.05$) of time were present in both interventions. Muscular creatine kinase was normalized entirely at 68 h post-game, while neuromuscular and perceptual outcomes were homogenized at 44 h. No statistically significant effects between protocols were found. Still, the interaction effects showed changes only in the group using protocol (a) at post-game and 20 h after in neuromuscular and muscle soreness. There were large correlations between muscular creatine kinase and accelerations, decelerations, sprints, and high-speed running distances. In conclusion, the interventions are equally effective for improving physiological, neuromuscular, and perceptual outcomes. Thus, elite soccer players may benefit from different combinations of methods after practices or games to obtain positive effects on recovery after them.

Keywords

Association football, carbohydrate and protein shake, cherry juice, cold-water immersion, creatine kinase, foam roller, global positioning system, high-speed running

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Introduction

Soccer is a complex, strenuous contact team sport characterized by unpredictable intermittent activity patterns interspersing low and high-intensity efforts with passive or active recovery.[1] From an organizational point of view, elite professional soccer is defined as a medium-density sport where the average player is exposed to high-congested fixture periods with a mean of 60 competitive games per season, 5.5 per month, 1–3 per week, or one every 4.3 days.[2] Frequent national team participation during the competitive season and travel issues may create an even more complex scenario to achieve a proper recovery before competitions.[3,4] This accumulation of events, games and training sessions, combined with reduced recovery time between all these activities results in potential underperformance.[3] Thus, the ability to recover after competitive or intense training bouts is important to maintain or increase performance in subsequent efforts.[5]

Soccer-related physical performance is immediately impaired after a game and recovers to the previous levels gradually.[6] After a single game, total normalization of performance parameters such as sprint, jumping ability, or maximal strength is frequently observed after 72 h,[7] even with signs of biochemical and physiological stress.[8] However, when playing additional games during the week, subjective wellness values, perceived recovery, and physical performance parameters (e.g. sprint, jump, and strength) take longer, 96 h, to be normalized,[9,10] which increases the need for recovery strategies.[11] Moreover, some external load parameters of the game, such as high-intensity distance covered (total and per minute), high-speed running distance (HSR), and the number of sprints were significantly correlated to a creatine kinase (CK) increase, a muscle damage marker, at 24-h post-game.[12,13] These levels may remain increased for 3 days[14] and have to be considered as a basic marker that may be targeted by recovery strategies.[11] Therefore, quickly restoring pre-performance levels before the next competition is one of the main aims for soccer players.[15] Although protocols for specific soccer post-exercise recovery based on scientific evidence are available,[16] a gap exists between theory and practice in professional settings. The use of recovery interventions is not always based on research evidence,[17] which can negatively affect players' recovery and limit the ability to provide new guidelines to professional standards.[18] Thus, deep knowledge about physical performance profiles, time courses, players management, personal approaches, and players' awareness of recovery strategies post-practice/game can lead to faster performance recovery.[19]

Currently, scientific literature presents many methods to enhance recovery based on the type of practice, the time between sessions or competitions, and equipment or staff availability.[15] According to data from elite professional soccer staffs, the strategies most frequently used after a competition are an active recovery, stretching, food/fluid intake, ergogenic aids, cold/ice bath/shower/immersion, massage, and foam rolling.[17] However, to our knowledge, only three scientific studies present positive effects when combining different recovery methods in soccer.[20–22] Still, none of them have assessed the impact on health or performance, neither additive nor adverse effects in elite soccer players after a competition, although team staffs report combining more than one method when periodizing and performing recovery.[23] Therefore, the main aim of the current study was to compare the effectiveness of two comprehensive protocols on physiological, neuromuscular, and perceptual outcomes after an unofficial soccer game in elite players during a national team camp. It was hypothesized that a comprehensive recovery protocol combining more methods could speed up and be more effective in enhancing objective and subjective players' recovery parameters. In addition, as a secondary aim hypothesis, the acute changes of muscular CK (CK-III) correlate with the global positioning system (GPS) external load variables recorded during the game.

Methods

Experimental approach to the problem and participants

Twenty elite male soccer players (mean ± SD: age = 20 ± 1 years; height = 178.8 ± 5.0 cm; body mass = 72.9 ± 6.1 kg) from the under 21 (U-21) Mexican National Team were enrolled in this study. The study used a convenience sampling technique to select players from the U-21 Mexican National Team, allocating the players to the two groups using a block randomization technique.[24] All players had more than 10 years of experience playing soccer and performed 5–7 full-team soccer training sessions for a total training load of approximately 8–10 h per week, with at least one official game. Participants completed a medical questionnaire and initial screening. None of them had any diseases, and they did not smoke, drink alcohol, or take stimulants or substances that potentially alter hormonal responses. No participant presented any severe lower limb muscle injuries 2 months before the research. To ensure that the load and the intensity imposed were representative and similar, goalkeepers and outfield players who did not complete the total training camp sessions were excluded from the final analyses. After receiving information about the study aims, possible risks, benefits, and requirements, participants signed a written informed consent. Every participant could withdraw from the study at any moment. The study was conducted following the Declaration of Helsinki and its later amendments and was approved by the Research Ethics Committee of the University of Vic-Central University of Catalonia, Spain (registration number: 123/2020).

Design

An interventional balanced (1:1) parallel group-randomized trial was conducted to determine the effect of the two recovery protocol interventions after a 90-min unofficial soccer game. In this professional context, establishing a comparison group (control) was not suitable.[24] The study was conducted during the FIFA International break (August-September 2021) as a training camp developed for 9 days in Mexico DF. Before any data acquisition, the participants performed 6 days of similar practices. Food and fluid intake were controlled individually by a nutritionist using a food diary. Players were instructed to avoid any strenuous exercise outside the training requirements nor modify usual sleeping patterns monitored and controlled, in quality[25] and duration. One familiarization session was developed to practice all the tests to ensure reliability, with a full explanation of the experimental protocols and testing procedures. Every participant had more than 1 year of experience using recovery methods and perceptual/well-being questionnaires. The outcomes were assessed on four different days (five time points). The first part of each testing session, except post-game, was designed to collect the players' perceptual outcomes. Immediately after that, the team physician took blood samples from all participants. Before performing the neuromuscular tests, a 5-min standardized dynamic warm-up using several different running patterns at an increasing intensity, joint mobility exercises, and dynamic stretches followed by two submaximal jumps was implemented (Figure 1). The testing battery lasted 25 min for every group of four players. Three days after the game, players participated in the regular training routine of the training camp.

The primary researcher was responsible for the stratified randomizing, using players' positions as the matching characteristic. Although being an unofficial game, licensed referees were present. Internal load data were collected after the game, using players' perceived exertion (RPE) rate on a 1–10 scale .[26,27] External data from the game were collected using valid and reliable WIMU® pro 10-Hz GPS devices (RealTrack Systems, Almería, Spain) which managed accelerometry data at 100 Hz.[28]

Before the start of the study, the protocol was registered at https://clinicaltrials.gov (ID: NCT04716049; https://clinicaltrials.gov/ct2/show/NCT04716049). Moreover, CONSORT guidelines were followed to report data (supplementary material I).

Outcomes

The same researchers supervised all the testing procedures and conducted them in an open official soccer facility at a temperature of 19 ± 1°C and humidity of 65.5 ± 6%.

Physiological outcomes. Creatine kinase muscular isoenzyme III (CK-III or CK-MM). Venous blood sample collection for CK-III isoform ratio in serum determination involved players passively drooling directly into a plastic tube. Samples were sealed and maintained at ideal conditions until analyses were carried out. CK-III was separated from total CK and measured in U/L using an electrophoretic method.[29]

Neuromuscular outcomes. Hamstring maximal voluntary contraction (MVC). Participants laid in a supine position, with the tested leg strapped around the ankle (in a neutral position), and performed a hip extension from 90° of hip

Figure 1. Protocol design timeline. CHP + FR + CWI + CJ: 250 mL of water with carbohydrate and protein, foam roller, cold-water immersion, and tart cherry juice concentrate; CHP + STR + ICWI: 250 mL of water with carbohydrate and protein, stretching, intermittent cold-water immersion; CK-III: creatine kinase muscular isoenzyme; MVC: hamstring maximal voluntary contraction; CMJ: countermovement jump; GPS: global positioning system; TQRper: total quality recovery perceived; MS: muscle soreness; MD + 1: 20 h after game; MD + 2: 44 h after game; MD + 3: 68 h after game; au: arbitrary units; RPE: rate of perceived exertion.

flexion (with a slight knee flexion of 20°). The nontested leg was resting on the floor and was fixed by one member of the research team. This test was adapted from Matinlauri and colleagues by using a strain gauge instead of a force plate.[30] Players placed their hands on the wall to avoid sliding on the floor. A strain gauge was placed between the ankle strap and the cord to evaluate the force (MVC, measured in Newtons) exerted at a sampling frequency of 80 Hz (Chronojump, Boscosystem®, Barcelona, Spain). The tester gave all participants the exact instructions; "to exert maximal force down to the floor" and continuous and standardized verbal motivation for 5 s. Each limb (dominant and nondominant) was tested three times, in a randomized order and the average values were used in the subsequent analysis. The assessment of both legs was separated by 30 s, while the time separating two trials of the same leg was 60 s.[30]

Countermovement jump (CMJ) was performed using an Optojump® system (Microgate, Italy) with an accuracy of 1 kHz to determine the jump height (cm). For the CMJ, soccer players were required to bend their knees to approximately 90° angle and perform a maximal vertical thrust with the hands fixed on the hips.[31] Participants were instructed to keep their bodies upright throughout the jump and to land with their knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated. Three trials were allowed, and the average values were used in subsequent analysis.[32] A 30-s passive recovery was provided between jumps.[33]

Perceptual outcomes. Total quality recovery perceived (TQRper). Players were asked to rate their recovery perception using the subjective validated TQRper questionnaire answering, "How recovered do you feel?". A scale ranging from 0 (very poorly recovered) to 10 (very well recovered) was used as a subjective measurement to assess fatigue.[34]

Muscle soreness (MS) was collected using a 5-point validated scale, with 5 being the best state and 0 being the worst.[25]

Procedures

After the soccer game, players were randomly assigned to one of two intervention groups: a carbohydrate and protein shake, foam roller, cold-water immersion, and tart cherry juice concentrate (CHP + FR + CWI + CJ) or a carbohydrate and protein shake, stretching, and intermittent cold-water immersion (CHP + STR + ICWI).

Both included a combination of natural and physical recovery methods and were performed twice, immediately after the game and the day after (20-h). All players drank a maximum of 500 mL of an isotonic sports drink and water "ad libitum" during the game.

"CHP + FR + CWI + CJ" intervention. Players drank 30 mL of CJ[35] and 250 mL of water with carbohydrates and protein within 30-min of completing the game; performed the foam rolling exercises using a polyvinylchloride pipe roller of 10.3-cm diameter and 0.3-cm thickness surrounded by a 1.5-cm thickness neoprene foam.[36] They were instructed and supervised to begin with the foam roller at the most proximal portion of the muscle and to roll as much body mass as tolerable from proximal to distal as smoothly as possible at a cadence of 1 s superior and 1 s inferior determined with a metronome. The foam roller activity was performed for 45 s, followed by a 15-s rest for each muscle group and in the same order (quadriceps, adductors, hamstrings, abductors, and gastrocnemius) in each lower extremity and repeated once. This protocol concluded with a cold-water immersion (CWI) where players immersed their lower body (up to the iliac crest) for 10 min in cold water (13–14°C)[37] inside a pool. Researchers closely monitored the water temperature every minute to maintain it.

"CHP + STR + ICWI" intervention. Players drank 250 mL of water with carbohydrates and protein within 30 min of completing the game. They performed 10 min of static stretching, involving two unilateral repetitions of 30 s, holding stretches to the quadriceps, adductors, hamstrings, abductors, and gastrocnemius muscles in each lower extremity.[38] An investigator supervised players during the stretching exercises. Intermittent cold-water immersion (ICWI) was the last recovery method used in this protocol. It consisted of five 2 min of intermittent immersions of the lower limb (up to the iliac crest) in a cold-water bath (13–14°C), separated by 2 min of rest in ambient air[39] using a fixed pool. Investigators closely monitored the water temperature every minute and monitored the 2-min immersions.

Statistical analyses

Data were presented as mean ± SD (or SE as stated) and 95% confidence intervals (CIs). Within-participant reliability of test measures (intra-session repeated efforts) was analyzed using the two-way random intraclass correlation coefficient (ICC) and coefficient of variation (CV). ICC values were >0.9 excellent, 0.9–0.75 good, 0.75–0.5 moderate, and <0.5 poor, and CV values were considered acceptable if <10%.

Independent samples *t*-test was used to check for baseline between-group differences in participants' characteristics and GPS outcomes. Cohen's *d* (mean difference/pooled SD) was reported for the analyses and interpreted as follows: <0.2 trivial; 0.2–0.5 small; 0.5–0.8 medium; >0.8 large.

The relationships among variables were analyzed using a linear mixed model (LMM) for continuous data and a generalized linear mixed model (GLMM) for categorical data. Both models considered the individuals as a random effect, and the time of testing (time) and the recovery strategy used (group) as fixed effects. Mean and interaction effects were represented by the F for LMM and the chi-squared (χ^2) for GLMM. The GLMM used gamma distributions with identity as a link function. Estimated marginal means from LMM and GLMM with 95% CI were used to consider the effect of each factor. For those significant factors ($p < .05$), a post hoc test with Holm adjustment was used to evaluate the interaction effect and the main effect of time or group. No missing data was present in the study. Still, two participants, one from each group, could not complete the study due to injuries that occurred during the game (see supplementary material II). Thus, 18 participants (CHP + FR + CWI + CJ = 9, CHP + STR + ICWI = 9) were finally included in the final analyses.

Pearson correlation coefficients were used to analyze the relationship between CK-III changes (pre- to post-game) and GPS game data. The magnitude of the relationships (r) was interpreted as follows: <0.1 trivial; 0.1–0.3 small; 0.3–0.5 medium; 0.5–0.7 large; 0.7–0.9 very large; and >0.9 extremely large.

Statistical analyses were conducted using the statistical package JASP for Macintosh (version 0.16.1, University of Amsterdam, Netherlands).

Results

Both groups had similar physical characteristics and game demands ($p > .05$; trivial to small effects, see supplementary material III). The reliability measures were for the CMJ (ICC = 0.90; 95% CI [0.82–0.95], CV = 4.6%; for the MVC (dominant) (ICC = 0.84; 95% CI [0.72–0.92], CV = 8.8%) and for the MVC (non-dominant) (ICC = 0.85; 95% CI [0.74–0.93], CV = 7.8%).

Main effects and interaction effects

The results from the LMM and GLMM are shown in Tables 1 and 2 and Figure 2. The main effect of time was large ($p < .001$, $F > 6.99$; and $\chi^2 > 46.49$, see Table 1) for all the outcomes. There was no main effect of the group (CHP + FR + CWI + CJ or CHP + STR + ICWI) for any of the outcomes ($p > .05$, see Table 1).

The interaction effect (group * time) was present for the CMJ, MVC (non-dominant limb), and TQRper models ($p < .05$, $F > 2.74$; and $\chi^2 = 10.58$, see Table 1,Figure 2).

Post hoc tests or contrasts

The effect of time for all the outcomes is presented in supplementary material IV and Figure 2.

The interaction effect for the CMJ and TQRper only revealed changes for the CHP + FR + CWI + CJ group at MD + 1 (supplementary material IV, Figure 2).

The interaction effect for the MVC (non-dominant) only revealed changes for the CHP + FR + CWI + CJ group at post-game and MD + 1 (supplementary material IV, Figure 2).

Relationship between CK-III and GPS data

The changes in CK-III from baseline to post-game related to the GPS data were performed by Pearson correlations and can be seen in Figure 3.

The changes in CK-III were correlated to the number of accelerations ($p < .001$; very large effect), the number of decelerations ($p = .003$; large effect), HSR distance ($p = .007$; large effect), and sprinting distance ($p = .04$; large effect). Instead, total distance ($p = .34$) was not correlated to the changes in CK-III.

Discussion

The present study was designed to compare the effectiveness of two recovery protocols after a game on physiological, neuromuscular, and perceptual outcomes with elite U-21 soccer players. Both protocols had a positive time effect, indicating that both could be beneficial at providing accelerated recovery after a game at different time points (20–44-68 h) depending on the variable of interest. However, no differences were found between them; therefore, this study cannot report the superiority of one protocol over the other. Based on this study, practitioners and players may choose different possibilities to ensure recovery effectiveness. Large and very large correlations between CK-III and external load parameters such as accelerations, decelerations, HSR distance, and sprinting distance were observed.

Top-tier soccer players show low levels of muscle damage during official tournaments and have faster recovery before the next game.[40] In this sense, current scientific evidence demonstrates that CK normalization time courses are up to ≥72 h, despite physical performance recovery lasting up to ≥48 h.[7] These findings are like those reported in the present study, showing that neuromuscular outcomes (MVC and CMJ) recovered faster than CK-III, returning to similar baseline levels at MD + 2. However, CK-III baseline levels were reached between 48 and 72 h,[41] where the peak CK-III levels were obtained at MD + 1 in both groups, like what has been reported in previous research.[42] CK-III isoform inter-subject variability response should be considered when using it as a recovery-specific marker.[43] Furthermore, four GPS parameters, such as HSR and sprint distance, accelerations, and decelerations, showed large to very large correlations with CK-III and muscle damage immediately after the game. While this was not one of the study's primary aims, the possibility of determining recovery needs using noninvasive markers coming from GPS technology could provide a useful framework to individualize the recovery process in different soccer settings.[12,15]

Table 1. Results from the linear mixed models (LMM) and the generalized linear mixed models (GLMM).

Linear mixed models	Variables		df	F	d
Interaction effects	CK-III		4, 64	0.20	0.94
	CMJ		4, 64	2.77	0.035
	MVC	Dominant	4, 64	1.07	0.38
		Non-dominant	4, 64	2.73	0.036
Time effect	CK-III		4, 64	35.54	<0.001
	CMJ		4, 64	6.99	<0.001
	MVC	Dominant	4, 64	10.01	<0.001
		Non-dominant	4, 64	8.91	<0.001
Group effect	CK-III		1, 16	0.31	0.586
	CMJ		1, 16	0.95	0.344
	MVC	Dominant	1, 16	1.67	0.214
		Non-dominant	1, 16	1.57	0.228
Generalized linear mixed models	Variables		df	χ^2	p
Interaction effects	TQRPer		3	10.58	.01
	MS		3	3.36	.34
Time effect	TQRPer		3	50.98	<.001
	MS		3	46.79	<.001
Group effect	TQRPer		1	0.11	.74
	MS		1	0.07	.96

CK-III: creatine kinase muscular isoenzyme; CMJ: countermovement jump; MVC: hamstring maximal voluntary contraction.
TQRper: total quality recovery perceived: MS: muscle soreness.

No decrement was found when analyzing the CMJ performance immediately after the game. Instead, different trends were observed depending on the group at MD + 1. Considering a real change in performance in any value above the CV (4.6% = 1.7 cm), the CHP + FR + CWI + CJ group showed a decrement of 3.2 cm, while the CHP + STR + ICWI group reported no changes (−1.1 cm). Although some differences can be observed in the groups, they are not statistically significant. In a recent investigation by Romagnoli and colleagues, where no recovery intervention was applied, CMJ was compromised at 48-h post-game compared to the baseline level,[44] suggesting the need to perform recovery strategies such as the ones used in this piece of research. Hence, applying recovery strategies seems important when lower body performance needs to be recovered within 48 h, with the CHP + STR + ICWI protocol providing slightly better benefits (although not significant compared to the other protocol) for maintaining CMJ performance following a game. Future studies must be implemented to confirm this claim.

When CJ was used for two consecutive days in combination with the other methods of the protocol (CHP + FR + CWI), this intervention did not significantly improve any variable analyzed compared to the CHP + STR + ICWI. Nevertheless, when using it as a unique recovery method for eight consecutive days and compared to a control group, neuromuscular outcomes (CMJ, MVC) recovered faster such as MS indicators were lower and inflammatory response was attenuated.[45] Although these beneficial effects, no effects on oxidative stress or CK were observed.[45] The intake frequency used in the protocol (only 2 days) and synergistic or additive possible effects when combining several recovery methods could attenuate CJ's impact.

The present study used two ways of applying immersion in cold water and other recovery methods. Both obtained similar results in terms of physiological, neuromuscular, and perceptual outcomes. CWI significantly affects delayed onset muscle soreness (DOMS), perceived fatigue and recovery, muscular power performance, and serum CK.[46] However, these effects were only observed 24 h after high-intensity exercise and not after eccentric loads. CWI was only effective for positively influencing muscular power but not muscular strength performance.[46] A moderate difference in favor of this recovery method (CWI) was observed in soccer at 48 h when analyzing CMJ and MVC.[47] Nevertheless, in a recent review, Schons and colleagues[48] found beneficial effects of CWI on muscle strength but no effects on jumping and running performance. Additionally, CWI and active recovery after a game did not improve jumping performance [22] in youth players. However, according to a recent study,[46] the duration and temperature of CWI can play a crucial role in enhancing recovery. For instance, lowering the time and temperature may improve the efficacy of CWI after high-intensity exercises, such as removing CK and incrementing endurance performance.

The literature lacks evidence supporting the muscular and physiological effects of stretching after physical activity or competitive soccer games on reducing MS.[49] Moreover, some authors concluded that it might even lead to an increase in DOMS and CK levels,[50] while others[49] found a CK reduction after performing static stretches.

Table 2. Descriptive of the outcome variables for group and time.

		CK-III				CMJ			
Time	Group	CK-III (U/L)	SE	95% CI		CMJ (cm)	SE	95% CI	
Baseline	CHP + FR + CWI + CJ	264.82	54.51	157.98	371.67	37.51	1.41	34.75	40.27
Post-game		394.84	54.51	287.99	501.68	36.49	1.41	33.73	39.24
MD + 1		424.48	54.51	317.63	531.32	34.29	1.41	31.53	37.05
MD + 2		311.18	54.51	204.34	418.02	36.54	1.41	33.79	39.3
MD + 3		248.38	54.51	141.53	355.22	38.44	1.41	35.68	41.19
Baseline	CHP + STR + ICWI	220.56	54.51	113.71	327.4	38.86	1.41	36.1	41.62
Post-game		360.56	54.51	253.72	467.41	38.43	1.41	35.67	41.18
MD + 1		368.27	54.51	261.43	475.11	37.72	1.41	34.96	40.47
MD + 2		267.83	54.51	160.99	374.68	38.85	1.41	36.09	41.61
MD + 3		221.61	54.51	114.77	328.46	38.57	1.41	35.81	41.33
		MVC (dominant)				**MVC (non-dominant)**			
Time		**MVC (*N*)**	**SE**	**95% CI**		**MVC (*N*)**	**SE**	**95% CI**	
Baseline	CHP + FR + CWI + CJ	361.86	22.82	317.13	406.59	357.3	22.2	313.8	400.8
Post-game		311.65	22.82	266.93	356.38	289.2	22.2	245.6	332.7
MD + 1		349.01	22.82	304.28	393.74	321.1	22.2	277.6	364.7
MD + 2		353.54	22.82	308.81	398.27	338.8	22.2	295.3	382.3
MD + 3		376.95	22.82	332.22	421.68	357.0	22.2	313.5	400.6
Baseline	CHP + STR + ICWI	406.39	22.82	361.66	451.12	379.1	22.2	335.6	422.6
Post-game		371.01	22.82	326.28	415.74	361.1	22.2	317.6	404.6
MD + 1		375.14	22.82	330.41	419.87	361.1	22.2	317.6	404.7
MD + 2		386.05	22.82	341.32	430.78	362.5	22.2	319.0	406.0
MD + 3		409.61	22.82	364.89	454.34	383.3	22.2	339.8	426.8
		TQRper				**MS**			
Time	**Group**	**TQRPer (au)**	**SE**	**95% CI**		**MS (au)**	**SE**	**95% CI**	
Baseline	CHP + FR + CWI + CJ	7.56	0.67	6.24	8.87	4	0.34	3.34	4.66
MD + 1		4.14	0.54	3.08	5.2	2.71	0.3	2.12	3.3
MD + 2		6.34	0.62	5.12	7.55	3.36	0.32	2.74	3.98
MD + 3		8.61	0.71	7.21	10	3.79	0.33	3.15	4.44
Baseline	CHP + STR + ICWI	6.93	0.62	5.72	8.15	3.66	0.33	3.02	4.3
MD + 1		5.69	0.57	4.57	6.8	2.56	0.3	1.98	3.14
MD + 2		6.8	0.61	5.6	8	3.52	0.32	2.88	4.15
MD + 3		8.17	0.67	6.85	9.48	4.05	0.34	3.39	4.72

CHP+FR+CWI+CJ: 250 mL of water with carbohydrate and protein, foam roller, cold-water immersion, and tart cherry juice concentrate; CHP+STR+ICWI: 250 mL of water with carbohydrate and protein, stretching, intermittent cold-water immersion; CK-III: creatine kinase muscular isoenzyme; CMJ: countermovement jump; MVC: hamstring maximal voluntary contraction; MS: muscle soreness; TQRPer: total quality recovery perceived; MD+1: 20 hours after game; MD+2: 44 hours after game; MD+3: 68 hours after game.

Therefore, the existing evidence is quite conflicting. However, when stretching exercises were combined with other recovery techniques, such as massage (after a competition),[51] it induced a lower perception of leg soreness and better CMJ values.[52] Previous research has found that CMJ values were significantly higher 24 h after a training session when using a combination of recovery methods consisting of submaximal running and static stretching.[21] These findings are similar to the ones in the present study, where stretching within a recovery protocol induced positive changes in the variables studied; yet, it is impossible to state that these improvements were caused by stretching or other recovery strategies.

A recent review has reported ambiguous conclusions and recommendations about foam rolling when analyzing the use among different-level athletes.[53] In another recent study, after a typical soccer session, foam rolling had a large effect on the recovery of agility, TQRper, and perceived MS compared to a passive recovery. Nevertheless, and according to the current study findings, similar perceptual and neuromuscular outcomes were found when comparing two protocols that combined different recovery methods. Nonetheless, and due to these non-conclusive results, foam rolling may be recommended as a recovery tool for this typology of athletes.

Despite the lack of definitive scientific evidence, some recovery methods, such as stretching or foam rolling, are widely used by elite soccer teams after training and competition.[17] One of the reasons could be that these recovery methods can influence players' perceptions and may increase adherence to the protocols.[21] Therefore, practitioners should consider their use when planning and

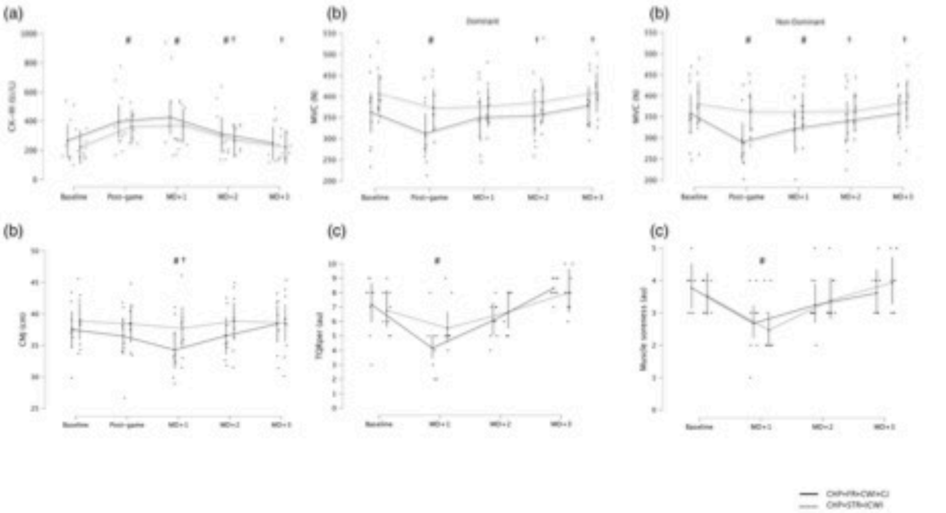

Figure 2. Physiological (a), neuromuscular (b), and perceptual (c) outcomes. CHP + FR + CWI + CJ: 250 mL of water with carbohydrate and protein, foam roller, cold-water immersion, and tart cherry juice concentrate; CHP + STR + ICWI: 250 mL of water with carbohydrate and protein, stretching, intermittent cold-water immersion; CK-III: creatine kinase muscular isoenzyme; MVC: hamstring maximal voluntary contraction; CMJ: countermovement jump; TQRper: total quality recovery perceived; MS: muscle soreness; MD + 1: 20 h after game; MD + 2: 44 h after game; MD + 3: 68 h after game; au: arbitrary units. Notes: # different from baseline. † different from post-game.

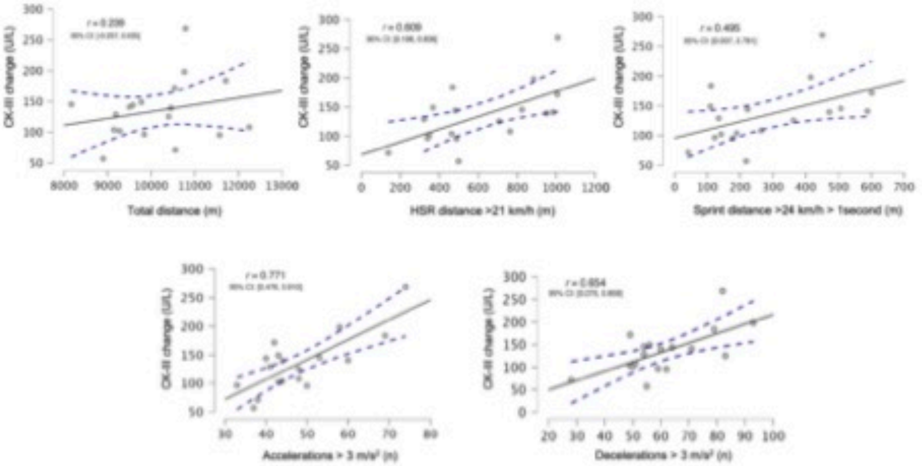

Figure 3. Relationship between CK-III and GPS variables. CK-III: creatine kinase muscular isoenzyme; HSR: High-Speed Running distance.

designing multimethod recovery protocols. Based on this study's findings, we recommend including different recovery methods based on several criteria, such as scientific agreement, but first, considering players' preferences and perceptions based on wellness, especially at elite levels.

This study found a time effect on recovery parameters in both interventions. Specifically, CK-III was normalized at MD + 3 and neuromuscular and perceptual outcomes at MD + 2. However, no differences between protocols were found, except for the interaction effect found in the CHP + FR + CWI + CJ group at post-game and MD + 1 in neuromuscular and TQRper outcomes. Therefore, based on these results, this paper's authors consider both protocols similarly effective. Practitioners could combine the recovery methods proposed in this study as post-competition recovery strategies and adjust the interventions to meet elite soccer players' requests and team contexts based on their fixtures or training schedule.

The protocol used a convenience sampling technique to select players from the U-21 Mexican National Team. Consequently, the sample size ($N = 20$) is relatively small, which could have limited the statistical power and affected the significance of some comparisons (between effects).[24] However, using "sample quality criteria," the specificity of the players enrolled (elite young soccer players) may have increased its representativity. Moreover, the players in the study were only male; therefore, these protocols should be replicated in female populations of a similar competitive level before their implementation. Finally, the lack of a control group in the study limits the possibility of concluding our investigation by understanding if any experimental conditions were more effective than controls in a similar population. However, this is a common limitation when professional players are enrolled.

Practical applications

- Elite soccer players could combine different recovery methods after games, such as the two combinations used in this study that reported a positive effect on recovery.
- Both protocols used in this study had a positive time effect, but since no differences were found between them. Practitioners could use the ones more suitable for their players.
- It is suggested that practitioners and players be given a choice among different options based on their preferences and the perceived effectiveness of recovery.
- Since large and very large correlations between CK-III and external load parameters such as accelerations, decelerations, HSR, and sprint distance were observed. Practitioners are invited to monitor these parameters to manage the recovery strategies better.

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Supplemental material

Supplemental material for this article is available online.

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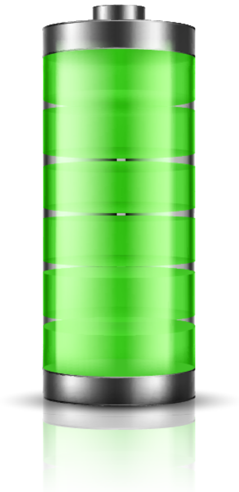

Chapter 5 –

Discussion

General Discussion

This thesis aims to gain insight into the using recovery strategies and their effects on post-game neuromuscular, physiological, and perceptual outcomes within elite male soccer players. Three studies were conducted to address this purpose and achieve a more contextualized approach.

First, current body of knowledge was systematically reviewed and analyzed (Article-I) to understand the effects of different post-game recovery strategies on elite male soccer players' performance, physiological and wellness parameters. It was found that using compression garments, CWI and sleep hygiene strategies offers greater positive effects on CMJ and muscle damage (physiological markers and wellness data) compared to a control group. However, no effect was found on other performance outcomes, such as sprint or MVC outcomes. Those results were partially contrary to the initial hypothesis that using recovery strategies would provide better performance on all outcomes. Studies with this population were scarce when the systematic review with meta-analysis was carried out. To the best of our knowledge, no previous systematic review has previously analyzed the empiric use of recovery strategies in professional soccer settings. After our article publication, other authors published a systematic review with graded recovery recommendations for professional soccer 1.

After that, to understand the actual map, we focused on describing and reporting the use of recovery strategies by "La Liga" teams (Article-II). It turned out that all of them combined and used recovery strategies at some point during the season, being natural (sleep/nap and food/fluid replacement) and physical (cold/ice bath/shower/immersion and massage) ones always utilized. In contrast, psychological and alternative recovery strategies were less popular among the teams. On top of that, recovery strategies were only designed by a single person in 13% of the teams. Moreover, 65% of the teams acknowledged following scientific recommendations. Thus, our hypotheses were partially correct. Since the publication of this study (Article-II), other research papers describing professional soccer players' recovery habits have been published 2,3 and questionnaires have been validated 4 following our proposal (Article-II).

Finally, we focused on comparing the effectiveness of two comprehensive recovery protocols (which combined natural and physical strategies) on physiological, neuromuscular, and perceptual outcomes after a soccer game in elite players using a parallel group-randomized trial. This study (Article-III) found a time effect in both interventions, with CK-III normalized at MD+3 and neuromuscular and perceptual outcomes at MD+2. While no differences between protocols were found, the interaction effects showed changes only in the CHP+FR+CWI+CJ group at post-game and MD+1 in neuromuscular and TQRper outcomes. Our first hypothesis was incorrect after acknowledging that both interventions were equally effective for improving these outcomes, and no superior effect from one versus another was found. However, the second hypothesis was correct; GPS parameters such as accelerations, decelerations, sprint and HSR distance correlated with muscular CK.

Combination of methods

Different authors have examined and demonstrated the positive effects of combining recovery interventions in athletes [5–7]. In soccer, elite teams combine more than one technique when planning their recovery strategies, being natural and physical strategies such as sleep/nap, food/fluid replacement, cold/ice bath/shower/immersion and massage the most used [2,3,8]. Several authors [9,10] found positive effects on perceived recovery after combining methods but no effects on physical performance. Thus, combining them after a high-intensity training session or gameplay was more effective than using only one. However, recovery interventions carried out by these investigators were not performed after a competition, or the level of the players was not elite.

Hence, the study presented [11] was mainly designed to compare the effectiveness of two comprehensive recovery protocols: a) carbohydrate and protein shake, foam roller, cold-water immersion, and tart cherry juice (CHP+FR+CWI+CJ) or b) carbohydrate and protein shake, stretching and intermittent cold-water immersion (CHP+STR+ICWI), both involving and combining physical and natural recovery strategies, on physiological (CK-III), neuromuscular (CMJ and MVC), and perceptual (TQRper and MS) outcomes with elite soccer players after a game. Both protocols could benefit and equally effectively provide accelerated recovery after a game. Both had a positive time effect at different time points (20-44-68 hours) depending on the variable of interest. No differences were found between them. Although no significant effects between protocols were found in any of the outcomes analyzed, the interaction effects presented changes in neuromuscular and perceptual outcomes (TQRper), indicating that changes were only present in the CHP+FR+CWI+CJ group at post-game and MD+1.

Furthermore, CK-III was completely normalized at MD+3, while neuromuscular and perceptual outcomes were normalized at MD+2 in both groups. Additionally, large, and very large correlations between CK-III and external load parameters such as accelerations, decelerations, sprinting and HSR distance were present. These findings demonstrate the effectiveness of both interventions and indicate that the combination of recovery methods may produce a synergetic effect and induce similar outcomes with gentle differences. Consequently, elite soccer players could combine natural and physical recovery methods, and it could be helpful to give them the possibility to choose from different options according to their preferences and perceived recovery effectiveness.

Outcomes

Physiological outcomes

Elite soccer players show low levels of muscle damage during official tournaments and recover before the next game [12]. In this sense, several authors demonstrate that CK completely normalization time courses are up to ≥72 hours, despite physical performance recovery lasting up to ≥48 hours [13,14]. Similar findings have been obtained in the investigation [11], showing a faster recovery of neuromuscular outcomes, CMJ and MVC, than physiological ones, CK-III, returning to similar baseline levels at MD+2. Nevertheless, according to previous investigations and data presented, CK peak levels were obtained at MD+1 [15,16] and baseline ones were reached between 48-72 hours [17] in both groups, stating that these biomarkers are sensitive to recovery time [18]. These findings differ from other studies' results where peaks were reached at 48 hours [14,19,20] and 72 hours [21]. Furthermore, pregame CK levels and fatigue in multi-game weeks were significantly higher when a minimum of 60 minutes was achieved in the previous game [22]. Nonetheless, and given the considerable intraindividual variability in its response, some authors have considered CK irrelevant as a marker of the state of recovery [23]. Moreover, the presence of congested periods, multi-game weeks [22], and inter-subject variability of CK activity should be considered [24]. When analyzing external load variables, four GPS parameters such as accelerations, decelerations, sprinting, and HSR distance, showed large to very large effect correlations with muscle damage, CK-III, immediately after the game [11], which indicates that soccer is a physically high demanding sport. Similar findings immediately post, relating decelerations and muscle soreness were reported by other authors [25]. Further, knowing that the process of load and recovery in athletes is nonergodic, using an individual-level analysis is essential to ensure an optimal balance of individual load and recovery [26]. Thus, the possibility of applying personal recovery strategies related to specific game demands, performance decrements, perceived individual recovery, and MS could provide a comprehensible framework to individualize the recovery process [27].

Neuromuscular outcomes

As pointed out before neuromuscular outcomes, MVC and CMJ, recovered faster than physiological ones, CK-III [11]. Moreover, the interaction effect for the MVC (non-dominant) only revealed changes for the CHP+FR+CWI+CJ group at post-game and MD+1, but no differences between the two comprehensive protocols [11]. Similar results were obtained when analyzing the effects of using isolated strategies, which revealed that CWI, compression garments and a sleep hygiene strategy produced no effects on the MVC compared to a control group [28]. Furthermore, when combining different strategies, the CMJ analysis immediately after the game revealed no decrement [11]. Nevertheless, different trends were observed depending on the group at MD+1. Considering a real change in performance in anything above the CV (4.6% or 1.7cm), the CHP+FR+CWI+CJ group showed a decrease of 3.2 cm, while in the CHP+STR+ICWI group, no changes (-1.1 cm) were observed. It must be highlighted that more than this difference needed to be considered, not statistically significant, a between-group difference. Moreover, when no recovery intervention was performed, CMJ was lower 48 hours post-game compared to baseline [20], suggesting the necessity to perform recovery and showing the positive effects of both interventions from the present study [11]. Hence, recovery should be applied when lower body performance needs to be recovered within 48 hours. The CHP+STR+ICWI protocol provides more significant benefits, although not significant compared to CHP+FR+CWI+CJ, for maintaining CMJ values after a game.

Perceptual outcomes

Different authors [9,10] found greater positive effects on perceived recovery after combining methods than using only one, but no effects on physical performance. Our study [11] obtained similar findings when we compared two comprehensive protocols. Perceptual outcomes (MS and TQRper) showed a similar trend, and TQRper values were above baseline at MD+3 after using either one of the two protocols. However, contrary to other authors [9,10] we did not use a control group that carried out a single strategy.

Recovery methods

Food/Fluid replacement and supplementation

Food and fluid replacement was among the most utilized recovery strategies by Spanish male professional soccer teams, being adopted by all [8]. To combine hydration and refueling [29] fluids should be loaded with CH and sodium to quickly replenish glycogen stores [30], which is essential to maintain and restore optimal performance, and to fully recover for the upcoming training sessions [31]. In our study [11], neither the amount of CH, protein, sodium, and fluid intake was individualized, nor was the CJ supplementation, which was only administered in one group of players. However, a nutritionist controlled food and fluid intake individually using a food diary.

Supplementing with CJ for two consecutive days in combination with the other protocol methods (CHP+FR+CWI) showed no significant improvements in any variable analyzed when compared to CHP+STR+ICWI [11]. Nevertheless, neuromuscular outcomes (CMJ and MVC) recovered faster; muscle soreness was lower, inflammatory response was attenuated and no effects on oxidative stress nor CK were observed when it was used as a unique recovery method for eight consecutive days compared to a control group [32]. These findings suggest that its beneficial effects could be attenuated when combining it with other methods and that the dose administrated, or the intake frequency was insufficient. Nevertheless, future studies are needed to corroborate this hypothesis.

Cold-water immersion

Immersion in cold water, even in a continuous (CWI) or intermittent way (ICWI), are popular among soccer players [2,3,8,33]. CWI has several benefits and significant effects on physiological (serum CK), neuromuscular (muscular power), and perceptual/psychological (delayed onset muscle soreness, DOMS) outcomes [34–42]. However, these effects were only observed 24 hours after high-intensity exercise but not after applying eccentric loads. CWI was only effective for positively influencing muscular power but not muscular strength performance [38]. While some authors reported CWI was no more effective than active recovery for reducing inflammation or cellular stress in muscle after a bout of resistance exercise [43], others found that the regular use of CWI has a deleterious effect on resistance training adaptations [44,45] but appears not to affect aerobic exercise performance [46]. This can be particularly challenging in soccer, where both attributes are important to achieve an optimal performance. In soccer, a moderate difference in favor of its use was observed at 48 hours when analyzing jumping (CMJ) and strength (MVC) performance [28]. Nevertheless, according to recent review results, only beneficial effects on muscle strength were found; but no effects on the jumping and running performance were observed [47]. Similar conclusions were reported by other investigations [48,49], which found no positive effects on the use of CWI on physical performance recovery, neither when using it isolated nor combined with active recovery after a game, but it showed effectiveness for perceptive recovery [1]. However, the mentioned studies, had youth soccer players in their samples, which may affect the overall results because they recover faster than adults from strenuous exercise due to their lower susceptibility to muscle damage [50]. Moreover, durations and temperatures should be revised. Lowering them may improve the efficacy of CWI after high-intensity exercise for removing serum CK and/or endurance performance [38]. Other authors [51,52] discussed whether placebo effects might increase readiness and decrease muscle pain after CWI and could not demonstrate significantly different effects between cold (5-10ºC) and tepid water (24-35ºC). Furthermore, when CWI or ICWI is combined with other recovery methods, both strategies showed similar results in physiological, neuromuscular, and perceptual outcomes [11]. Thus, according to other authors [31], we could recommend applying CWI in an individualized, but also contextual manner.

Stretching

As well as CWI, stretching is a popular recovery strategy used by elite soccer players [2,3,8,33], and according to a recent survey, nearly 60% of athletic trainers prescribed static stretching post-exercise [53]. However, there are controversial results and a lack of evidence in the literature supporting the muscular and physiological effects of stretching after a physical activity or competitive soccer games on reducing muscle soreness [34,54–56]. While some authors stated that it might even lead to an increase in DOMS and CK levels [57], others [56] found a CK reduction after performing static stretches. Moreover, and even though there was not sufficient evidence to reject the hypothesis that passive recovery and stretching have the same influence on recovery and the high risk of bias of the included trials, in a recent meta-analysis, stretching was shown to have no significant effects on post-exercise DOMS at 24h, 48h and 72h (ES=0.09 to -0.24) and on strength recovery (ES=0.08) compared to passive recovery [58]. Nevertheless, when stretching was combined with another recovery method (massage) after a competitive event [34,59], it induced a better perception of leg soreness and CMJ values but worst performance during repeated sprint ability [36]. Similarly to the study findings [11], where stretching within a recovery protocol showed positive changes in the variables studied, Rey and colleagues [60] found that CMJ values were significantly better 24 hours when combining 12 minutes of submaximal running and 8 minutes of static stretching. However, even though this study [60] simulated the demands of a soccer game, it was performed after training sessions and not after a competitive event. Thus, and in agreement with other authors' proposals [31], it seems reasonable to let players decide whether they stretch, as sometimes it is considered a ritual by some of them [61].

Foam roller

Like CWI and stretching, professional soccer players use FR as a common recovery technique [2,3,8,33]. Nevertheless, ambiguous recommendations and conclusions about using FR have been reported when analyzing its effects among athletes [62,63]. While some authors found that its use induced acute improvements in joint range of motion, attenuated decrements in muscle performance, and reduced perceived muscle soreness after exercise [64,65]; others suggested that a placebo effect could be the responsible for pain relief and, consequently, small performance improvements [62,66]. Rey and colleagues, [67] reported that FR greatly affected the recovery of agility, TQRper and perceived muscles soreness. However, no effects on CMJ or sprint performance when compared to a passive group after a standard training session on professional soccer players. Nonetheless, and according to the present study findings [11], comparing two comprehensive recovery protocols, better (but non-significant) neuromuscular and perceptual outcomes were found in favor of the one that incorporated STR instead of the one that used the FR at MD+1. Nevertheless, and due to non-conclusive results, FR may still be recommended as a recovery tool with this elite group of players that believe in its effects [31], and allow 10-12 minutes post-game to use it. However, it should be noted that excessive rolling with high pressure may lead to harmful effects on neuronal tissues, nerves, and vessels [68].

Sleep

As well as food and fluid replacement, sleep was adopted by all Spanish professional soccer teams [8]. However, the use of this strategy differed when pre-season and in-season were compared (83% vs. 78%) because players are on tour or at a training camp, and time availability and player's predisposition could be slightly increased [8].

Recovery mechanisms run optimally when players have adequate sleep quantity and quality [69]. Players should sleep 7-9 hours with an increased need after games or training because of the high psychological and physical demands [70]. Nevertheless, sleep disturbances are common in elite athletes [71], and they lack strategies to improve it [72]. Thus, sleep hygiene strategies can be introduced to enhance sleep quantity and subsequently, performance [73]. However, in our first study [28], using a sleep hygiene strategy offered greater positive effects only on one of the physical performance tests (CMJ). However, no effects on the 20-m sprint or MVC compared to a control group. On top of that, this recovery strategy offered greater positive effects on muscle damage (physiological markers and wellness data) compared to a control group. Moreover, in our third study [11], since sleep was performed by all players and is considered a "natural" recovery strategy and interventions after the game were hardly possible, emphasis was only placed on registering the quality [74] and duration of it.

How should it be implemented?

Combining natural and physical recovery methods showed benefits that could be considered, and the non-beneficial effects of using isolated recovery methods may be elucidated [11]. Furthermore, as was described before, despite its poor scientific evidence support, some recovery strategies such as STR (natural) or FR (physical) are widely accepted and used as recovery techniques by elite male soccer teams after training and competition [3,8]. Therefore, it should be considered when designing multimethod recovery protocols to influence perception, favoring mental well-being from a psychological point of view [60,75], and increasing adherence to its use. Further, and following Reilly's recommendations [7] to ensure a full recovery, strategies should be multifactorial. Resources and the necessary time needed to implement should be considered, as these factors will determine its feasibility [76–78]. Thus, it raises the need to achieve athlete and coach buy-in to any intervention [79], and the challenge to balance expectations, preferences, and beliefs of coaches and athletes with an evidence-based approach, especially in elite [2,27,80,81].

Moreover, and as stated before, an individual-level analysis should be also considered to ensure the optimal balance between load and recovery [26], and to have a deep knowledge about intra- and inter-individual recovery responses, including responders and non-responders to certain interventions [27]. To determine this individual need for recovery, performance, physiological and perceptual tools are used [31]. To identify time courses and ensure recovery, biochemical, performance, or self-reported tests are applied multiple times in the hours after exercise. Their values should be at least the same as pre-exercise baseline [30]. Biochemical markers in team sports are altered inconsistently, showing relevant differences in the recovery profile of every sport and large variations between players [13]. CK and hormonal parameters are the most relevant biomarkers of the recovery process in soccer [18]. However, invasive measurements are difficult and unpleasant to apply in elite team sports players. Nevertheless, performance tests such as running, jumping, or strengthening have practical implementation limitations around games because of the physical strain applied [13]. Moreover, soccer players may have similar physical performance after a 72-h recovery period to pre-game, even with signs of physiological and biochemical stress [82]. Furthermore, self-reported tests to assess wellness or perceived recovery are commonly used around training or competitions [74,83] for many reasons: they are less time-consuming, do not add physical strain compared with biochemical or performance tests, and express a physical or psychosocial state of players' perception ideally [83], with superior sensitivity and consistency assessing within-subject changes [84]. These findings confirm that staff members should be vigilant on hidden recovery processes [13] as there needs to be more association between biochemical responses, performance, and self-reported measures in recovery. Therefore, a complementary use of them should be applied to give a representative picture of the current recovery state [84–87].

Strengths and Limitations

The present thesis provides extensive insight in recovery. The studies reflect the unique context of elite soccer players accounting for recovery. The empiric use of recovery in soccer has been analyzed through a systematic review and meta-analysis (Article-I) for the first time. Professional teams' staff were asked about using recovery strategies (Article-II), and a comprehensive recovery intervention with elite players was performed within their professional environment (Article-III). These methodological approaches are scarce at elite levels but necessary to understand recovery practices undertaken and their effects on different outcomes.

In the present thesis, some limitations need to be highlighted. In Article-I, very few RCTs comparing recovery strategies after a soccer game were available, with only five studies involving professional male soccer players. For this reason, a parallel group-randomized trial (Article-III), combining two different recovery protocols, has been performed to contribute to the research on this topic.

In Article-II, the use of online surveys has some limitations. The answers may not be 100% truthful, and questions could be misunderstood or interpreted differently depending on the reader. However, the survey was tested and validated before the start of the study, and the contact of the lead researcher was provided to every team in case they had any questions. Furthermore, the study used a purely quantitative research paradigm and may miss some relevant information regarding the motivations for players and staff to use one strategy or another.

The main limitation of Article-III might be the number of participants within the intervention performed. This is a well-known issue for elite sports studies and may affect the outcomes' generalizability and the significance of some comparisons [88–90]. However, using "sample quality criteria", the level (elite) of the players enrolled may have increased its representativity. Additionally, the lack of a control group limits the possibility of concluding the investigation by understanding if any experimental protocol were more effective than the controls. Nevertheless, this is a common limitation when professional players are enrolled.

Another limitation may be that the players (Article-III) involved were only male; therefore, these protocols should be replicated in a female population before implementation.

Directions for future research

It is essential to understand that only staff members were asked about recovery strategies performed (Article-II) in their teams, generalizing it, which may differ from individual players' answers. However, in Article-III, only players' perceptions about load and recovery were considered. Future research should focus on obtaining, analyzing, and comparing both as they work together daily. Interpreting training and game loads and their implications for recovery should be studied more accurately. Furthermore, motivations for using strategies may also be the object of future qualitative research.

Besides that, since researchers have emphasized the importance of alleviating mental fatigue due to potential performance and recovery impairment [91,92], it should be adequate to implement psychological recovery strategies in these protocols to counteract its effects and evaluate its impact.

Moreover, further studies combining post-competition recovery strategies, ensuring ecology, and adjusting the interventions to individual game demands and recovery preferences are highly recommended, especially with elite soccer players. Thus, more consistency between current scientific evidence recommendations and practices used by professional soccer players will be acquired.

Also, combining strategies with scientific evidence, when used isolated, should be studied to understand, and determine a possible synergetic effect.

Finally, the whole thesis could be replicated focusing on other team sports, female soccer, or amateur soccer environments.

Practical applications

Practical applications of this thesis are presented below:

- CWI, compression garments and a sleep hygiene strategy can be used isolated to enhance physiological, neuromuscular, and perceptual recovery.

- An ecological analysis should be performed before it when designing and prescribing recovery protocols, depending on the logistics, game venue, and players' preferences.

- It is essential to individualize, periodize and use recovery methods at the right moment and frequency according to the desired objectives and to follow scientific recommendations.

- Lower usage of recovery methods has been reported after in-season training compared with pre-season ones. This indicates the need to optimize recovery practices after in-season training sessions.

- Elite soccer players could combine different recovery methods after practices or games, such as the two combinations (CHP+FR+CWI+CJ and CHP+STR+ICWI), used in Article-III, that reported a positive time effect on recovery. But since no differences were found, practitioners could use the ones more suitable for their players.

- It is suggested that practitioners and players be given a choice between different options based on their preferences and the perceived effectiveness of recovery.

- Practitioners are invited to monitor external load parameters such as accelerations, decelerations, HSR, and sprint distance to manage the recovery strategies better.

Conclusions

The main conclusions of this thesis are presented below:

- The systematic review with meta-analysis demonstrated that CWI, compression garments, and a sleep hygiene strategy offer greater positive effects on muscle damage (physiological and perceptual outcomes) and CMJ (neuromuscular outcomes) but no impact on the 20-m sprint or MVC compared to a control group.

- All teams from "La Liga" used recovery strategies to one extent or another. However, there was no general agreement on the strategy employed nor the moments where they were applied. Moreover, when analyzing practices, more teams used them after pre-season practices than after the ones conducted in-season.

- Elite professional soccer teams in Spain used natural strategies more than physical, psychological, or complementary ones by. However, natural, and physical strategies were always present, such as sleep/nap, food/fluid replacement, cold/ice bath/shower/immersion, and massage.

- All Spanish first-division male teams regularly used food and fluid replacement (natural strategy). They had the highest levels of adherence after games and practices. In contrast, three physical strategies (cold/ice bath/shower/immersion, massage, and FR) showed a higher presence in the recovery protocols after competition.

- The two comprehensive recovery protocols (CHP+FR+CWI+CJ and CHP+STR+ICWI) were equally effective, and no significant effects between them were found for improving physiological (CK-III), neuromuscular (MVC and CMJ), and perceptual (TQRper and MS) outcomes.

- The interaction effects showed changes in the CHP+FR+CWI+CJ group immediately after the game and MD+1 in neuromuscular and TQRper outcomes. Moreover, significant effects of time were present in both interventions, with physiological outcomes completely normalized at MD+3 and neuromuscular and perceptual ones at MD+2.

- There were large and very large correlations between physiological outcomes (CK-III) and external load parameters registered by GPS, such as accelerations, decelerations, sprint distance and HSR distance.

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Appendices

Appendix I - Supplementary tables from Article-I

Supplementary Table 1: Primary and secondary outcomes for the experimental group relative to baseline data.

	Variable	Study	Mean Difference [95% CI]	Random effects model	P-value	SMD [95% CI]
Primary outcomes	CMJ 24h	Ascensão et al. 2011	-6.70 [-14.00; 0.60]	-1.06 [-2.87; 1.36]	0.391	-0.29 [-0.72; 0.18]
		Marqués-Jiménez (a) et al. 2018	-0.21 [-3.35; 2.92]			
		Clifford et al. 2018	-0.60 [-3.31; 2.11]			
	CMJ 48 h	Ascensão et al. 2011	-3.70 [-9.20; 1.80]	0.10 [-1.76; 1.97]	0.914	-0.05 [-0.49; 0.41]
		Marqués-Jiménez (a) et al. 2018	0.56 [-3.15; 4.28]			
		Clifford et al. 2018	0.60 [-1.60; 2.82]			
	20-m sprint 24 h	Ascensão et al. 2011	0.16 [0.10; 0.31]	0.08 [-0.02; 0.199]	0.142	0.53 [-0.09; 1.15]
		Marqués-Jiménez (a) et al. 2018	0.04 [-0.05; 0.13]			
	20-m sprint 48 h	Ascensão et al. 2011	0.31 [0.09; 0.52]	0.14 [-0.16; 0.44]	0.412	0.34 [-0.85; 1.54]
		Marqués-Jiménez (a) et al. 2018	-0.01 [-0.08; 0.08]			
	MVC 24 h	Ascensão et al. 2011	-8.00 [-157.90; 141.90]	-60.37 [-169.03; 48.29]	0.276	-1.06 [-2.25; 0.13]
		Clifford et al. 2018	-118.36 [-276.10; 39.38]			
	MVC 48 h	Ascensão et al. 2011	-146.00 [-270.38; -21.61]	-99.54 [-210.44; 11.35]	0.078	-0.72 [-1.57; 0.13]
		Clifford et al. 2018	-30.63 [-190.09; 128.83]			
Secondary outcomes	QS DOMS Post-match 24 h	Ascensão et al. 2011	0.33 [-1.11; 1.77]	-0.17 [-1.37; 1.04]	0.731	-0.15 [-0.72; 0.31]
		Marqués-Jiménez (b) et al. 2018	-1.30 [-3.48; 0.88]			
	QS DOMS Post-match 48 h	Ascensão et al. 2011	-0.20 [-1.45; 1.05]	-1.61 [-4.60; 1.39]	0.293	-0.61 [-1.45; 0.22]
		Marqués-Jiménez (b) et al. 2018	-3.27 [-3.90; 0.08]			
	HS DOMS Post-match 24 h	Ascensão et al. 2011	0.31 [-1.56; 2.18]	0.03 [-1.52; 1.58]	0.972	-0.42 [-0.95; 0.11]
		Marqués-Jiménez (b) et al. 2018	-0.58 [-3.32; 2.16]			
	HS DOMS Post-match 48 h	Ascensão et al. 2011	-0.35 [-2.11; -1.40]	-1.01 [-2.72; 0.71]	0.250	-0.04 [-0.57; 0.48]
		Marqués-Jiménez (b) et al. 2018	-2.17 [-4.75; 0.411]			
	CS DOMS Post-match 24 h	Ascensão et al. 2011	-0.76 [-2.30; 0.78]	-1.08 [-2.42; 0.25]	0.111	-0.49 [-1.01; 0.06]
		Marqués-Jiménez (b) et al. 2018	-2.70 [-4.75; 0.61]			
	CS DOMS Post-match 48 h	Ascensão et al. 2011	-0.47 [-1.88; 0.94]	-1.09 [-2.09; -0.09]	0.009	-0.47 [-1.01; -0.06]
		Marqués-Jiménez (b) et al. 2018	-2.46 [-5.23; 0.32]			
	CK 24 h[a]	Ascensão et al. 2011	586.00 [541.97; 630.02]	586.48 [542.53; 630.42]	<0.0001	0.88 [0.33; 1.43]
		Fullagar et al. 2016	719.00 [-13.27; 1451.27]			
	CK 48 h[a]	Ascensão et al. 2011	654.00 [613.69; 694.30]	653.23 [613.00; 693.46]	<0.0001	0.86 [0.03; 1.70]
		Fullagar et al. 2016	449.00 [-209.03; 1107.03]			
	CRP 24 h[a]	Ascensão et al. 2011	1.35 [1.07; 1.62]	1.32 [1.055; 1.560]	<0.0001	1.41 [0.01; 2.82]
		Fullagar et al. 2016	0.9 [-0.24; 2.04]			
	CRP 48 h[a]	Ascensão et al. 2011	-0.15 [-0.46; 0.16]	-0.12 [-0.848; 1.448]	0.433	-0.02 [-0.54; 0.50]
		Fullagar et al. 2016	0.3 [-0.85; 1.45]			

S1 Table. Primary and secondary outcomes for the experimental group relative to the base-line data. SMD: Standardized Mean Difference; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; CRP: C-reactive protein; QS: quadriceps; HS: hamstrings; CS: calf. [a]Ascensão evaluated at 24-hours and 48-hours, while Fullagar evaluated at 20-hours and 44-hours post-match.

Supplementary Table 2: Primary and secondary outcomes for the control group relative to baseline data.

	Variable	Study	Mean Difference [95% CI]	Random effects model	P-value	SMD [95% CI]
Primary outcomes	CMJ basal 24h	Ascensão et al. 2011	-11.11 [-19.03; -3.16]	-3.31 [-7.70; 1.07]	0.1383	-0.78 [-1.63; 0.07]
		Marqués-Jiménez (a) et al. 2018	-1.25 [-5.77; 3.27]			
		Clifford et al. 2018	-1.52 [-4.36; 1.32]			
	CMJ basal 48 h	Ascensão et al. 2011	-9.60 [-16.80; -2.39]	-3.40 [-7.02; 0.21]	0.0655	-0.66 [-1.51; 0.19]
		Marqués-Jiménez (a) et al. 2018	-0.89 [-5.32; 3.54]			
		Clifford et al. 2018	-2.79 [-5.35; -0.22]			
	20-m sprint basal 24 h	Ascensão et al. 2011	0.20 [0.01; 0.40]	0,09 [-0.02; 0.22]	0.1143	0.48 [-0.05; 1.01]
		Marqués-Jiménez (a) et al. 2018	0.06 [-0.02; 0.14]			
	20-m sprint basal 48 h	Ascensão et al. 2011	0.28 [-0.09; 0.40]	0.12 [-0.17; 0.42]	0.413	0.32 [-0.87; 1.52]
		Marqués-Jiménez (a) et al. 2018	-0.02 [-0.09; 0.05]			
	MVC 24 h	Ascensão et al. 2011	-349.33 [-351.60; -175.36]	-236.50 [-467.28; -5.73]	0.0446	-0.70 [-1.20; -0.19]
		Clifford et al. 2018	-113.63 [-259.63; 32.37]			
	MVC 48 h	Ascensão et al. 2011	-265.48 [-375.30; -1558.65]	-193.30 [-345.19; -41.40]	0.012	-1.34 [-2.02; -0.66]
		Clifford et al. 2018	-110.09 [-246.64; 26.46]			
Secondary outcomes	QS DOMS Post-match 24 h	Ascensão et al. 2011	2.00 [0.91; 3.09]	2.02 [1.02; 3.01]	<0.0001	1.29 [0.72; 1.86]
		Marqués-Jiménez (b) et al. 2018	2.10 [-0.39; 4.59]			
	QS DOMS Post-match 48 h	Ascensão et al. 2011	0.64 [-0.39; 1.66]	0.52 [-0.44; 1.48]	0.286	0.98 [-0.40; 2.36]
		Marqués-Jiménez (b) et al. 2018	-0.3 [-3.01; 2.40]			
	HS DOMS Post-match 24 h	Ascensão et al. 2011	1.98 [0.63; 3.33]	1.35 [-0.61; 3.32]	0.1786	0,54 [-1.38; 2.46]
		Marqués-Jiménez (b) et al. 2018	-0.25 [-3.43; 2.93]			
	HS DOMS Post-match 48 h	Ascensão et al. 2011	0.56 [-0.55; 1.67]	0.18 [-1.28; 1.64]	0.8061	1.26 [-0.18; 2.66]
		Marqués-Jiménez (b) et al. 2018	-1.30 [-4.35; 1.72]			
	CS DOMS Post-match 24 h	Ascensão et al. 2011	1.29 [0.20; 2.37]	1.25 [0.20; 2.30]	0.0188	1.20 [0.01; 2.40]
		Marqués-Jiménez (b) et al. 2018	0.80 [-2.88; 4.48]			
	CS DOMS Post-match 48 h	Ascensão et al. 2011	-2.60 [-3.72; -1.49]	-2.23 [-3.88; -0.57]	0.0082	-0.40 [-0.52; -0.28]
		Marqués-Jiménez (b) et al. 2018	-0.35 [-4.13; 3.43]			
	CK 24 h[a]	Ascensão et al. 2011	754.00 [718.03; 789.96]	753.54 [717.63; 789.46]	<0.0001	1.91 [1.12; 2.70]
		Fullagar et al. 2016	607.00 [-41.80; 1255.80]			
	CK 48 h[a]	Ascensão et al. 2011	750.00 [717.74; 782.25]	665.90 [345.43; 986.37]	<0.0001	2.12 [0.55; 3.70]
		Fullagar et al. 2016	348.00 [-253.74; 949.74]			
	CRP 24 h[a]	Ascensão et al. 2011	1.65 [1.34; 1.95]	1.62 [1.32; 1.91]	<0.0001	2.26 [1.47; 3.07]
		Fullagar et al. 2016	1.2 [0.09; 2.31]			
	CRP 48 h[a]	Ascensão et al. 2011	0.15 [-0.16; 0.46]	0.27 [-0.42; 0,97]	0.442	0.47 [-0.05; 1.01]
		Fullagar et al. 2016	1.3 [-0.72; 3.32]			

S2 Table. Primary and secondary outcomes for the control group relative to baseline data.
SMD: Standardized Mean Difference; CMJ: counter movement jump; MVC: maximal voluntary contraction; DOMS: delayed onset muscle soreness; CK: creatine kinase; CRP: C-reactive protein; QS: quadriceps; HS: hamstrings; CS: calf. [a]Ascensão evaluated at 24-hours and 48-hours, while Fullagar evaluated at 20-hours and 44-hours post-match.

Supplementary File 1: PRISMA checklist

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7-8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	S1_File
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7-8 and Fig1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9-10
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	10
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	10

Page 1 of 2

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9-10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	11 and Fig1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	12-17
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	18-20
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	21-27
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	21-27
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	18-20
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	27-30
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	31
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	31-32
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

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Supplementary File 2: Search strategies

All databases were searched using the Boolean method with the following terms (1 AND 2 AND 3 AND 4 AND 5 AND 6 AND 7):

1. Athletes: athletes OR players OR participants
2. Sport: sport OR team sport (any of them) OR exercise OR football OR soccer
3. Recovery: recovery OR recovery strategies OR recovery modalities OR recovery methods
4. Match: match OR game OR competition OR post-match OR post-game OR post-competition
5. Recovery strategies: cold water immersion OR active recovery OR passive recovery OR stretching OR stretch OR compression garments OR massage OR whole-body vibration OR electrical stimulation OR foam roller OR foam rolling OR contrast baths OR chamber OR cooling.
6. Performance: performance OR muscle soreness OR muscle damage OR delayed onset muscle soreness OR biochemical markers OR heart rate OR tendon damage OR countermovement jump OR countermovement jump OR sprint OR agility OR creatine kinase OR cortisol OR testosterone
7. Feeling perception: perception OR perceived OR rate perceived exertion OR wellness OR sleep OR total quality recovery

<u>Medline (PubMed)</u>
(athletes OR players OR participants) AND (sport OR team sport OR exercise OR football OR soccer) AND (recovery OR recovery strategies OR recovery modalities OR recovery methods) AND (match OR game OR competition OR post-competition OR post-match) AND (cold water immersion OR active recovery OR passive recovery OR stretching OR stretch OR compression garments OR massage OR whole-body vibration OR electrical stimulation OR foam roller OR foam rolling OR contrast baths OR chamber OR cooling) AND (performance OR muscle soreness OR muscle damage OR doms OR delayed onset muscle soreness OR biochemical markers OR heart rate OR tendon damage OR countermovement jump OR Counter movement jump OR sprint OR agility OR creatine kinase OR cortisol OR testosterone) AND (perception OR perception feeling OR perceived OR rate perceived exertion OR wellness OR sleep OR total quality recovery)

<u>SCOPUS</u>
(((ALL (*"recovery"*)) OR (ALL (*"recovery strategies"*)) OR (ALL (*"recovery modalities"*)) OR (ALL (*"recovery methods"*))) AND ((ALL (*"match"*)) OR (ALL (*"game"*)) OR (ALL (*"competition"*)) OR (ALL (*"post-match"*)) OR (ALL (*"post-competition"*)) OR (ALL (*"post-game"*))) AND ((((ALL (*"cold water immersion"*)) OR (ALL (*"active recovery"*)) OR (ALL (*"passive recovery"*)) OR (ALL (*"stretch"*)) OR (ALL (*"stretching"*)) OR (ALL (*"compression garments"*)) OR (ALL (*"massage"*))) OR (ALL (*"whole body vibration"*)) OR (ALL (*"electrical stimulation"*)) OR (ALL (*"foam roller"*)) OR (ALL (*"foam rolling"*)) OR (ALL (*"contrast baths"*)) OR (ALL (*"chamber"*))) OR (ALL (*"cooling"*))) AND ((((ALL (*"performance"*)) OR (ALL (*"muscle soreness"*)) OR (ALL (*"muscle damage"*)) OR (ALL (*"delayed onset muscle soreness"*)) OR (ALL (*"biochemical markers"*)) OR (ALL (*"heart rate"*)) OR (ALL (*"tendon damage"*)))) OR (ALL (*"countermovement jump"*)) OR (ALL (*"sprint"*)) OR (ALL (*"counter movement jump"*)) OR (ALL (*"agility"*)) OR (ALL (*"creatine kinase"*)) OR (ALL (*"cortisol"*))) OR (ALL (*"testosterone"*))) AND ((ALL (*"perception"*)) OR (ALL (*"perceived"*)) OR (ALL (*"rate perceived exertion"*)) OR (ALL (*"wellness"*)) OR (ALL (*"sleep"*)) OR (ALL (*"total quality recovery"*))))) AND ((ALL (*"athletes"*)) OR (ALL (*"players"*)) OR (ALL (*"participants"*))) AND ((ALL (*"sport"*)) O R (ALL (*"team sport"*)) OR (ALL (*"exercise"*)) OR (ALL (*"football"*)) OR (ALL (*"soccer"*))) AND (LIMIT-TO (DOCTYPE , *"ar"*)) AND (LIMIT-TO (LANGUAGE , *"English"*) OR LIMIT-TO (LANGUAGE , *"Spanish"*))

<u>SPORTDiscus</u>
((athletes) OR (players) OR (participants)) AND ((sport) OR (team sport) OR (exercise) OR (football) OR (soccer)) AND ((recovery) OR (recovery strategies) OR (recovery modalities) OR (recovery methods)) AND ((match) OR (game) OR (competition) OR (post-match) OR (post-game) OR (post-competition)) AND ((cold water immersion) OR (active recovery) OR (passive recovery) OR (stretching) OR (stretch) OR (compression garments) OR (massage) OR (whole-body vibration) OR (electrical stimulation) OR (foam roller) OR (foam rolling) OR (contrast baths) OR (chamber) OR (cooling)) AND ((performance) OR (muscle soreness) OR (muscle damage) OR (delayed onset muscle soreness) OR (doms) OR (biochemical markers) OR (heart rate) OR (tendon damage) OR (countermovement jump) OR (counter movement jump) OR (sprint) OR (agility) OR (creatine kinase) OR (cortisol) OR (testosterone)) AND ((perception) OR (perceived) OR (rate perceived exertion) OR (wellness) OR (sleep) OR (total quality recovery))

ISI WEB OF SCIENCE (WOS)

(TS=("athletes") OR TS=("players") OR TS=("participants")) AND (TS=("sport") OR TS=("team sport") OR TS=("exercise") OR TS=("football") OR TS=("soccer")) AND (TS=(recovery) OR TS=("recovery strategies") OR TS=("recovery modalities") OR TS=("recovery methods")) AND (TS=("match") OR TS=("game") OR TS=("competition") OR TS=("post-match") OR TS=("post-game") OR TS=("post-competition") AND (TS=("cold water immersion ") OR TS=("active recovery") OR TS=("passive recovery") OR TS=("stretching") OR TS=("stretch") OR TS=("compression garments ") OR TS=("massage") OR TS=("whole-body vibration") OR TS=("electrical stimulation") OR TS=("foam roller") OR TS=("foam rolling") OR TS=("contrast baths") OR TS=("chamber") OR TS=("cooling")) AND (TS="performance") OR TS=("muscle soreness") OR TS=("delayed onset muscle soreness") OR TS=("biochemical markers ") OR TS=("heart rate") OR TS=("tendon damage") OR TS=("countermovement jump") OR TS=("counter movement jump") OR TS=("sprint") OR TS=("agility") OR TS=("creatine kinase") OR TS=("cortisol") OR TS=("testosterone")) AND (TS=("perception") OR TS=("perceived") OR TS=("rate perceived exertion") OR TS=("wellness") OR TS=("sleep") OR TS=("total quality recovery"))

CINAHL

(athletes OR players OR participants) AND (sport OR team sport OR exercise OR football OR soccer) AND (recovery OR recovery strategies OR recovery modalities OR recovery methods) AND (match OR game OR competition OR post-competition OR post-match) AND (cold water immersion OR active recovery OR passive recovery OR stretching OR stretch OR compression garments OR massage OR whole-body vibration OR electrical stimulation OR foam roller OR foam rolling OR contrast baths OR chamber OR cooling) AND (performance OR muscle soreness OR muscle damage OR doms OR delayed onset muscle soreness OR biochemical markers OR heart rate OR tendon damage OR countermovement jump OR Counter movement jump OR sprint OR agility OR creatine kinase OR cortisol OR testosterone) AND (perception OR perception feeling OR perceived OR rate perceived exertion OR wellness OR sleep OR total quality recovery)

Cochrane Central Register of Controlled Trials

(athletes OR players OR participants) AND (sport OR team sport OR exercise OR football OR soccer) AND (recovery OR recovery strategies OR recovery modalities OR recovery methods) AND (match OR game OR competition OR post-competition OR post-match) AND (cold water immersion OR active recovery OR passive recovery OR stretching OR stretch OR compression garments OR massage OR whole-body vibration OR electrical stimulation OR foam roller OR foam rolling OR contrast baths OR chamber OR cooling) AND (performance OR muscle soreness OR muscle damage OR doms OR delayed onset muscle soreness OR biochemical markers OR heart rate OR tendon damage OR countermovement jump OR Counter movement jump OR sprint OR agility OR creatine kinase OR cortisol OR testosterone) AND (perception OR perception feeling OR perceived OR rate perceived exertion OR wellness OR sleep OR total quality recovery)

Supplementary File 3: Data extraction form for randomized controlled trials

Reviewer:	**Date:**	**Study number:**

GENERAL STUDY INFORMATION

First author (e.g. Smith F):

Correspondence to: ☐ *not provided*

Title:

Journal:

Year of publication: **Vol.:** **Num.:** **Pages:**

Country: **Language:**

Sources of support:

STUDY DESIGN

☐ Randomised Controlled Trial

☐ Cluster Randomised Controlled Trial

Details:

Setting: ☐Unicenter ☐Multicenter (☐National / ☐International) ☐ Detail not provided

Recruitment period (months): ☐ Detail not provided

STUDY POPULATION AND PARTICIPANTS

Study population description:

Inclusion criteria:

Exclusion criteria:

Flow of participants		
	Groups Intervention / Control	**Reasons/Details**
Invited to participate and/or screened for eligibility		
Declined to participate		
Excluded		
Randomized		
Dropouts		
Completed		
Analysed		

Baseline characteristics				
	Total: (n=)	**Intervention (n=)**	**Control (n=)**	**Between group difference (statistically significant)**
Age				☐ Yes ☐ No
Gender				☐ Yes ☐ No
Weight				☐ Yes ☐ No
Height				☐ Yes ☐ No
BMI				☐ Yes ☐ No
				☐ Yes ☐ No

INTERVENTION

Intervention general description and objectives:

Duration (weeks/months):

Intervention characteristics					
	Recovery method	**Type & Brand**	**Duration (sets & reps)**	**Frequency**	**Attendance / compliance rate**
Intervention:					
Control:					

DATA COLLECTION

Data collection procedures: PRIMARY OUTCOME			
Variables	**Responsible** (who collected data**)**	**Method** (scale, instrument,etc.)	**Details**
Physical performance			

Data collection procedures: SECONDARY OUTCOMES			
Variables	**Responsible** (who collected data**)**	**Method** (scale, instrument,etc.)	**Details**
Other			
Subjective perception			
Technical & Tactical			
Physiological			

RESULTS

Drop-outs		
Group	**Num. (%)**	**Description/Reasons**
Intervention		
Control		

Results				
Intervention (n=)				
Variable (and timing)	**Baseline**	**Post-competition**	**P-value**	**Effect size**

Results				
Control (n=)				
Variable and timing	**Baseline**	**Post-competition**	**P-value**	**Effect size**

ADVERSE EVENTS

Adverse events collection and reporting			
Registering adverse events	☐ Yes ☐ No		
Results	**Total:**	**Intervention group:**	**Control group:**
Other descriptions:			

CONCLUSIONS

Conclusions
Primary outcome:

COMMENTS
(Add general comments if relevant)

METHODS

Methodological details		
		Description / details
Eligibility criteria specified	☐ Yes ☐ No	
Power calculation	☐ Yes ☐ No	
Method of randomization	☐ Adequate / computer generated ☐ Inadequate ☐ Not reported	
Allocation concealment	☐ Adequate ☐ Doubtful ☐ Inadequate ☐ Not reported	
Blinding	Participants: ☐ Yes ☐ No Coach/es: ☐ Yes ☐ No Outcome assessor/s: ☐Yes ☐ No ☐ Not reported	
Handling of withdrawals description	☐ Yes ☐ No	
Pre-published study protocol	☐ Yes ☐ No	

RISK OF BIAS ASSESSMENT FORM
FOR RANDOMISED CONTROLLED TRIALS

Reviewer:

First author (year): ( ) Assessment data: Study number:		
Bias domain	**Author's judgment (low, unclear, high)**	**Support for judgment**
Random sequence generation (selection bias)		
Allocation concealment (selection bias)		
Blinding of participants and researchers (performance bias)		
Blinding of outcome assessment (detection bias)		
Incomplete outcome data (attrition bias)		
Selective reporting (reporting bias)		
Other bias		

Appendix II - Supplementary tables from Article-III

Supplementary Table 1: Descriptive and comparison of baseline physical characteristics and game demands

		CHP+FR+CWI+CJ (n = 9)	CHP+STR+ICWI (n = 9)	p - value	Cohen's d
Physical characteristics	Age (years)	20 ± 1	19 ± 1	0.886	-0.068
	Body mass (kg)	72.5 ± 6.6	72.9 ± 6.0	0.730	-0.165
	Body height (cm)	178.4 ± 5.7	179.3 ± 4.6	0.461	0.356
Game demands	Total distance (m)	9941.6 ± 1208.8	10322.4 ± 926.0	0.464	-0.354
	HSR (m)	639.5 ± 292.4	587.2 ± 278.7	0.703	0.183
	Sprint distance (m)	303.6 ± 185.5	266.5 ± 181.5	0.673	0.202
	Acc >3 m/s^2 (n)	49.4 ± 11.7	46.7 ± 10.9	0.608	0.246
	Dec >3 m/s^2 (n)	58.8 ± 17.4	63.3 ± 14.3	0.552	-0.286
	RPE (au)	7.6 ± 0.5	7.4 ± 0.5	0.661	0.211

CHP+FR+CWI+CJ: 250 mL of water with carbohydrate and protein, foam roller, cold-water immersion, and tart cherry juice concentrate; CHP+STR+ICWI: 250 mL of water with carbohydrate and protein, stretching, intermittent cold-water immersion; HSR: high speed running distance; Acc: accelerations; Dec: decelerations, RPE: rate of perceived exertion

Supplementary Tables 2-7: Post-hoc effects of time

Post-hoc effects of time

CK-III - Contrasts

	Estimate	SE	df	z	p†
Baseline vs Post-game	**135.01**	**17.83**	∞	**7.57**	**< .001**
Baseline vs MD+1	**153.68**	**17.83**	∞	**8.62**	**< .001**
Baseline vs MD+2	**46.82**	**17.83**	∞	**2.63**	**0.03**
Baseline vs MD+3	-7.70	17.83	∞	-0.43	0.67
Post-game vs MD+1	18.67	17.83	∞	1.05	0.59
Post-game vs MD+2	**-88.19**	**17.83**	∞	**-4.95**	**< .001**
Post-game vs MD+3	**-142.71**	**17.83**	∞	**-8.00**	**< .001**

CMJ - Contrasts

	Estimate	SE	df	z	p†
Baseline vs Post-game	-0.73	0.52	∞	-1.41	0.63
Baseline vs MD+1	**-2.18**	**0.52**	∞	**-4.22**	**< .001**
Baseline vs MD+2	-0.49	0.52	∞	-0.95	1.00
Baseline vs MD+3	0.32	0.52	∞	0.62	1.00
Post-game vs MD+1	**-1.45**	**0.52**	∞	**-2.81**	**0.03**
Post-game vs MD+2	0.24	0.52	∞	0.47	1.00
Post-game vs MD+3	1.05	0.52	∞	2.03	0.21

MVC dominant - Contrasts

	Estimate	SE	df	z	p†
Baseline vs Post-game	**-42.79**	**9.01**	∞	**-4.75**	**< .001**
Baseline vs MD+1	-22.05	9.01	∞	-2.45	0.06
Baseline vs MD+2	-14.33	9.01	∞	-1.59	0.22
Baseline vs MD+3	9.16	9.01	∞	1.02	0.31
Post-game vs MD+1	20.74	9.01	∞	2.30	0.06
Post-game vs MD+2	**28.46**	**9.01**	∞	**3.16**	**7.93e-3**
Post-game vs MD+3	**51.95**	**9.01**	∞	**5.76**	**< .001**

MVC non-dominant - Contrasts

	Estimate	SE	df	z	p†
Baseline vs Post-game	**-43.05**	**8.95**	∞	**-4.81**	**< .001**
Baseline vs MD+1	**-27.05**	**8.95**	∞	**-3.02**	**0.01**
Baseline vs MD+2	-17.52	8.95	∞	-1.96	0.15
Baseline vs MD+3	1.98	8.95	∞	0.22	0.82
Post-game vs MD+1	16.01	8.95	∞	1.79	0.15
Post-game vs MD+2	**25.53**	**8.95**	∞	**2.85**	**0.02**
Post-game vs MD+3	**45.03**	**8.95**	∞	**5.03**	**< .001**

TQRper - Contrasts

	Estimate	SE	df	z	p†
Baseline vs MD+1	**-2.17**	**0.42**	∞	**-5.17**	**< .001**
Baseline vs MD+2	-0.62	0.46	∞	-1.35	0.18
Baseline vs MD+3	1.19	0.52	∞	2.29	0.04

Muscle Soreness - Contrasts

	Estimate	SE	df	z	p†
Baseline vs MD+1	**-1.07**	**0.19**	∞	**-5.70**	**< .001**
Baseline vs MD+2	-0.33	0.20	∞	-1.66	0.19
Baseline vs MD+3	0.13	0.21	∞	0.60	0.55

Supplementary File 1: CONSORT checklist

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4-6
	2b	Specific objectives or hypotheses	6
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	8
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	6-7
Participants	4a	Eligibility criteria for participants	6-7
	4b	Settings and locations where the data were collected	9
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	7
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5-6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	5
Sample size	7a	How sample size was determined	4
	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	8
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	8
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	8
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	8-9
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	NA

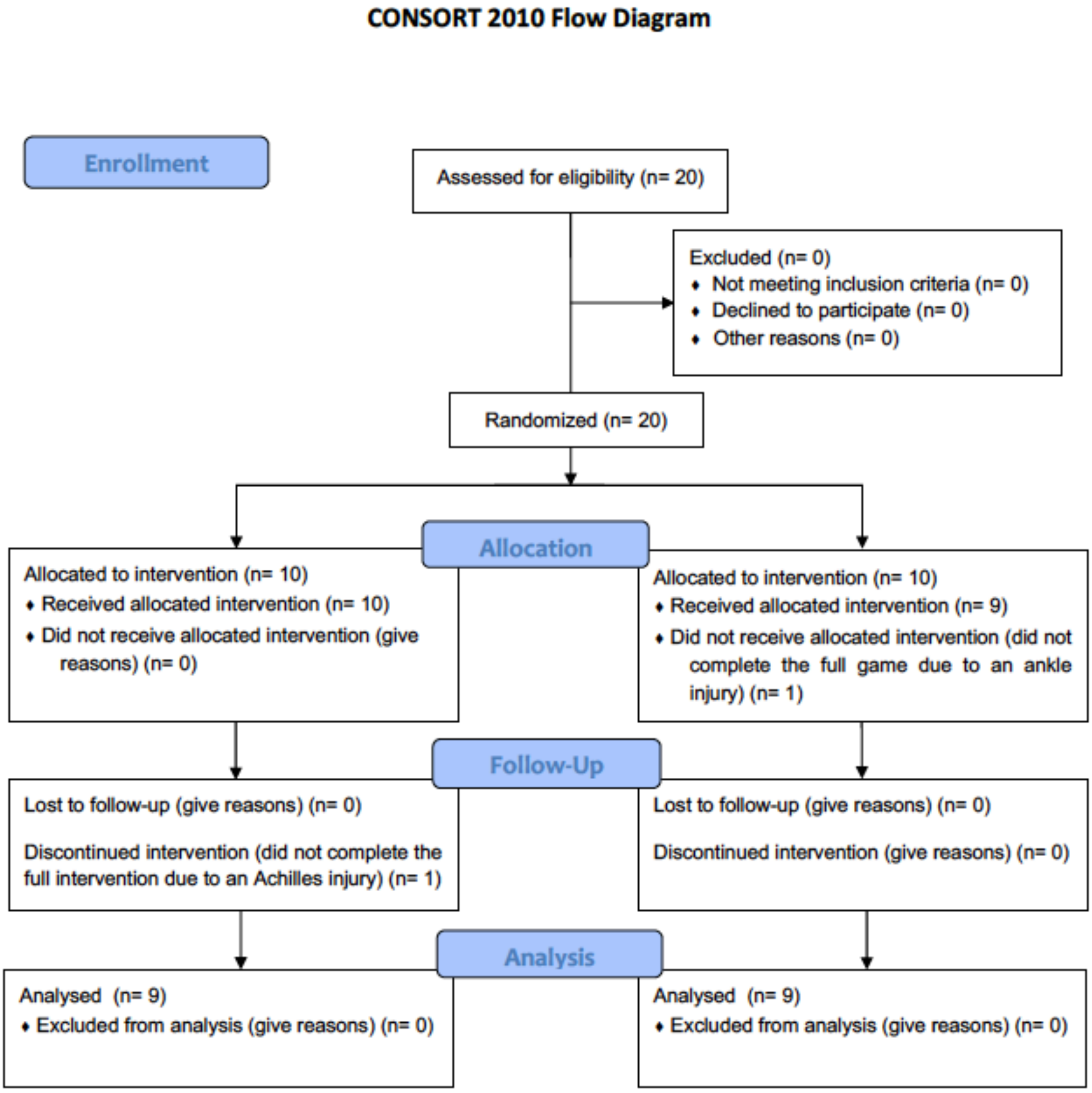
CONSORT 2010 checklist Page 1

Section/Topic	Item No	Checklist item	Reported on page No
		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	12-13
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	13-15
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	13-15
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	15 and Supp Mat II
	13b	For each group, losses and exclusions after randomisation, together with reasons	15 and Supp Mat II
Recruitment	14a	Dates defining the periods of recruitment and follow-up	7-8
	14b	Why the trial ended or was stopped	7-8
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Supp Mat III
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	15
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	15-17
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	NA
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	NA
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	24
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	25
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	18-23
Other information			
Registration	23	Registration number and name of trial registry	8-9
Protocol	24	Where the full trial protocol can be accessed, if available	8-9
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	NA

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

CONSORT 2010 checklist Page 2

Supplementary File 2: CONSORT Flow diagram



"Labor omnia vincit improbus"

"Work conquers all"

Publius Vergilius Maro "Virgil"

Albert Altarriba Bartés
albert.altarriba@uvic.cat

Book cover design: U_Media UVic-UCC
Book and chapter covers have been designed using assets from vectorpocket / Freepik.com