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

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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

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 electro-stimulation 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.
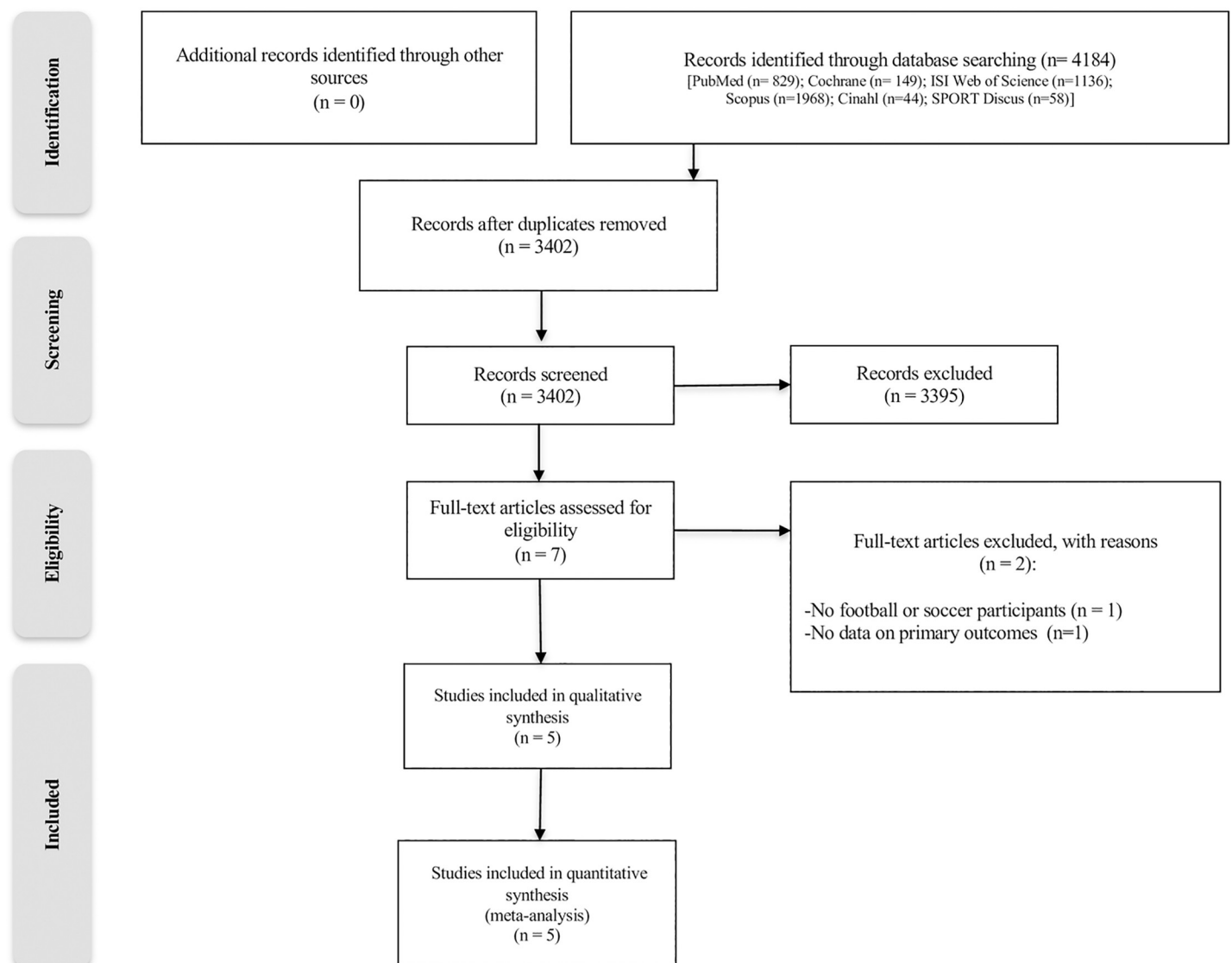

Fig 1. Eligibility flow diagram showing the selection process for the inclusion studies in this meta-analysis. n: sample size.

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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 ($p < 0.05$)

[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 15°. 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

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[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.
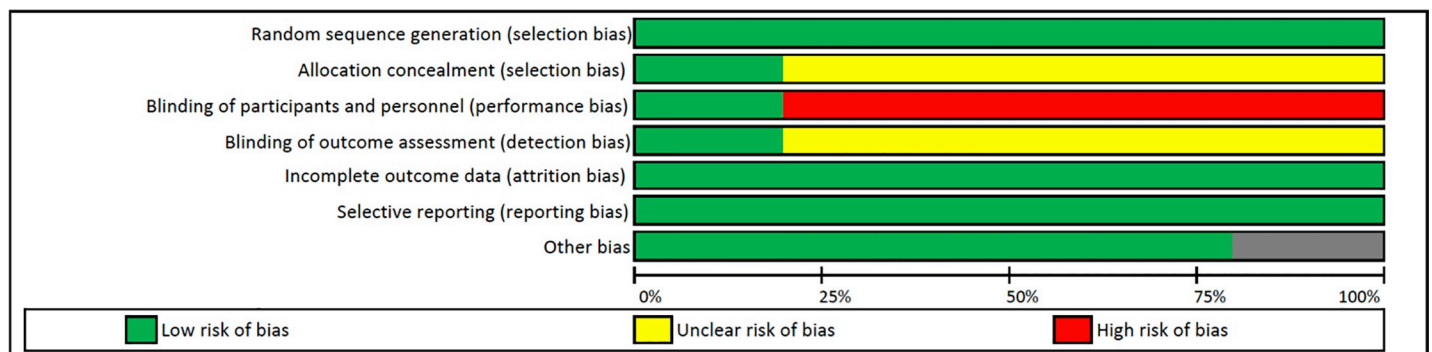

Fig 2. Risk of bias (RCTs).

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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;
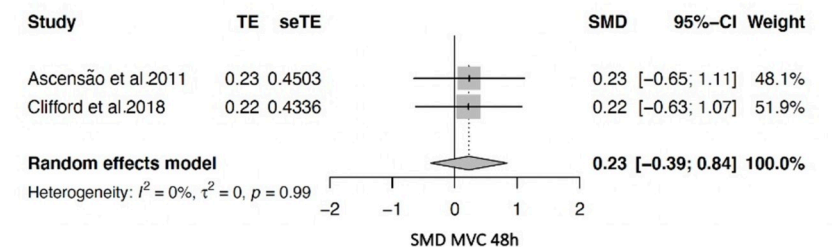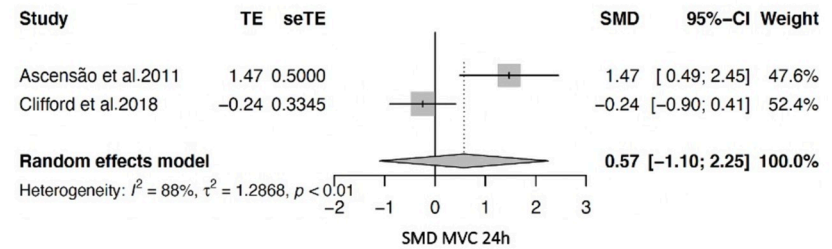
Study	TE	seTE		SMD	95%-CI	Weight
Ascensão et al.2011	0.45	0.4524		0.45	[−0.44; 1.34]	26.0%
Marqués-Jiménez et al.2018	0.21	0.3342		0.21	[−0.45; 0.86]	47.6%
Clifford et al.2018	−0.29	0.4493		−0.29	[−1.17; 0.59]	26.4%
Random effects model				**0.14**	**[−0.31; 0.59]**	**100.0%**

Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.49$

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: $I^2 = 27\%$, $\tau^2 = 0.0654$, $p = 0.26$

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: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.75$

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: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.52$

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: $I^2 = 88\%$, $\tau^2 = 1.2868$, $p < 0.01$

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%**

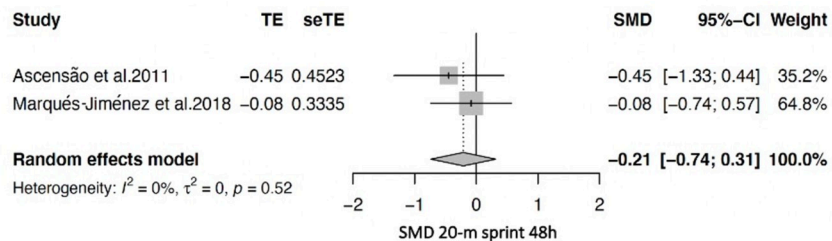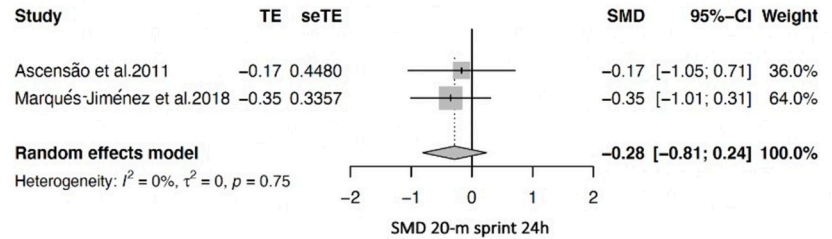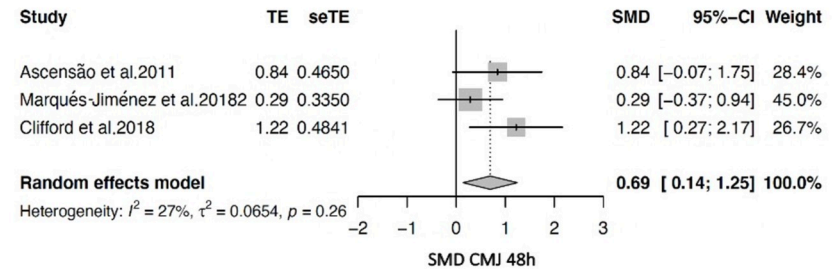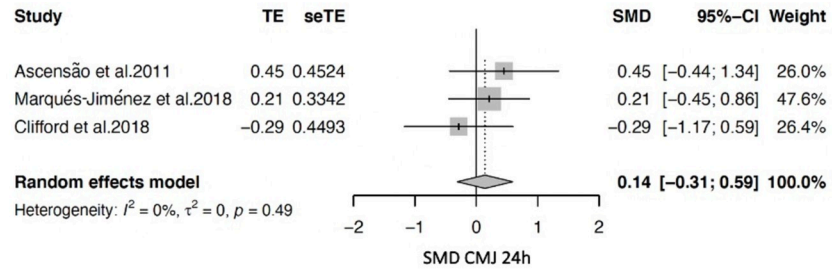Heterogeneity: $I^2 = 0\%$, $\tau^2 = 0$, $p = 0.99$

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.

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
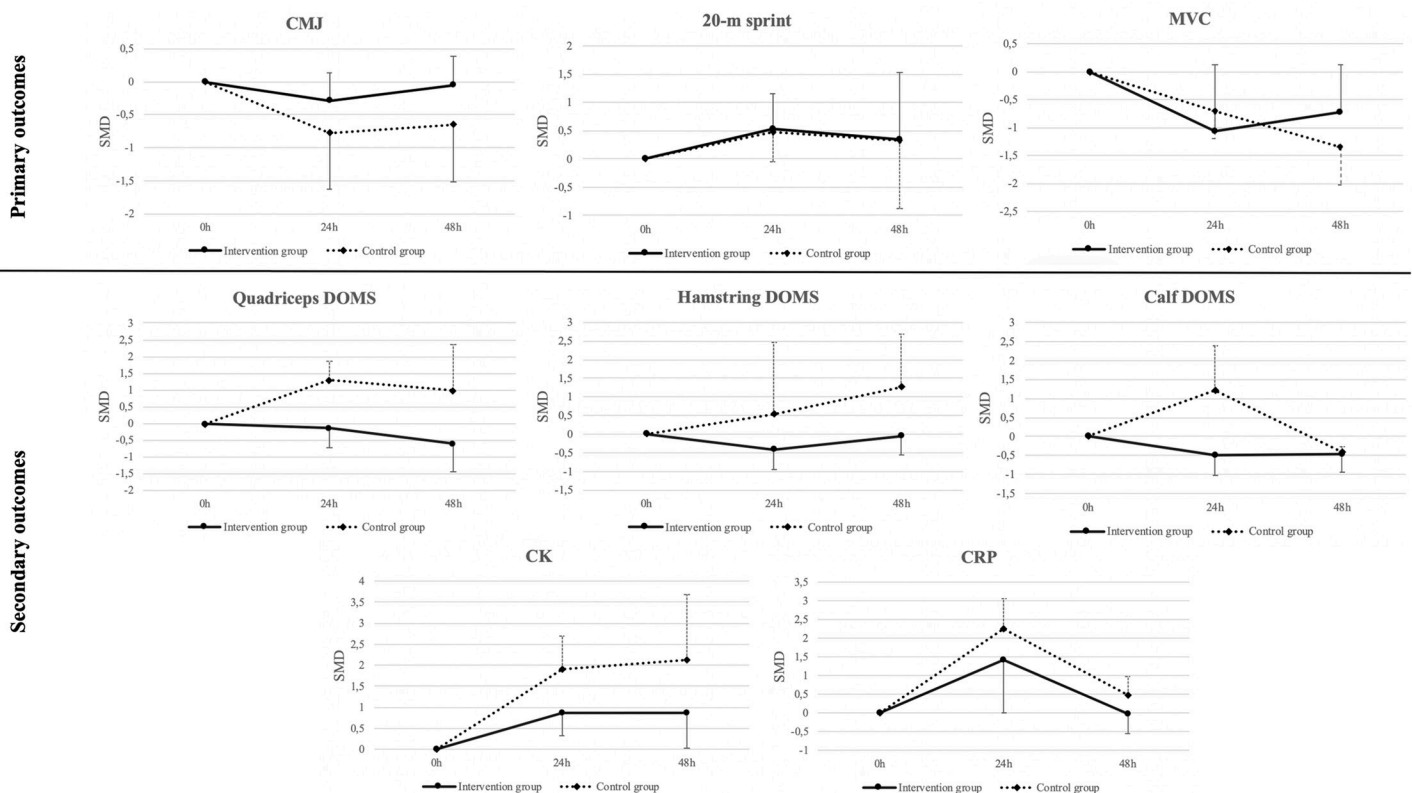

Fig 4. Time trends for primary and secondary outcomes from the experimental and control group.

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 timeframes 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)

Acknowledgments

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Writing – review & editing: Albert Altarriba-Bartes, Javier Peña, Jordi Vicens-Bordas, Julio Calleja-González.

References

1. Halson SL, Bartram J, West N, Stephens J, Argus CK, Driller MW, et al. Does hydrotherapy help or hinder adaptation to training in competitive cyclists? Med Sci Sports Exerc. 2014; 46: 1631–1639. https://doi.org/10.1249/MSS.0000000000000268 PMID: 24504431

2. Halson S. Recovery techniques for athletes. Aspetar Sport Med J. 2015; 4: 12–16.

3. Dupuy O, Douzi W, Theurot D, Bosquet L, Dugué B. An evidence-based approach for choosing post-exercise recovery techniques to reduce markers of muscle damage, {Soreness}, fatigue, and inflammation: {A} systematic review with meta-analysis. Front Physiol. 2018; 9: 403. https://doi.org/10.3389/fphys.2018.00403 PMID: 29755363

4. Bishop PA, Jones E, Woods AK. Recovery from training: A brief review. J Strength Cond Res. 2008; 22: 1015–1024. https://doi.org/10.1519/JSC.0b013e31816eb518 PMID: 18438210

5. Minett GM, Costello JT. Specificity and context in post-exercise recovery: it is not a one-size-fits-all approach. Front Physiol. 2015; 6: 130. https://doi.org/10.3389/fphys.2015.00130 PMID: 25964762

6. Hausswirth C, Le Meur Y. Physiological and nutritional aspects of post-exercise recovery: specific recommendations for female athletes. Sports Med. 2011; 41: 861–82. https://doi.org/10.2165/11593180-000000000-00000 PMID: 21923203

7. Barnett A. Using recovery modalities between training sessions in elite athletes. Sport Med. 2006; 36: 781–796. https://doi.org/10.2165/00007256-200636090-00005 PMID: 16937953

8. Calleja-González J, Terrados N, Mielgo-Ayuso J, Delextrat A, Jukic I, Vaquera A, et al. Evidence-based post-exercise recovery strategies in basketball. Phys Sportsmed. 2016; 44: 74–78. https://doi.org/10.1080/00913847.2016.1102033 PMID: 26512912

9. Poppendieck W, Wegmann M, Ferrauti A, Kellmann M, Pfeiffer M, Meyer T. Massage and performance recovery: A meta-analytical review. Sport Med. 2016; 46: 183–204. https://doi.org/10.1007/s40279-015-0420-x PMID: 26744335

10. Marin PJ, Zarzuela R, Zarzosa F, Herrero AJ, Garatachea N, Rhea MR, et al. Whole-body vibration as a method of recovery for soccer players. Eur J Sport Sci. 2012; 12: 2–8. https://doi.org/10.1080/17461391.2010.536579

11. Terrados N, Mielgo-Ayuso J, Delextrat A, Ostojic SM, Calleja-González J. Dietetic- nutritional, physical and physiological recovery methods post-competition in team sports. A review. J Sports Med Phys Fitness. 2018 [cited 30 Jan 2019]. https://doi.org/10.23736/S0022-4707.18.08169–0

12. Luttrell MJ, Halliwill JR. Recovery from exercise: vulnerable state, window of opportunity, or crystal ball? Front Physiol. 2015; 6: 204. https://doi.org/10.3389/fphys.2015.00204 PMID: 26257656

13. Ostojic SM. Editorial: Post-exercise recovery: fundamental and interventional physiology. Front Physiol. 2016; 7: 3. https://doi.org/10.3389/fphys.2016.00003 PMID: 26834646

14. Strudwick A. Contemporary issues in the physical preparation of elite players. 1st ed. In: Williams A, editor. Science and soccer: developing elite performers. 1st ed. London: Routledge; 2012. pp. 335–56.

15. Kellmann M. Current status and directions of recovery research. 1st ed. In: Kellman M, editor. Enhancing Recovery: Preventing Underperformance in Athletes. 1st ed. Champaign, IL: Human Kinetics; 2002. pp. 301–311.

16. Doeven SH, Brink MS, Frencken WGP, Lemmink KAPM. Impaired player-coach perceptions of exertion and recovery during match congestion. Int J Sports Physiol Perform. 2017; 12: 1151–1156. https://doi.org/10.1123/ijspp.2016-0363 PMID: 28095076

17. Dupont G, Nédélec M, McCall A, McCormack D, Berthoin S, Wisløff U. Effect of 2 soccer matches in a week on physical performance and injury rate. Am J Sports Med. 2010; 38: 1752–8. https://doi.org/10.1177/0363546510361236 PMID: 20400751

18. Dupont G, Nédélec M, McCall A, Berthoin S, Maffiulletti N. Football recovery strategies. Practical aspects of blending science and reality. Aspetar Sport Med J. 2015; 4: 20–27.

19. Bengtsson H, Ekstrand J, Hägglund M. Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013; 47: 743–7. https://doi.org/10.1136/bjsports-2013-092383 PMID: 23851296

20. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. Br J Sports Med. 2010; 44: 809–15. https://doi.org/10.1136/bjsm.2009.069476 PMID: 20511621

21. Schmikli SL, Brink MS, de Vries WR, Backx FJG. Can we detect non-functional overreaching in young elite soccer players and middle-long distance runners using field performance tests? Br J Sports Med. 2011; 45: 631–636. https://doi.org/10.1136/bjsm.2009.067462 PMID: 20404001

22. Doeven SH, Brink MS, Kosse SJ, Lemmink KAPM. Postmatch recovery of physical performance and biochemical markers in team ball sports: a systematic review. BMJ open Sport Exerc Med. 2018; 4: e000264. https://doi.org/10.1136/bmjsem-2017-000264 PMID: 29527320

23. Krustrup P, Mohr M, Steensberg A, Bencke J, Kjaer M, Bangsbo J. Muscle and blood metabolites during a soccer game: implications for sprint performance. Med Sci Sports Exerc. 2006; 38: 1165–74. https://doi.org/10.1249/01.mss.0000222845.89262.cd PMID: 16775559

24. Rampinini E, Bosio A, Ferraresi I, Petruolo A, Morelli A, Sassi A. Match-related fatigue in soccer players. Med Sci Sports Exerc. 2011; 43: 2161–2170. https://doi.org/10.1249/MSS.0b013e31821e9c5c PMID: 21502891

25. Romagnoli M, Sanchis-Gomar F, Alis R, Risso-Ballester J, Bosio A, Graziani RL, et al. Changes in muscle damage, inflammation, and fatigue-related parameters in young elite soccer players after a match. J Sports Med Phys Fitness. 2016; 56: 1198–1205. Available: http://www.ncbi.nlm.nih.gov/pubmed/26558831 PMID: 26558831

26. Magalhães J, Rebelo A, Oliveira E, Silva JR, Marques F, Ascensão A. Impact of Loughborough Intermittent Shuttle Test versus soccer match on physiological, biochemical and neuromuscular parameters. Eur J Appl Physiol. 2010; 108: 39–48. https://doi.org/10.1007/s00421-009-1161-z PMID: 19756713

27. Andersson H, Raastad T, Nilsson J, Paulsen G, Garthe I, Kadi F. Neuromuscular fatigue and recovery in elite female soccer: effects of active recovery. Med Sci Sports Exerc. 2008; 40: 372–80. https://doi.org/10.1249/mss.0b013e31815b8497 PMID: 18202563

28. Ispirlidis I, Fatouros IG, Jamurtas AZ, Nikolaidis MG, Michailidis I, Douroudos I, et al. Time-course of changes in inflammatory and performance responses following a soccer game. Clin J Sport Med. 2008; 18: 423–31. https://doi.org/10.1097/JSM.0b013e3181818e0b PMID: 18806550

29. Ascensão A, Rebelo A, Oliveira E, Marques F, Pereira L, Magalhães J. Biochemical impact of a soccer match—analysis of oxidative stress and muscle damage markers throughout recovery. Clin Biochem. 2008; 41: 841–51. https://doi.org/10.1016/j.clinbiochem.2008.04.008 PMID: 18457670

30. Silva JR, Rumpf MC, Hertzog M, Castagna C, Farooq A, Girard O, et al. Acute and residual soccer match-related fatigue: A systematic review and meta-analysis. Sports Med. 2018; 48: 539–583. https://doi.org/10.1007/s40279-017-0798-8 PMID: 29098658

31. Doeven SH, Brink MS, Kosse SJ, Lemmink KAPM. Postmatch recovery of physical performance and biochemical markers in team ball sports: a systematic review. BMJ open Sport Exerc Med. 2018; 4: e000264. https://doi.org/10.1136/bmjsem-2017-000264 PMID: 29527320

32. Marqués-Jiménez D, Calleja-González J, Arratibel I, Terrados N. Relevant biochemical markers of recovery process in soccer. Arch Med Deport. 2016. Available: http://archivosdemedicinadeldeporte.com/articulos/upload/rev02_marques-ingles.pdf

33. Carling C, Le Gall F, Dupont G. Are physical performance and injury risk in a professional soccer team in match-play affected over a prolonged period of fixture congestion? Int J Sports Med. 2012; 33: 36–42. https://doi.org/10.1055/s-0031-1283190 PMID: 22012641

34. Dellal A, Lago-Peñas C, Rey E, Chamari K, Orhant E. The effects of a congested fixture period on physical performance, technical activity and injury rate during matches in a professional soccer team. Br J Sports Med. 2015; 49: 390–4. https://doi.org/10.1136/bjsports-2012-091290 PMID: 23422422

35. Linke D, Link D, Weber H, Lames M. Decline in match running performance in football is affected by an increase in game interruptions. J Sports Sci Med. 2018; 17: 662–667. Available: http://www.ncbi.nlm.nih.gov/pubmed/30479536 PMID: 30479536

36. Lago-Peñas C, Rey E, Lago-Ballesteros J, Casáis L, Domínguez E. The influence of a congested calendar on physical performance in elite soccer. J strength Cond Res. 2011; 25: 2111–7. https://doi.org/10.1519/JSC.0b013e3181eccdd2 PMID: 21572352

37. Carling C, Le Gall F, Dupont G. Analysis of repeated high-intensity running performance in professional soccer. J Sports Sci. 2012; 30: 325–336. https://doi.org/10.1080/02640414.2011.652655 PMID: 22248291

38. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer: part I—post-match fatigue and time course of recovery. Sport Med. 2012; 42: 997–1015. https://doi.org/10.2165/11635270-000000000-00000 PMID: 23046224

39. Hawkins RD, Hulse MA, Wilkinson C, Hodson A, Gibson M. The association football medical research programme: an audit of injuries in professional football. Br J Sports Med. 2001; 35: 43–7. https://doi.org/10.1136/bjsm.35.1.43 PMID: 11157461

40. Ekstrand J, Waldén M, Hägglund M. A congested football calendar and the wellbeing of players: correlation between match exposure of European footballers before the World Cup 2002 and their injuries and performances during that World Cup. Br J Sports Med. 2004; 38: 493–7. https://doi.org/10.1136/bjsm.2003.009134 PMID: 15273193

41. Benjamin HJ, Boniquit NT, Hastings ES. The Traveling Athlete. Adolesc Med State Art Rev. 2015; 26: 189–207. Available: http://www.ncbi.nlm.nih.gov/pubmed/26514039 PMID: 26514039

42. Calleja-González J, Mielgo-Ayuso J, Sampaio J, Delextrat A, Ostojic SM, Marques-Jiménez D, et al. Brief ideas about evidence-based recovery in team sports. J Exerc Rehabil. 2018; 14: 545–550. https://doi.org/10.12965/jer.1836244.122 PMID: 30276172

43. Rowell AE, Aughey RJ, Hopkins WG, Stewart AM, Cormack SJ. Identification of sensitive measures of recovery after external load from football match play. Int J Sports Physiol Perform. 2017; 12: 969–976. https://doi.org/10.1123/ijspp.2016-0522 PMID: 27967334

44. Russell M, Sparkes W, Northeast J, Cook CJ, Bracken RM, Kilduff LP. Relationships between match activities and peak power output and Creatine Kinase responses to professional reserve team soccer match-play. Hum Mov Sci. 2016; 45: 96–101. https://doi.org/10.1016/j.humov.2015.11.011 PMID: 26615476

45. Andersson H, Karlsen A, Blomhoff R, Raastad T, Kadi F. Active recovery training does not affect the antioxidant response to soccer games in elite female players. Br J Nutr. 2010; 104: 1492–1499. https://doi.org/10.1017/S0007114510002394 PMID: 20609267

46. Silva JR, Ascensão A, Marques F, Seabra A, Rebelo A, Magalhães J. Neuromuscular function, hormonal and redox status and muscle damage of professional soccer players after a high-level competitive match. Eur J Appl Physiol. 2013; 113: 2193–201. https://doi.org/10.1007/s00421-013-2633-8 PMID: 23661147

47. Calleja-González J, Mielgo-Ayuso J, Sampaio J, Delextrat A, Ostojic SM, Marqués-Jiménez D, et al. Brief ideas about evidence-based recovery in team sports. J Exerc Rehabil. 2018; 14: 545–550. https://doi.org/10.12965/jer.1836244.122 PMID: 30276172

48. Rey E, Padrón-Cabo A, Barcala-Furelos R, Casamichana D, Romo-Pérez V. Practical active and passive recovery strategies for soccer players. Strength Cond J. 2018; 40: 45–57. https://doi.org/10.1519/SSC.0000000000000247

49. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer. Sport Med. 2013; 43: 9–22.

50. Abaïdia A-E, Dupont G. Recovery strategies for football players. Swiss Sport Exerc Med. 2018; 66: 28–36.

51. Van Hooren B, Peake JM. Do we need a cool-down after exercise? A narrative review of the psycho-physiological effects and the effects on performance, injuries and the long-term adaptive response. Sport Med. 2018; 48: 1575–1595. https://doi.org/10.1007/s40279-018-0916-2 PMID: 29663142

52. Ortiz ROJ, Sinclair Elder AJ, Elder CL, Dawes JJ. A Systematic review on the effectiveness of active Recovery interventions on athletic performance of professional-, collegiate-, and competitive-level adult

athletes. J strength Cond Res. 2018. https://doi.org/10.1519/JSC.0000000000002589 PMID: 29742750

53. Rey E, Lago-Peñas C, Lago-Ballesteros J, Casáis L. The effect of recovery strategies on contractile properties using tensiomyography and perceived muscle soreness in professional soccer players. J Strength Cond Res. 2012; 26: 3081–3088. https://doi.org/10.1519/JSC.0b013e3182470d33 PMID: 22210472

54. Rey E, Lago-Peñas C, Casáis L, Lago-Ballesteros J. The effect of immediate post-training active and passive recovery interventions on anaerobic performance and lower limb flexibility in professional soccer players. J Hum Kinet. 2012; 31: 121–129. https://doi.org/10.2478/v10078-012-0013-9 PMID: 23486836

55. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effect of post-match cold-water immersion on subsequent match running performance in junior soccer players during tournament play. J Sports Sci. 2011; 29: 1–6. https://doi.org/10.1080/02640414.2010.512640 PMID: 21077001

56. Rowsell GJ, Coutts AJ, Reaburn P, Hill-Haas S. Effects of cold-water immersion on physical performance between successive matches in high-performance junior male soccer players. J Sports Sci. 2009; 27: 565–73. https://doi.org/10.1080/02640410802603855 PMID: 19308790

57. Ascensão A, Leite M, Rebelo AN, Magalhaes S, Magalhaes J. Effects of cold water immersion on the recovery of physical performance and muscle damage following a one-off soccer match. J Sports Sci. 2011; 29: 217–225. https://doi.org/10.1080/02640414.2010.526132 PMID: 21170794

58. De Nardi M, Torre ALA, Barassi A, Ricci C, Banfi G. Effects of cold-water immersion and contrast-water therapy after training in young soccer players. J Sports Med Phys Fitness. 2011; 51: 609–615. PMID: 22212263

59. Rey E, Padron-Cabo A, Costa P, Barcala-Furelos R. The effects of foam rolling as a recovery tool in professional soccer players. J strength Cond Res. 2017. https://doi.org/10.1519/JSC.0000000000002277 PMID: 29016479

60. Tessitore A, Meeusen R, Cortis C, Capranica L. Effects of different recovery interventions on anaerobic performances following preseason soccer training. J strength Cond Res. 2007; 21: 745–50. https://doi.org/10.1519/R-20386.1 PMID: 17685701

61. Valle X, Til L, Drobnic F, Turmo A, Montoro JB, Valero O, et al. Compression garments to prevent delayed onset muscle soreness in soccer players. Muscles Ligaments Tendons J. 2013; 3: 295–302. Available: http://www.ncbi.nlm.nih.gov/pubmed/24596693 PMID: 24596693

62. Kinugasa T, Kilding AE. A comparison of post-match recovery strategies in youth soccer players. J strength Cond Res. 2009; 23: 1402-1407. https://doi.org/10.1519/JSC.0b013e3181a0226a PMID: 19620926

63. García-Concepción MA, Peinado AB, Paredes Hernández V, Alvero-Cruz JR. Efficacy of different recovery strategies in elite football players. Rev Int Med y Ciencias la Act Física y del Deport. 2015; 15: 355–389. Available: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84932106411&partnerID=40&md5=1d10d1d374dcf55cade83775d3b1f0a5

64. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA Statement. PLoS Med. 2009; 6: e1000097. https://doi.org/10.1371/journal.pmed.1000097 PMID: 19621072

65. Shamseer L, Moher D, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015; 350: g7647. Available: http://www.ncbi.nlm.nih.gov/pubmed/25555855 https://doi.org/10.1136/bmj.g7647 PMID: 25555855

66. Higgins J, Green S. Cochrane handbook for systematic reviews of interventions | Cochrane Training. 2008 [cited 22 Oct 2018]. Available: https://training.cochrane.org/handbook

67. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011; 343: d5928. Available: http://www.ncbi.nlm.nih.gov/pubmed/22008217 https://doi.org/10.1136/bmj.d5928 PMID: 22008217

68. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986; 7: 177–88. https://doi.org/10.1016/0197-2456(86)90046-2 PMID: 3802833

69. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. New York: Routledge; 1988. https://doi.org/10.1234/12345678

70. Clifford T, Abbott W, Kwiecien SY, Howatson G, McHugh MP. Cryotherapy reinvented: application of phase change material for recovery in elite soccer. Int J Sport Physiol Perform. 2018; 13: 584–589. https://doi.org/10.1123/ijspp.2017-0334 PMID: 28872368

71. Fullagar H, Skorski S, Duffield R, Meyer T. The effect of an acute sleep hygiene strategy following a late-night soccer match on recovery of players. Chronobiol Int. 2016; 33: 490–505. https://doi.org/10.3109/07420528.2016.1149190 PMID: 27031035

72. Marqués-Jiménez D, Calleja-González J, Arratibel-Imaz I, Delextrat A, Uriarte F, Terrados N. Physiological and physical responses to wearing compression garments during soccer matches and recovery. J Sports Med Phys Fitness. 2018a; 58: 1642–1651. https://doi.org/10.23736/S0022-4707.17.07831-8 PMID: 28738672

73. Marqués-Jiménez D, Calleja-González J, Arratibel-Imaz I, Delextrat A, Uriarte F, Terrados N. Influence of different types of compression garments on exercise-induced muscle damage markers after a soccer match. Res Sports Med. 2018b; 26: 27–42. https://doi.org/10.1080/15438627.2017.1393755 PMID: 29082755

74. Haugen T, Buchheit M. Sprint running performance monitoring: methodological and practical considerations. Sport Med. 2016; 46: 641–656. https://doi.org/10.1007/s40279-015-0446-0 PMID: 26660758

75. Marginson V, Rowlands A V., Gleeson NP, Eston RG. Comparison of the symptoms of exercise-induced muscle damage after an initial and repeated bout of plyometric exercise in men and boys. J Appl Physiol. 2005; 99: 1174–1181. https://doi.org/10.1152/japplphysiol.01193.2004 PMID: 15817716

76. Thomas K, Dent J, Howatson G, Goodall S. Etiology and recovery of neuromuscular fatigue after simulated soccer match Play. Med Sci Sports Exerc. 2017; 49: 955–964. https://doi.org/10.1249/MSS.0000000000001196 PMID: 28060035

77. Crowther F, Sealey R, Crowe M, Edwards A, Halson S. Team sport athletes' perceptions and use of recovery strategies: a mixed-methods survey study. BMC Sports Sci Med Rehabil. 2017; 9: 6. https://doi.org/10.1186/s13102-017-0071-3 PMID: 28250934

78. Crowther F, Sealey R, Crowe M, Edwards A, Halson S. Influence of recovery strategies upon performance and perceptions following fatiguing exercise: a randomized controlled trial. BMC Sports Sci Med Rehabil. 2017; 9. https://doi.org/10.1186/s13102-017-0087-8 PMID: 29299318