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REVIEW ARTICLE

Effects of cryoimmersion in the recovery of post-exercise muscle pain: systematic review with meta-analysis

Efeitos da crioimersão na recuperação da dor muscular pós-exercício: revisão sistemática com meta-análise

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ABSTRACT

BACKGROUND AND OBJECTIVES: Cryotherapy is a resource widely used in rehabilitation and sport, mainly to reduce pain and improve recovery in athletes. The objective of this study was to determine the effects of immersion cryotherapy on the perception of muscle pain in athletes from different sports.

METHODS: The studies were collected by searching the following databases**:** Pubmed, Embase, The Cochrane Library, The Physiotherapy Evidence Database (PEDro), Scopus, Web of Science and LILACS. As well as the following gray literature**:** Google Scholar, LIVIVO, Open Grey and the CAPES Catalog of Theses and Dissertations. The risk of bias assessment was conducted using Cochrane's RoB 2 tool. The primary outcome was muscle pain/ perception of soreness, and the secondary outcome was perception of recovery.

RESULTS: Nine randomized clinical trials were selected. The meta-analysis included two studies on the muscle pain/ perception of soreness outcome. The combined analysis suggests that, overall, the intervention has a statistically significant effect on reducing the measure evaluated (SMD = -0.64, [-1.27, -0.02], p = 0.04); I^2 = 0%. However, specific analyses of 24 h (p=0.24), 48 h (p=0.10) and 72 h (p=0.50) post-intervention individually did not show statistical significance.

CONCLUSION: Cold water immersion can have beneficial effects on reducing muscle pain, but the lack of primary studies of high methodological quality prevents certainty in this statement.

KEYWORDS: Athletes, Cryotherapy, Pain measurement.

RESUMO

JUSTIFICATIVA E OBJETIVOS: A crioterapia é um recurso muito utilizado na reabilitação e no esporte, para este, principalmente visando reduzir a dor e melhorar a recuperação de atletas. O objetivo deste estudo foi analisar uma revisão sistemática sobre os efeitos da crioterapia de imersão na percepção da dor muscular em atletas de diferentes modalidades desportivas.

MÉTODOS: Os estudos foram recolhidos através da pesquisa nas seguintes bases de dados**:** Pubmed, Embase, *The Cochrane Library*, *The Physiotherapy Evidence Database* (PEDro), Scopus, *Web of Science* e LILACS. Assim como a seguinte literatura cinzenta**:** *Google Scholar*, LIVIVO, *Open Grey* e o Catálogo de Teses e Dissertações da CAPES. A avaliação do risco de viés foi realizada utilizando a ferramenta RoB 2 da Cochrane. O desfecho primário foi a dor muscular/percepção de dor e o desfecho secundário foi a percepção de recuperação.

RESULTADOS: Foram selecionados nove ensaios clínicos aleatórios. A meta-análise incluiu dois estudos sobre o resultado dor muscular/percepção de dor. A análise combinada sugere que, globalmente, a intervenção tem um efeito estatisticamente significativo na redução da medida avaliada (DMP = -0,64, [-1,27,-0,02], p=0,04); I^2 = 0%. No entanto, análises específicas de 24 h (p=0,24), 48 h (p=0,10) e 72 h (p=0,50) pós-intervenção, individualmente, não apresentaram significância estatística.

CONCLUSÃO: A imersão em água fria pode ter efeitos benéficos na redução da dor muscular, mas a falta de estudos primários de alta qualidade metodológica impede a certeza dessa afirmação.

DESCRITORES: Atletas, Crioterapia, Medição da dor.

HIGHLIGHTS

- Cryotherapy is a therapeutic modality that aims to reduce tissue temperature in order to reduce pain and metabolism
- This tool is widely used in sports, but its protocols are still lacking a better foundation
- In this systematic review, it was possible to observe a reduction in pain in athletes who underwent cryoimmersion

INTRODUCTION

Cryotherapy is a method in which a substance is used to remove heat from the body, resulting in a reduction in tissue temperature, to achieve therapeutic goals (curative and/or preventive)[1,2]. The effectiveness of the treatment depends on factors such as the period of application, the size of the treatment area, the level of physical activity carried out previously, and the application of the technique. The method results in analgesic repercussions and enables functional and structural restoration, facilitating rehabilitation performance. Pain tolerance can be increased when exposed to low temperatures, due to the reduction in nerve conduction velocity, making it difficult for nociceptive information to reach higher centers; reducing the production of inflammatory mediators due to reduced metabolism; release of beta-endorphins centrally, and all these mechanisms are important in the reduction in pain perception[3-8].

It is a fact that the routine of a high-performance athlete requires high physical and physiological demands, which are individual and specific to each sport. Such competitive demands can trigger some tensions in various physiological systems, such as the musculoskeletal system, thus, for the preparation of upcoming sporting events, post-exercise recovery strategies become essential, quickly returning performance to its natural state[9-11]. There are different methods for alleviating late onset muscle damage and soreness (DOMS), either alone or in combination, including cold water immersion, where there are huge differences in protocols[12].

There are still controversies regarding its effects and different protocols[13-16]. This gave rise to the research question: "Is cryoimmersion effective in reducing pain and discomfort in athletes?" Since systematic reviews condense the literature and seek to answer objective questions in a transparent way[17], this was the opted study design. The objective of the study was to analyze the effects of immersion cryotherapy on the perception of muscle pain in athletes from different sports.

CONTENTS

Protocol and registration

A systematic review in question followed and was documented in accordance with the standards established by the Preferred Reporting Items for Systematic Reviews and Meta- analysis (PRISMA). Registered with The Open Science Framework: https://doi.org/10.17605/OSF.IO/E7K52.

Eligibility criteria

The acronym PICOS was used to formulate the question focused on in this study: P - population: athletes of any sport; I - intervention: cryoimmersion; C - comparator: sitting, active recovery, rest, immobile in a semi-reclined position, passive recovery, immersion in thermo-neutral water, bioceramics, treadmill at a comfortable walking pace; O - outcomes: muscle pain / perception of soreness; S - study design: randomized clinical trials. There were no limitations on language or period and no filters were used, to obtain as many manuscripts as possible in the search. For the search strategy, the Boolean descriptors "AND" and "OR" were used, covering various terms, but in summary the strategy was: "Athletic Performance" OR "Sports Performance" AND "Cold Temperature" OR "Cold Temperature" OR "Cold Water Immersion" OR "Cold Temperatures" OR "Cold" OR "Cryotherapy" OR "Cryotherapy" OR "Cold Therapy" OR "Cryostimulation".

Inclusion criteria: men and women; athletes in soccer, volleyball, basketball, street racing, hockey, rugby or any other sport, regardless of level or sport; adolescents (16 to 19 years) and adults (19 to 33 years). Immersion temperature between 0 and 10 C°. Duration of the immersion intervention: minimum of 5 minutes and maximum of 20 minutes. Randomized clinical trials. Exclusion criteria: intervention not carried out after exercise; players who have been injured in the last 6 months; pregnant women; cold allergy; vascular diseases; lower limb surgery; literature and editorial reviews, systematic reviews, cohort studies, case reports, case studies.

Selection of studies and data collection

The studies were collected by searching the following databases: Pubmed, Embase, The Cochrane Library, The Physiotherapy Evidence Database (PEDro), Scopus, Web of Science and LILACS. As well as the following gray literature (i.e. databases other than the traditional): Google Scholar, LIVIVO, Open Grey and the CAPES Catalog of Theses and Dissertations. In a two-stage process, two independent reviewers (R1 and R2) selected the studies for inclusion. In the first stage, titles and abstracts were reviewed according to pre-defined eligibility criteria. In the subsequent stage, the full texts were analyzed, applying the same criteria used previously. In the event of disagreement, a consensus meeting was held between the two reviewers in both phases, and if necessary, differences were resolved by reviewer R3. Data was gathered to detail the properties of the studies, including information on the authors, the year in which they were published and the country of origin. The characteristics of the sample were also examined, such as the number of participants, average age and gender distribution, as well as the type of intervention applied, the times at which evaluations were carried out to measure the results and formulate a conclusion. The primary outcome observed was pain, while secondary outcomes included analyses of physical performance.

Individual assessment of the risk of bias in studies

An assessment of the risk of bias was conducted using Cochrane's ROB 2 tool by blind reviewers R1 and R2, and if necessary, differences were resolved by reviewer R3. The included studies were judged in five domains: bias in the randomization process, deviations from the intended intervention, bias due to missing data, bias in the measurement of outcomes and bias in the selection of reported results. Each domain was given an overall rating of low risk, unclear or high risk.

Assessing the risk of publication bias

In order to minimize the likelihood of publication bias, a comprehensive study was carried out, without language or period restrictions, and including grey literature. In this way, the possibility of publication bias was reduced, although not eliminated.

Meta-analysis

Statistical analysis was carried out using RevMan 5.4.1 (The Cochrane Collaboration, Software Update, Oxford, UK)[18]. Continuous results were expressed as standard mean differences (with ninety-five percent confidence intervals - 95% CI). A p-value of <0.05 was considered statistically significant. The value of the I^2 statistical test was calculated to test for heterogeneity between studies. An I^2 value ≥ 50% was considered significant heterogeneity. A random effects model was adopted.

RESULTS

Selection and summary of studies

During the search, 1.877 records were found, 1.699 in the main databases and 178 in the gray literature (Appendix A). The first search was carried out on December 1, 2023, and the last update on December 5, 2024. 783 duplicate studies were excluded automatically and manually. This left 1094 studies for Phase 1 (reading titles and abstracts). And 18 studies for Phase 2 (reading the full studies). This left 9 studies in this review (Apêndice A).

The entire process of selecting the studies, from the search and refinement to the final number of manuscripts analyzed, is shown in Figure 1, and their synthesis is presented in Table 1.

Analysis of the risk of bias of the studies

Nine randomized clinical trials were selected. The assessment of risk of bias with Cochrane's RoB 2 tool identified greater compromise in the randomization process, with studies[12,19] presenting high risk, while study[21] demonstrated low risk. In deviations from planned interventions, most studies, such as[13,22], presented low risk, but the article[12] raised some concern. In incomplete outcome data, asticles[15,20] had low risk, while[19] showed some concern. When measuring the outcome, studies[14,21] were classified as low risk, but study[12] showed some concern. For the selection of outcomes reported, articles[13,15] showed low risk, while[19] was classified at high risk. The results highlight the need for greater rigor in randomization, although robust practices have been observed in other domains.

Finally, the general analysis of bias showed that most of the included studies[13,15,16,19,21] were considered to have an unclear risk of bias and three studies[12,14,22] presented a high risk of bias (Figures 2 and 3).

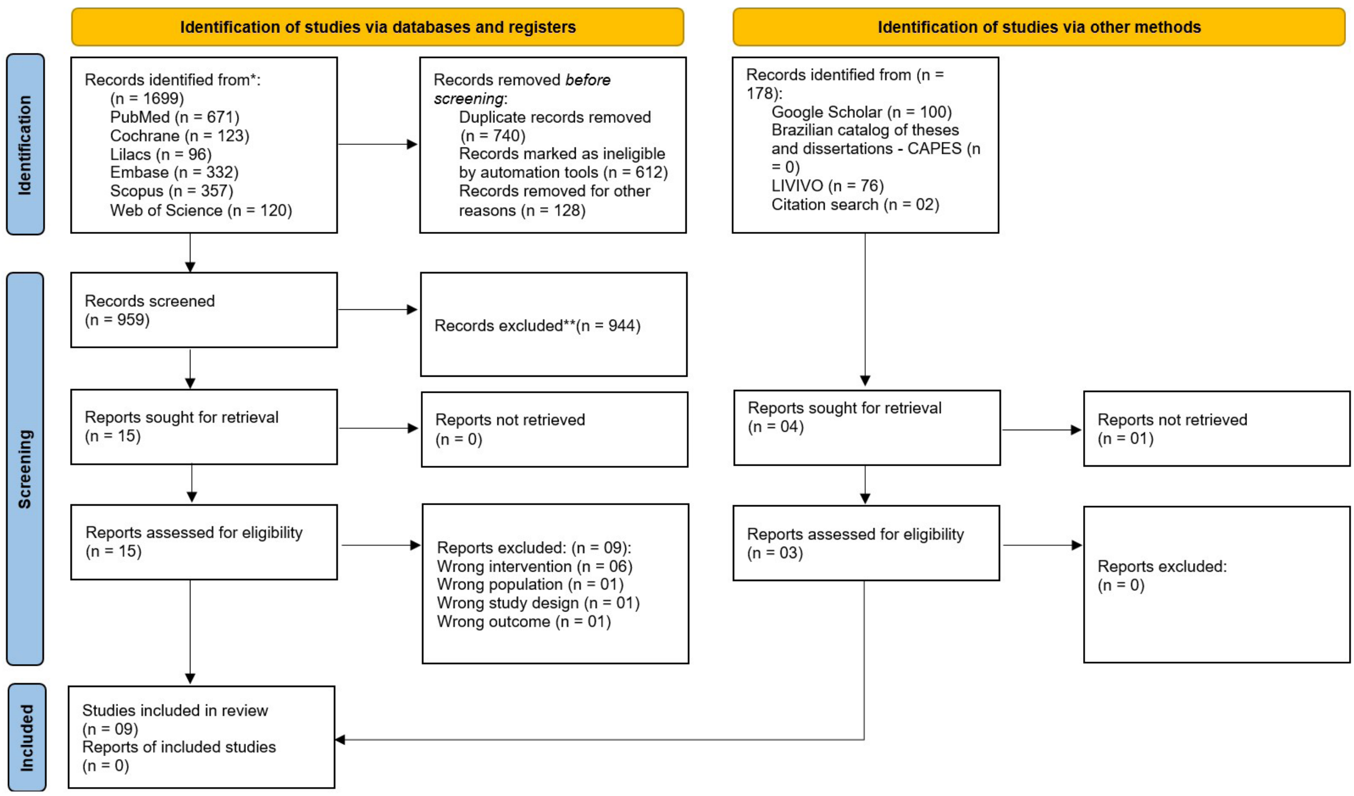

Figure 1. PRISMA flow diagram for new systematic reviews.

Table 1. Summary characteristics of the randomized clinical trials included in this review (n = 09).

Author/ Country	Study design	Sample size	Interventions	Follow-up time	Sport	Outcomes Measured	Main conclusion
Alexander et al.[19] United Kingdom	Randomized clinical trial	n = 24 EG: n = n/i CG: n = n/i Age: 20.58 ± 2.55 Gender: M	EG: CWI, 10°C, for 11 min CG: PAS	T0) Pre-Training T1) Immediately post-training T2) Immediately post-intervention T3)24hpost-intervention	Football (Elite)	Muscle soreness: Five-point scale, (1-5))	The present results suggest that cryotherapy, applied as an immediate single bout of cold-water immersion after a soccer match, effectively reduces some biochemical, functional, and perceptual markers of muscle damage.
Ascensão et al.[12] Portugal	Randomized clinical trial	n = 20 EG: n = 10 CG: n = 10 Age: CG: 18.3+0.8 EG: 18.1+1.8 Gender: M	EG: CWI, 10°C, for 10 min CG: 10 min thermoneutral water immersion, 35°C	T0) Baseline T1) 30 min of the end T2) 24h after the match T3) 48h after the match	Soccer (National league teams)	Muscle pain: Scale from 0 (“absence of soreness”) to 10 (“very intense soreness”).	Cryotherapy immediately after a soccer match effectively reduces some markers of muscle damage despite conflicting research on muscle adaptation mechanisms.
Coelho et al.[20] Brazil	Randomized clinical trial	n = 25 EG (CWI): n = 09 EG (BIO): n = 08 CG: n = 08 Age: EG (BIO): 22.63 ± 4.2 EG (CWI): 22.63 ± 3.- CG: 20.8 ± 3.2 Gender: M	CWI: 10°C for 10 min BIO: Bioceramic CG: Seated	T0) Baseline T1) Postmatch T2) 24h postmatch T3) 48h postmatch	Soccer (Uviversity level)	Perception of soreness: DOMS (0 – 10) - 0 (“absence of soreness”) to 10 (“very intense soreness”) Perceived recovery: Scale of 0 (“very poorly recovered”) and 10 (“very well recovered”)	For 48-hour recovery of muscle damage, BIO and CWI do not provide conclusive evidence of enhancing functional and perceptual recovery after a soccer match, with BIO needing further research to be accepted as an effective recovery modality.
Dantas et al.[21] Brazil	Double-blind randomized clinical trial	n = 30 EG (I): n = 10 EG (CWI): n = 10 CG: n = 10 Age: EG (IG): 31.71 ±5.43-EG (CWIG):30.28± 6.10 CG: 33.00 ± 4.84 Gender: M	I: Immersed of temperature (29.8°C ± 0.66°C) for 10 min CWI: 10°C for 10 min CG: Rested	T1) Immediately post-running T2) Immediately post-intervention T3) 24h post-intervention	Street racing (recreactional)	Perception of soreness: - VAS (0 - 100 mm)	CWI at 10°C for 10 minutes has been widely used in clinical settings, but it is no more effective than water immersion and rest in recovering functional performance, torque and CK blood concentration in muscles damaged after 10-km street runs.
Getto and Golden[16] USA	Randomized clinical trial	n = 23 EG (CWI): n = 07 CG (AR): n = 08 CG (PAS): n = 08 Age: n/i Gender: 13 M, 10 F	CWI: 10°C for 10 min AR: Active recovery PAS: Passive recovery	T0) Baseline T1) Postexercise T2)24h postintervention	Football, volleyball, basketball (Collegiate athletes)	Perception of soreness: VAS-PS: 1 - 10, with 10 indicating the most soreness.	On the basis of our investigation, neither CWI or AR while immersed were deemed as more advantageous in the recovery of speed or power, compared with passive recovery when implemented after routine conditioning and training.

(n/i): not informed; M = male; F = female; Age = years; VAS = visual analogue scale; CG = control group; EG = experimental group; PG = placebo group; CWI = Cold-water immersion; NSP = Numerical scale of pain; TWI = Thermoneutral water immersion; ARG = athletes used a treadmill; h = hours; min = minutes; DOMS = delayed-onset muscle soreness; PAS = passive recovery; AR = active recovery; VAS-PS = Visual analogue scale for perceived soreness; BIO = Bioceramics.

Table 1. Continued...

Author/ Country	Study design	Sample size	Interventions	Follow-up time	Sport	Outcomes Measured	Main conclusion
Nunes et al.[15] Brazil	Randomized clinical trial	n = 19 EG (CWI): n = 11 CG: n = 08 Age: 2.1 ± 1.6 Gender: M	CWI: 10 °C for 10 min CG: Seated	T0) A week before T1) Baseline T2) Post the match T3) 30min after the match T4) 24h after the match T5) 48h after the match T6) 72h after the match	Rugby (Professional)	Perception of soreness: DOMS (0-10) 0 (absence of soreness) to 10 (very intense soreness). Perceived recovery: VAS (0 – 10) - from 0 (very poorly recovered) and 10 (high-perceived recovery).	A single bout of CWI accelerated recovery, especially in inflammation and neuromuscular function. The study suggests using more sensitive and specific markers to measure CWI effects, as some recovery markers in the CWI group were better than in the control group, supporting CWI for postmatch recovery in rugby players.
Krueger et al.[14] Germany	Randomized clinical trial	n = 18 EG (CWI): n = 09 CG: n = 09 Age: 16.6 ± 0.6 Sex: M	CWI: 5 to 8 °C (6.4±0.8 °C) for 5 min CG: PAS	T1) 1 Post day T2) 2 Pre day T3) 2 Post day T4) 3 Pre day T5) 3 Post day T6) 4 Pre day T7) 4 Post day T8) 5 Pre day T9) 5 Post day	Field hockey (Elite)	Perception of soreness: DOMS - VAS (100-mm) - 0 (no soreness) to 100 (severe soreness.).	Daily post-exercise CWI did not improve match performance, perceptual recovery, or biomarkers of muscle damage and metabolic load in elite youth field-hockey players.
Pesenti et al.[13] Brazil	Blind randomized clinical trial	n = 28 EG (CWI): n = 07 CG (TWI): n = 07 EG (AR): n = 07 CG: n = 07 Age: of 16 and 19 Gender: M	CWI: 10°C for 10 min TWI: 10 min AR: treadmill for 10 min CG: seated for 10 min	T0) Baseline T1) 24h follow up T2) 48h follow up T3) 72h follow up.	Soccer	Perception of soreness: -NSP (0 – 10).	No significant differences in observed variables, including DOMS, were found between interventions, indicating a need for further studies to develop effective recovery strategies for soccer players
Batista et al.[22] Brazil	Randomized-crossover placebo-controlled clinical trial	n = 20 Age: 14.05±1.79 Gender: 12 M/8F EG (CWI): n = 19 PG (TWI): n = 16 CG (PAS): n = 16	CWI: 14 ± 1°C TWI: 27 ± 1°C (as placebo) PAS: passive recovery	T1: Baseline T2: wash-out (1-week) T3: before and after each intervention week	Swimming (Competitive team)	Perceptive outcomes: (1 to 5) poor well-being, heaviness, tiredness, discomfort and pain.	The repeated use of CWI over the course of a training week had no impact on the functional or swimming performance outcomes of adolescent competitive swimmers. The preference for CWI as TWI was similar.

(n/i): not informed; M = male; F = female; Age = years; VAS = visual analogue scale; CG = control group; EG = experimental group; PG = placebo group; CWI = Cold-water immersion; NSP = Numerical scale of pain; TWI = Thermoneutral water immersion; ARG = athletes used a treadmill; h = hours; min = minutes; DOMS = delayed-onset muscle soreness; PAS = passive recovery; AR = active recovery; VAS-PS = Visual analogue scale for perceived soreness; BIO = Bioceramics.

Characteristics of the included studies

Of the nine studies included in this review, only one was a randomized-crossover placebo-controlled clinical trial [19], the others were randomized clinical trials.

Several sports modalities were included in this review. football[16]; soccer[12,13,19]; street running[21]; football, volleyball and basketball[16]; hockey[14]; rugby[15] and swimming[22].

The total number of athletes sampled was 207, only two studies included females with an n = 18[16,22]. The remaining volunteers were male n = 189.

Most of the studies were conducted in Brazil[13,15,19-21]. The others in the United Kingdom[22]; Portugal[12]; United States of America[16] and Germany[14].

Collection instruments

Various instruments were used to measure the outcomes in this study. The perception of soreness/muscle pain outcome was assessed using a scale from 0 to 10[12,13,15,19]; from 1 to 10[16] from 0 to 100[21]; from 1 to 5[19,22]. However, in all the different instruments the Likert scale used the same interpretation, the higher the worse.

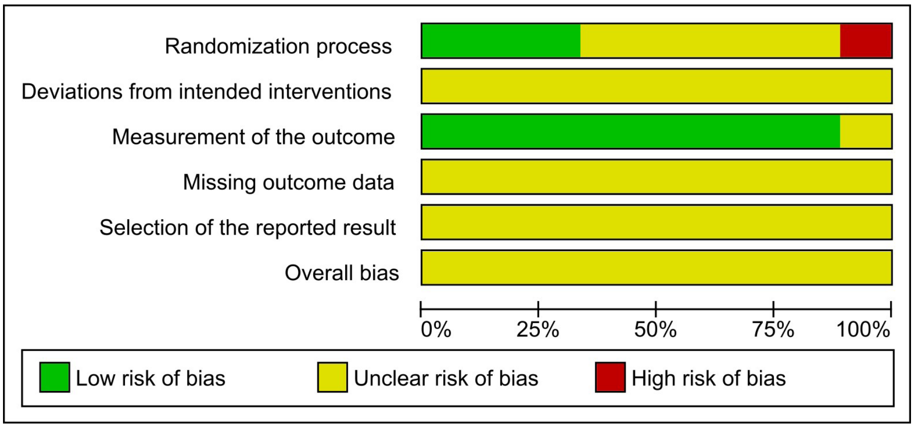

Figure 2. Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies.

The perception of soreness/muscle pain outcome was assessed in studies[14,21], which used the Visual Analog Scale (VAS - 0 to 100); the authors[16] used the Visual Analog Scale for perceived pain (VAS-PS; 1-10); the study[13] used the self-reported psychometric questionnaire and numerical pain scale (NSP – 0 to 10). The delayed onset muscle soreness (DOMS; 0 - 10) was measured in the studies[15,20]. Muscle soreness (1 – 5) was measured in study[19] and just pain (1 -5) in study[22]; finally, muscle pain (0 - 10) was measured in study[12].

Primary outcome - muscle pain/ perception of soreness

In three studies, a reduction in delayed onset muscle pain (DOMS) levels was observed[12,13,22]. However, six other studies found no advantages to the method[12-14,16,17,21].

Meta-analysis

Due to the great diversity in the studies, it was possible to include only two for meta-analysis[13,21], and only for the muscle pain intensity outcome.

The meta-analysis did not show a statistically significant difference between the experimental and control groups at 24 hours ($p = 0.24$). The lack of variability in the data from study[21] made it impossible to include the results in the combined estimate. Similarly, there was no significant difference at 48 ($p = 0.10$) and 72 hours ($p = 0.50$). However, there was a standard mean difference of -1.00 with a 95% confidence interval of [-1.27, -0.02], which is statistically significant ($p = 0.04$). Heterogeneity was low ($I^2 = 0\%$), indicating consistency between the studies. The test for differences between subgroups was not significant ($p = 0.75$), indicating that there was no significant difference in the effects between the different post-intervention periods.

The combined analysis suggests that, overall, the intervention has a statistically significant effect on reducing the measure evaluated (SMD = -0.64, $p = 0.04$). However, specific analyses of 24 h, 48 h and 72 h post-intervention individually did not show statistical significance, a cutoff value greater than 2 points of NPRS is considered clinically relevant. Thus, the high risk of bias of the studies must be considered, as well as the small sample size (Figure 4).

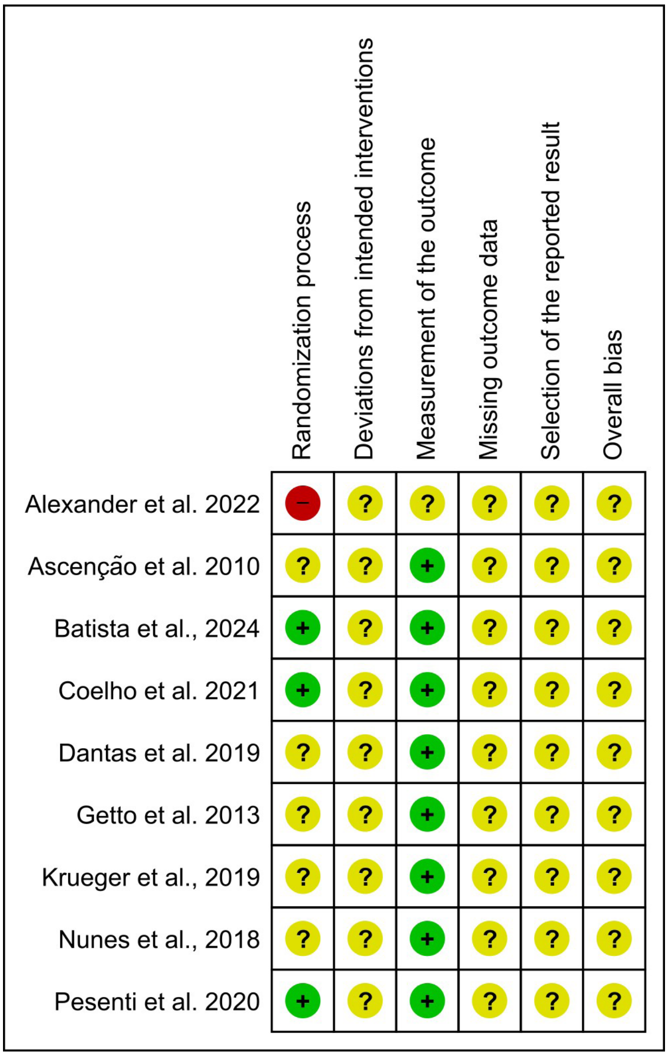

Figure 3. Risk of bias summary: review authors' judgments about each risk of bias item for each included study.

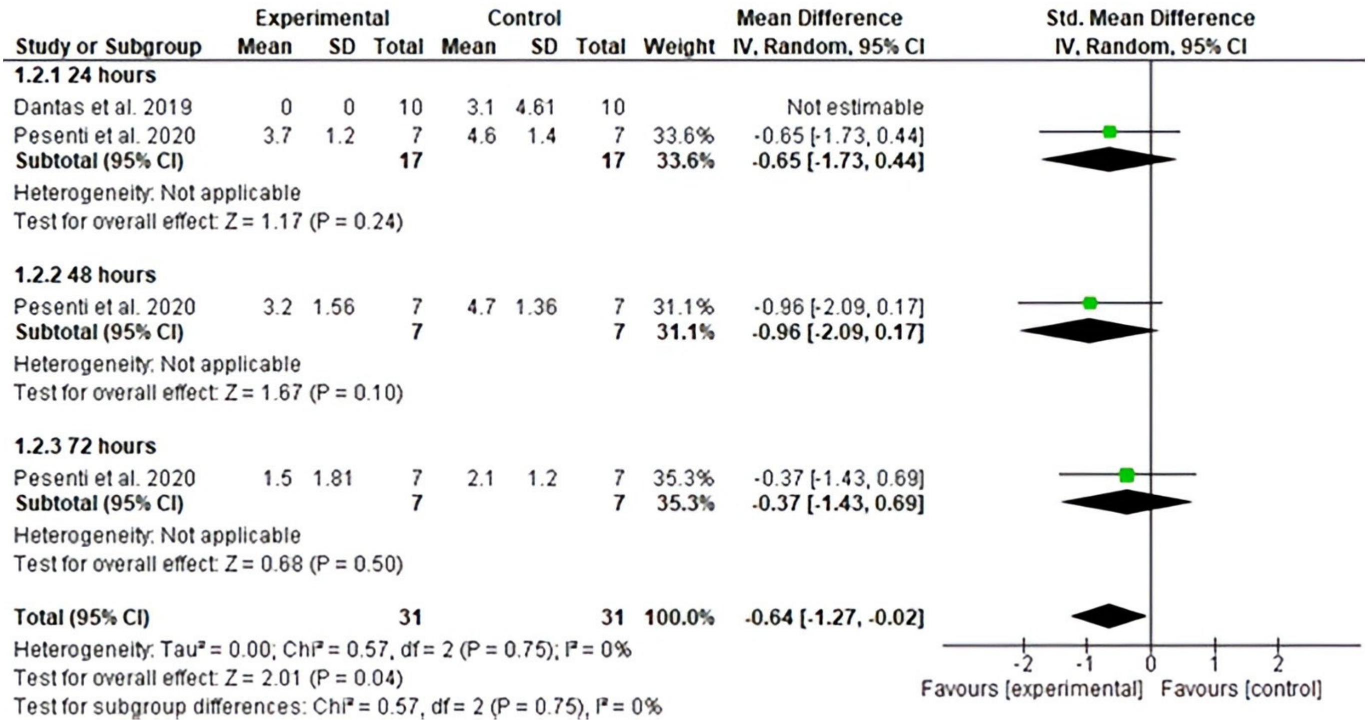

Figure 4. Forest plot of the comparison between cryoimmersion vs. control at rest - outcome muscle pain intensity.

DISCUSSION

The cold-water immersion technique is known as one of the most popular post-exercise intervention strategies and can be used in a variety of situations, such as reducing ITD, aiding recovery from muscle damage and maintaining physical performance after repetitive high-level training and competitions[1,13,15]. In this sense, it was possible to identify that only three studies showed favorable results for the use of post-exercise cryoimmersion, influencing various physiological aspects, such as DOMS, physical performance or muscle damage. The purpose of this study was to conduct a literature review on the effects of cryotherapy on post-exercise recovery in athletes from different sports, using the cryoimmersion method. It considered the results of perceived muscle pain. A brief narrative summary of the studies that were considered in this review is provided below.

The study by authors[19] aimed to evaluate the effect of cold-water immersion after strenuous exercise on multiple performance parameters, compared to passive recovery. Twenty-four elite soccer players were subjected to cryoimmersion up to the level of the sternum for 11 minutes at 10°C. Data was collected immediately after training, immediately after the intervention and 24 hours after the intervention. To assess perceived muscle pain, a self-reported psychometric questionnaire was used, which quantified general muscle pain, fatigue, sleep quality, stress levels and mood on a five-point scale. The authors concluded that there were impacts on muscle pain.

In another study[12], immersion in cold or thermoneutral water after practice was compared. Twenty soccer players underwent cryoimmersion therapy with their lower limbs submerged up to the iliac crest at 10°C for 10 minutes. Data was collected for 30 minutes, 24 and 48 hours after the match. To assess muscle pain, a questionnaire was used to classify the pain felt on a scale of 0 to 10. The authors concluded that there were beneficial effects in relation to cold water immersion in reducing late onset muscle soreness and general perceptions of fatigue, compared to the thermoneutral water immersion group.

The authors[22] used cold water immersion on 20 swimming athletes, comparing it with thermo-neutral water and passive recovery, three times a week. They carried out a crossover study, with a recovery time of 1 week. They analyzed pain using a questionnaire. The authors report that there was an improvement in recovery in all groups, with the athletes indicating a preference for immersion in both cold and thermoneutral water.

The study[20] also with soccer players, aimed to evaluate the effects of two common recovery methods, the use of cold-water immersion and infrared-emitting ceramic materials. In cold water immersion, 9 soccer players were submerged in water stirred at 10°C for 10 minutes, up to the height of the iliac crest. Data was collected immediately, 24 and 48 hours after a soccer match. The authors reported that there was no difference between the interventions applied in the treatment of ITD and the perception of recovery.

Study[21] investigated the effects of cold-water immersion after a 10km road race on the recovery of muscle damage markers. The cold-water immersion intervention took place for 10 minutes at 10°C, with 10 athletes submerged up to the level of the anterosuperior iliac spine. Baseline data on reported pain was collected 10 minutes before the race, after the race, immediately and 24 hours after the intervention. They report that there was no interaction in the different pain analyses between time and group.

The aim of the study by the authors[16] was to compare cold water immersion, active recovery and passive recovery in relation to perceived pain, power and speed after exhaustive exercise. Seven athletes from the first division of the National Collegiate Athletic Association (NCAA) were given the intervention of immersion in cold water for 10 minutes at 10º C, submerged up to chest height. Data was collected post-exercise and 24 hours after the intervention. The authors report that the interventions of cold-water immersion, active and passive recovery did not induce significant differences in the recovery of perceived pain.

The study by authors[14] evaluated the influence of daily post-exercise immersion in cold water on the athlete's recovery. The collection took place over a period of 5 days, with elite youth field field hockey players, with 9 players randomly assigned to immersion in cold water up to the neck, for 5 minutes, at 6 °C. Late onset muscle soreness was measured every morning and evening. Even with high levels of DOMS, several parameters, such as the perception of recovery and stress and sleep quality, remained unchanged during the tournament.

The study[15] aimed to verify the effect of post-match cold water immersion on muscle damage, neuromuscular fatigue and perceptual responses within 72 hours of a Rugby match. Eleven athletes were immersed in cold water at a temperature of 10ºC for 10 minutes, submerged up to the height of the iliac crest. The results were collected 24, 48 and 72 hours after exercise. There was no clear and substantial difference between the groups.

The study by the authors[13] evaluated the impact of cold-water immersion on late muscle pain, muscle recruitment and postural control in soccer players. Seven players were immersed in cold water for 10 minutes at 10°C, up to the level of the iliac crest. The results indicated that the induced DOMS protocol was effective, with significant increases at 24 and 48 hours. Cryoimmersion allowed the athletes to return to baseline levels of pain intensity within 72 hours.

In this manuscript, it was decided to present the discussion with a description of the studies, due to the wide variety of protocols, forms of analysis (including statistics) and results. These characteristics led to limitations in the possibilities for meta-analysis. Thus, only two studies were included[13-22] on the outcome of muscle pain intensity. The result of the meta-analysis of the muscle pain intensity outcome included two clinical trials[13-22] with 62 individuals at all times included (24, 48 and 72 hours after the intervention).

The study[11] presented results 24 hours post-intervention (SMD = -0.65 [-1.73, 0.44]; p = 0.24). The article[20] was not able to make the same estimation due to the lack of variability in the experimental group (standard deviation = 0.0). Thus, combined SMD: 0.65 [-1.73, 0.44], not significant (p = 0.24). 48h after the study[11] intervention (SMD = -0.96 [-2.09, 0.17]; p = 0.10) and 72h post-intervention (SMD = -0.37 [-1.43, 0.69]; p = 0.50). The combined effect estimate (-0.64 [-1.27, -0.02]; p = 0.04) was significant; $I^2 = 0\%$. It is important to consider the limitation that the combined estimate was mainly influenced by a single study[11], due to the lack of estimable data from other studies. In other words, although statistical results for muscle pain have occurred, it is not possible to infer it as a therapeutic truth, mainly due to the high level of bias risks observed. Thus, there is a need for primary studies with high methodological quality and repetition of protocols and outcomes, so that an in-depth analysis can be carried out in the future.

The nine studies analyzed presented some concerns about the risk of bias in various domains, especially due to the impossibility of blinding the participants and administrators of the interventions, as well as some uncertainties about the concealment of the allocation sequence and the selection of the reported results. However, most studies managed to maintain a low risk of bias in missing data and in the measurement of outcomes. It is also worth mentioning the limitation of this study to only target athletes, which does not allow it to be extrapolated to other populations. It is essential to consider these limitations when interpreting the results and planning future studies to improve the methodological quality and robustness of the evidence.

CONCLUSION

The results indicate that cold water immersion can have some beneficial effects on reducing muscle pain, but the lack of primary studies of high methodological quality prevents certainty in this statement, as there is a lot of variability and different contexts. It is therefore considered necessary to carry out studies with a high level of methodology on the subject, extending to other populations as well.

REFERENCES

1. Bouzigon R, Grappe F, Ravier G, Dugue B. Whole- and partial-body cryostimulation/cryotherapy: current technologies and practical applications. J Therm Biol. 2016;61:67-81. http://doi.org/10.1016/j.jtherbio.2016.08.009. PMid:27712663.
2. Tarahovsky YS, Khrenov MO, Kovtun AL, Zakharova NM. Comparison of natural and pharmacological hypothermia in animals: Determination of activation energy of metabolism. J Therm Biol. 2020;92:102658. http://doi.org/10.1016/j.jtherbio.2020.102658. PMid:32888562.
3. Carvalho AR, de Medeiros DL, Souza FT, Paula GF, Barbosa PM, Vasconcellos PRO, Buzanello MR, Bertolini GRF. Temperature variation of the quadriceps femoris muscle exposed to two forms of cryotherapy by means of thermography. Rev Bras Med Esporte. 2012;18(2):109-11. https://doi.org/10.1590/S1517-86922012000200009.
4. Mendes IE, Ribeiro Filho JC, Lourini LC, Salvador MD, de Carvalho AR, Buzanello MR, Bertolini GRF. Cryotherapy in anterior cruciate ligamentoplasty pain: a scoping review. Ther Hypothermia Temp Manag. 2022;12(4):183-90. http://doi.org/10.1089/ther.2021.0032. PMid:35085042.
5. Pradal LA. Single application of immersion cryotherapy in Wistar rats with experimental gout. J Therm Biol. 2022;107:103253. http://doi.org/10.1016/j.jtherbio.2022.103253. PMid:35701022.
6. Krampe PT, Bendo AJP, Barros MIG, Bertolini GRF, Buzanello Azevedo MR. Cryotherapy in knee arthroplasty: Systematic review and meta-analysis. Ther Hypothermia Temp Manag. 2023;13(2):45-54. http://doi.org/10.1089/ther.2022.0043. PMid:36472555.
7. Jong RH, Hershey WN, Wagman IH. Nerve conduction velocity during hypothermia in man. Anesthesiology. 1966;27(6):805-10. http://doi.org/10.1097/00000542-196611000-00013. PMid:5924554.
8. Barłowska-Trybulec M, Zawojska K, Szklarczyk J, Góralska M. Effect of whole body cryotherapy on low back pain and release of endorphins and stress hormones in patients with lumbar spine osteoarthritis. Reumatologia. 2022;60(4):247-51. http://doi.org/10.5114/reum.2022.119040. PMid:36186838.

9. Randell RK, Clifford T, Drust B, Moss SL, Unnithan VB, De Ste Croix MBA, Datson N, Martin D, Mayho H, Carter JM, Rollo I. Physiological characteristics of female soccer players and health and performance considerations: A narrative review. Sports Med. 2021;51(7):1377-99. http://doi.org/10.1007/s40279-021-01458-1. PMid:33844195.

10. Bestwick-Stevenson T, Toone R, Neupert E, Edwards K, Kluzek S. Assessment of fatigue and recovery in sport: narrative review. Int J Sports Med. 2021;43(14):1151-62. PMid:35468639.

11. Kellmann M, Bertollo M, Bosquet L, Brink M, Coutts AJ, Duffield R, Erlacher D, Halson SL, Hecksteden A, Heidari J, Kallus KW, Meeusen R, Mujika I, Robazza C, Skorski S, Venter R, Beckmann J. Recovery and performance in sport: consensus statement. Int J Sports Physiol Perform. 2018;13(2):240-5. http://doi.org/10.1123/ijspp.2017-0759. PMid:29345524.

12. Ascensão A, Leite M, Rebelo AN, Magalhäes S, Magalhäes 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(3):217-25. http://doi.org/10.1080/02640414.2010.526132. PMid:21170794.

13. Pesenti FB, Silva RA, Monteiro DC, Silva LA, Macedo CSG. The effect of cold water immersion on pain, muscle recruitment and postural control in athletes. Rev Bras Med Esporte. 2020;26(4):323-7. http://doi.org/10.1590/1517-869220202604214839.

14. Krueger M, Costello JT, Stenzel M, Mester J, Wahl P. The physiological effects of daily cold-water immersion on 5-day tournament performance in international standard youth field-hockey players. Eur J Appl Physiol. 2020;120(1):295-305. http://doi.org/10.1007/s00421-019-04274-8. PMid:31797035.

15. Nunes RFH, Duffield R, Nakamura FY, Bezerra ES, Sakugawa RL, Loturco I, Bobinski F, Martins DF, Guglielmo LGA. Recovery following rugby union matches: effects of cold water immersion on markers of fatigue and damage. Appl Physiol Nutr Metab. 2019;44(5):546-56. http://doi.org/10.1139/apnm-2018-0542. PMid:30321486.

16. Getto CN, Golden G. Comparison of active recovery in water and cold-water immersion after exhaustive exercise. Athl Train Sports Health Care. 2013;5(4):169-76. http://doi.org/10.3928/19425864-20130702-03.

17. Patel JJ, Hill A, Lee ZY, Heyland DK, Stoppe C. Critical appraisal of a systematic review: A concise review. Crit Care Med. 2022;50(9):1371-9. http://doi.org/10.1097/CCM.0000000000005602. PMid:35853198.

18. Higgins JPT, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, Savovic J, Schulz KF, Weeks L, Sterne JAC. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343(2):d5928-5928. http://doi.org/10.1136/bmj.d5928. PMid:22008217.

19. Alexander J, Carling C, Rhodes D. Utilisation of performance markers to establish the effectiveness of cold-water immersion as a recovery modality in elite football. Biol Sport. 2022;39(1):19-29. http://doi.org/10.5114/biolsport.2021.103570. PMid:35173359.

20. Coelho TMH, Nunes RF, Nakamura FY, Duffield R, Serpa MC, da Silva JF, Carminatt LJ, Cidral-Filho FJ, Goldim MP, Mathias K, Petronilho F, Martins DF, Guglielmo LGA. Post-match recovery in soccer with far-infrared emitting ceramic material or cold-water immersion. J Sports Sci Med. 2021;20(4):732-42. http://doi.org/10.52082/jssm.2021.732. PMid:35321145.

21. Dantas G, Barros A, Silva B, Belém L, Ferreira V, Fonseca A, Castro P, Santos T, Lemos T, Hérickson W. Cold-water immersion does not accelerate performance recovery after 10-km street run: randomized controlled clinical trial. Res Q Exerc Sport. 2019;91(2):228-38. http://doi.org/10.1080/02701367.2019.1659477. PMid:31652109.

22. Batista NP, de Carvalho FA, Rodrigues CRD, Micheletti JK, Machado AF, Pastre CM. Effects of post-exercise cold-water immersion on performance and perceptive outcomes of competitive adolescent swimmers. Eur J Appl Physiol. 2024;124(8):2439-50. http://doi.org/10.1007/s00421-024-05462-x. PMid:38548939.

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APPENDIX A. DATABASE SEARCHES

Database	Terms
Pubmed	(((“Athletic Performance”[Mesh]) OR ((“Athletic Performance”)) OR (“Athletic Performance”[Title/Abstract]) OR” Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances”)) AND (((“Cold Temperature”[Mesh]) OR (“Cold Temperature”)) OR (“Cold Temperature”[Title/Abstract]) OR “Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR “Cold” OR “Cryotherapy”[Mesh] OR “Cryotherapy” OR “Cryotherapies” OR “Cold Therapy” OR “Cold Therapies” OR “Cryostimulation”))
Web of Science	(“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances”) (All Fields) and (“Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR Cold OR Cryotherapy OR cryotherapie OR “Cold Therapy” OR “Cold Therapies” OR costimulation)
Scopus	TITLE-ABS-KEY (“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances”) AND TITLE-ABS-KEY (“Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR cold OR cryotherapy OR cryotherapies OR “Cold Therapy” OR “Cold Therapies” OR cryostimulation)
Embase	(‘athletic performance’/exp OR ‘athletic performance’ OR ‘athletic performances’ OR ‘sports performance’/exp OR ‘sports performance’ OR ‘sports performances’) AND (‘cold temperature’/exp OR ‘cold temperature’ OR ‘cold water immersion’/exp OR ‘cold water immersion’ OR ‘cold temperatures’ OR ‘cold’/exp OR cold OR ‘cryotherapy’/exp OR cryotherapy OR cryotherapies OR ‘cold therapy’/exp OR ‘cold therapy’ OR ‘cold therapies’ OR cryostimulation)
Lilacs	(“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances” OR “Desempenho Atlético” OR “Rendimiento Atlético” OR “Desempenho Esportivo” OR “Performance Atlética” OR “Performance Esportiva” OR Esporte) AND (Cryotherapy OR Cryotherapies OR “Cold Therapy” OR “Cold Therapies” OR Cryostimulation OR “Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR Cold OR Crioterapia OR “Terapia a Frio” OR “Terapia por Frio” OR “Temperatura Baixa” OR Frío OR Esfriamento OR Frio OR Temperatura Mínima OR “Isquemia fria” OR “Cold Ischemia” OR “Isquemia Fría”)
Cochrane	Trials matching (“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances”) in All Text AND (“Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR Cold OR Cryotherapy OR Cryotherapies OR “Cold Therapy” OR “Cold Therapies” OR Cryostimulation) in Title Abstract Keyword - (Word variations have been searched)
Google scholar	(“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances” OR “Desempenho Atlético” OR “Rendimiento Atlético” OR “Desempenho Esportivo” OR “Performance Atlética” OR “Performance Esportiva” OR Esporte) AND (Cryotherapy OR Cryotherapies OR “Cold Therapy” OR “Cold Therapies” OR Cryostimulation OR “Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR Cold OR Crioterapia OR “Terapia a Frio” OR “Terapia por Frio” OR “Temperatura Baixa” OR Frío OR Esfriamento OR Frio OR Temperatura Mínima OR “Isquemia fria” OR “Cold Ischemia” OR “Isquemia Fría”)
Open Grey	Athletic Performance AND Cryotherapy
LIVIVO	(“Athletic Performance” OR “Athletic Performances” OR “Sports Performance” OR “Sports Performances”) AND (“Cold Temperature” OR “Cold Water Immersion” OR “Cold Temperatures” OR Cold OR Cryotherapy OR Cryotherapies OR “Cold Therapy” OR “Cold Therapies” OR Cryostimulation)
CAPES Thesis and Dissertation Catalog	Athletic Performance AND Cryotherapy