UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"

ARYANE FLAUZINO MACHADO

EFEITOS IMEDIATOS E TARDIOS DA IMERSÃO EM ÁGUA FRIA PÓS-EXERCÍCIO: UMA REVISÃO SISTEMÁTICA E UM ENSAIO CLÍNICO RANDOMIZADO

Presidente Prudente

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Orientador: Prof. Dr. Carlos Marcelo Pastre
Coorientador: Prof. Dr. Paulo Henrique Ferreira

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Dedicatória

À minha amada família por todo companheirismo, apoio e dedicação. Meus pais Jurandir e Vânia e meu irmão Gabriel. Nossa vitória, nossa conquista!

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Epígrafe

“Reconheça o que está ao alcance dos seus olhos e o que está oculto tornar-se-á claro para você.”

(Autor desconhecido)

SUMÁRIO

Essa dissertação está apresentada em consonância com as normas do modelo alternativo de dissertação do Programa de Pós-Graduação *Stricto Sensu* em Fisioterapia da Faculdade de Ciências e Tecnologia da Universidade Estadual Paulista "Júlio de Mesquita Filho". O conteúdo desse trabalho contempla o material originado a partir da pesquisa intitulada "*Efeitos imediatos e tardios da imersão em água fria pós-exercício: uma revisão sistemática e um ensaio clínico randomizado*" que foi realizada em duas etapas:

1-) Revisão Sistemática e Meta-análise, realizada na *The University of Sydney*, *Faculty of Health Sciences*, Sydney – NSW, Austrália, financiada pela Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (Linha de Fomento: Bolsa de Pesquisa de Estágio no Exterior, processo: 2014/03778-5);

2-) Ensaio clínico randomizado, realizado na Univ. Estadual Paulista "Júlio de Mesquita Filho", Faculdade de Ciências e Tecnologia, Presidente Prudente – SP, Brasil, financiada pela Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior – CAPES e posteriormente financiada pela Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP (Linha de Fomento: Bolsa de Mestrado no País, processo 2013/12474-7).

Assim, o presente material está dividido nas seguintes sessões:

- Introdução ao tema, para contextualização do tema pesquisado;
- Artigo I: Machado AF, Ferreira PH, Micheletti JK, Almeida AC, Lemes IR, Vanderlei FM, Netto Junior J, Pastre CM. *Can the water temperature and immersion time influence the effects of cold water immersion on pain? A systematic review and meta-analysis*; em revisão pelo periódico *Sports Medicine*;
- Artigo II: Machado AF, Almeida AC, Micheletti JK, Netto Junior J, Vanderlei FM, Netto Junior J, Pastre CM. *Immediate and delayed effects of cold water immersion after*

eccentric exercise-induced muscle damage: randomized controlled trial; em revisão pelo periódico *PLoS ONE*;

- Conclusões, a partir de ambas as pesquisas realizadas;
- Referências, em formato recomendado pelo *International Committee of Medical Journals Editours* (ICMJE), para as referências citadas na introdução.

Ressalta-se que cada artigo está apresentado de acordo com as normas dos seus respectivos periódicos, apresentadas em anexo ao final (com exceção das figuras que estão apresentadas no texto principal).

O processo de recuperação pós-exercício é fundamental para a preservação de estruturas e tecidos, bem como para a manutenção das funções motoras, visando à prevenção de agravos ou melhora da *performance* e rendimento do atleta. Seu objetivo principal é a restauração dos diferentes sistemas do corpo a condições basais, ou seja, a níveis pré-exercício[1,2].

Dentre as diversas técnicas que aceleram a recuperação pós-exercício, a crioterapia é um procedimento comumente utilizado na prática esportiva e é proposta para redução da resposta inflamatória em caso de lesão tecidual e dor muscular resultante do esforço físico, apresentando evidências particulares na aplicação após o dano muscular induzido por exercício (DMIE)[3–5].

Uma das modalidades da crioterapia é a imersão em água fria (IAF), que consiste na imersão de parte do corpo em água com temperatura igual ou inferior à 15°C[6]. Essa estratégia de recuperação aparece no cenário atual como uma técnica eficaz e de baixo custo, facilmente reproduzida em diferentes situações. Os potenciais efeitos dessa estratégia de recuperação têm sido avaliados a partir de diferentes marcadores de dano muscular, tais como concentração sanguínea de creatina quinase (CK) [5,7–9], dor[3,4,7–10], alteração de sensibilidade[10], percepção de recuperação[11] e força[3–5,7–9,11].

Sabe-se que a IAF é capaz de reduzir a temperatura do tecido muscular[3], a permeabilidade celular de vasos sanguíneos, linfáticos e capilares devido à vasoconstrição, com consequente diminuição da difusão dos fluídos nos espaços intersticiais[4,12,13] além de reduzir a velocidade da condução nervosa, a atividade do fuso muscular, a espasticidade e a dor[3]. Entretanto, autores afirmam que apesar dos efeitos relatados não há evidência fisiológica clara para confirmar essas teorias e que os reais efeitos ainda não estão plenamente elucidados[9].

Apesar dos resultados, os indivíduos ainda respondem de maneira diferente aos sinais e sintomas. Esse fato pode ser explicado pela utilização de diferentes metodologias adotadas e influenciado pela complexidade e especificidade de cada indivíduo[14]. Pastre *et al*.[15] atribuíram parte do cenário aos diferentes métodos de controle utilizados pelos pesquisadores tanto na maneira de indução de estresse quanto à forma de aplicação da técnica. Glasgow *et al.*[9] concordam ao afirmar que na prática clínica existe uma grande variação de protocolos de IAF, que se diferem principalmente quanto à temperatura da água e ao tempo de imersão. Essa variação corresponde à dose no qual o indivíduo é exposto, influenciando nos futuros desfechos.

Deve-se refletir à luz desta situação problema que requer uma melhor fundamentação científica a fim de eliminar possíveis vieses de rotina e de interpretação de resultados e objetivando identificar a melhor estratégia baseada na relação da dose-resposta na aplicação da IAF pós-exercício.

Assim, o objetivo da presente pesquisa foi determinar os efeitos da imersão em água fria pós-exercício, por meio de diferentes tipos de estudo, como a revisão sistemática e meta-análise e o ensaio clínico randomizado, além de identificar a melhor dose de aplicação dessa técnica, por meio da relação da dose-resposta e os possíveis efeitos deletérios.

Can water temperature and immersion time influence the effect of cold water immersion on pain? A systematic review and meta-analysis

Different protocols of CWI on pain: a meta-analysis

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ABSTRACT

Background: Cold water immersion (CWI) is a technique commonly used in post-exercise recovery. However, the procedures involved in the technique may vary, particularly in terms of water temperature and immersion time, and the most effective approach remains unclear.

Purpose: To determine the efficacy of CWI in pain management compared with passive recovery. We also aimed to identify which water temperature and immersion time provides the best results.

Methods: MEDLINE, EMBASE, SPORTDiscus, PEDro and The Cochrane Library databases were searched up to January 2015. Only randomized controlled trials that compared CWI to passive recovery were included in this review.

Results: Nine studies were included in the review and meta-analysis. The results of meta-analysis revealed that CWI has a more positive effect than passive recovery in terms of immediate (WMD=0.290, 95% CI [0.037, 0.543]; p=0.025) and delayed effects (WMD=0.315, 95% CI [0.048, 0.581], p=0.021). The pooled of studies that used water temperature of between 10-15°C demonstrated the best results for immediate (WMD=0.273, 95% CI [0.107, 0.440], p=0.001) and delayed effects (WMD=0.317, 95% CI [0.102, 0.532], p=0.004). In terms of immersion time, immersion of between 10-15 minutes had the best results for immediate (WMD=0.227, 95% [0.139, 0.314], p=0.000) and delayed effects (WMD=0.317, 95% [0.102, 0.532], p=0.004).

Conclusions: CWI is more effective than passive recovery in management of pain. The results also demonstrated the presence of a dose-response relationship, indicating that CWI with a water temperature of between 11 and 15ºC and an immersion time of 11 to 15 minutes provided the best results.

Keywords: recovery of function; cryotherapy; immersion; muscle soreness.

1. BACKGROUND

Several post-exercise recovery techniques are currently employed in an attempt to return the body to its pre-exercise state [1,2]. Cold water immersion (CWI) has become popular in sports [3,4] as it is a low-cost technique that is easily performed in different situations [5] and has been found to minimize the immediate and delayed negative effects of exercise [6]. Compared to controlled interventions and other traditional recovery techniques, CWI achieves positive pain reduction results following a range of exercise types [7,8]. Yet the specific mechanisms associated with CWI response are unknown [9,10].

Despite its widespread use, significant procedural variations in CWI exist [11,12]. Investigations have suggested that water temperature contributes to the beneficial effect of CWI [6]. However, other factors may influence recovery. Pastre et al. [13] attribute response variation to differences in the application of CWI, such as water temperature, immersion time and type of CWI.

In recent years, the number of studies focusing on CWI has increased, and major systematic reviews have been performed to compare the effects of CWI and other pain recovery strategies [8,12]. However, the dose-response relationship of this technique has not yet been investigated. Bleakley et al. [12] found no clinical trials comparing different procedures while authors [10] showed that studies focusing on different CWI application strategies can contribute to determining the risks and benefits for athletes.

A systematic review involving the dose-response relationship will clarify the most effective method of application of CWI for post-exercise pain. Therefore, the purpose of this systematic review was to determine the efficacy of cold water immersion on management of pain compared with control intervention (passive recovery). An analysis of which dosage of application provides the best results, focusing on water temperature and immersion time, was also undertaken.

2. METHODS

This systematic review was registered in an international database of systematic reviews in health and social care. (Available: registration number CRD42015016573; http://www.crd.york.ac.uk/PROSPERO/).

2.1 Search strategies

Studies were selected after searching five databases (MEDLINE, EMBASE, SPORTDiscus, PEDro and The Cochrane Library) from the earliest record of each database to January 21, 2015. The terms and keywords used to search optimization were related to randomized controlled trials; cold water immersion and post-exercise recovery (see details in Appendix 1). The reference list of eligible clinical trials was searched by hand to complement the electronic searches.

2.2 Study selection

The studies selected involved CWI treatment of human participants and assessed the effect on immediate and/or delayed pain or muscle soreness. CWI was defined as immersion in water with a temperature less than or equal to 15°C [5,6,11]. To be eligible, studies had to 1) be randomized controlled trials, comparing cold water immersion and control conditions (passive recovery) post-exercise; 2) be studies that assessed muscle soreness; 3) be studies that used a single session of exercises; 4) apply CWI within 1 hour of the end of the exercise; 5) include only one immersion on the first day. Studies using intermittent immersions or more than one immersion on subsequent days were excluded. No restrictions were applied to the sample conditions (age, gender, exercise level) or language of the studies.

The study selection process was conducted by title, followed by abstract and full text (Figure 1). These steps were performed independently by two authors (ACA and JKM) and consensus was used to solve disagreements.

2.3 Data extraction

Outcome data, including mean scores, SDs (final values) and sample size was extracted by two reviewers (AFM, JKM). The data extraction process was performed using a standardized form that included details such as characteristics of participants, exercise procedures, cold water immersion procedures, outcome measures and methodological characteristics. Disagreements between authors regarding data extraction were resolved by consensus.

Some studies included multiple observations. In such cases, data was extracted at a clinically relevant time point in order to analyze: immediate effects (up to 24 hours post-exercise) and delayed effects (after 24 hours post-exercise). For the delayed effects, the peak pain of the control group was considered, in order to minimize interference caused by the intervention. Pain scores were converted to a common 0-10 scale.

2.4 Quality Assessment

All studies included were assessed for methodological quality. This process was performed by two independent reviewers (AFM and JKM) using the PEDro Scale [14,15]. Each study was assessed for random allocation, concealed allocation, baseline comparability, blinding participants, therapists and assessors, adequate follow-up, intention-to-treat, between-group comparison, point estimates and variability. If trials had already been assessed and listed on the PEDro database, such scores were adopted. Methodological quality was not an inclusion criteria.

2.5 Data synthesis and analysis

Analysis of the temperature and immersion time of each study was performed. It was necessary to establish cutoff points for each of these covariates. For water temperature analysis two categories were created: severe cold, with water temperature between 5-10°C; and moderate cold, where temperature was between 11-15°C. Three categories were used for immersion time: short, immersions of 10 minutes or less; medium, immersions of 11-15 minutes; and longer, with immersions between 16-20 minutes.

Comprehensive Meta-Analysis software, version 2.2.04 (Biostat, USA) was used for all analysis and pooled estimates were calculated using a random-effect model, due to the heterogeneity of the studies (represented by I^2). Data was pooled in meta-analyses and described as weighted mean differences (WMD) with 95% confidence intervals (CI). The immediate and delayed effects were calculated in order to analyze the effect of cold water immersion, independent of water temperature and duration of immersion. In case of more than one intervention group per study, the group that represented the lowest effect size was used.

3. RESULTS

The database search identified 258 studies and 17 were chosen for full text review. Of these articles, eight were excluded: one was not a single exercise session, one used a cryotherapy technique other than cold water immersion and six did not feature an appropriate immersion, based on the inclusion criteria. Figure 1 shows the schematic process of the study selection based on a PRISMA flow diagram.

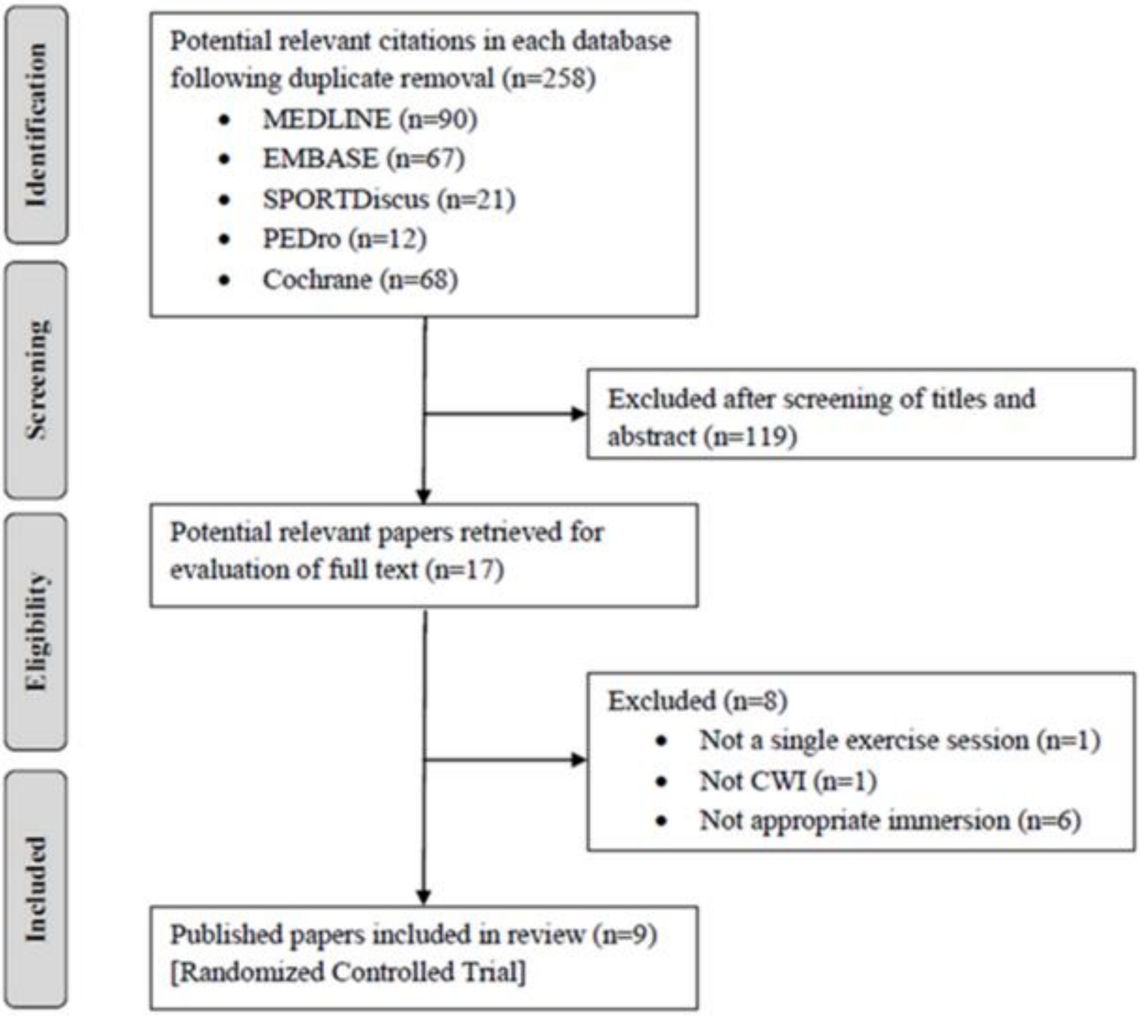

Fig.1 Flow chart for selection of studies

Assessment of the methodological quality of the studies included using the PEDro scale reported a mean of 4.2. Three studies [16–18] were considered as 'moderate quality' and another six studies as 'poor quality' [2,9,19–22]. Due to the type of intervention, blinding was often not possible, but 44.4% of the studies described adequate follow-up procedures (see details in Appendix 2). Figure 2 shows the number of clinical trials that fulfilled each criterion.

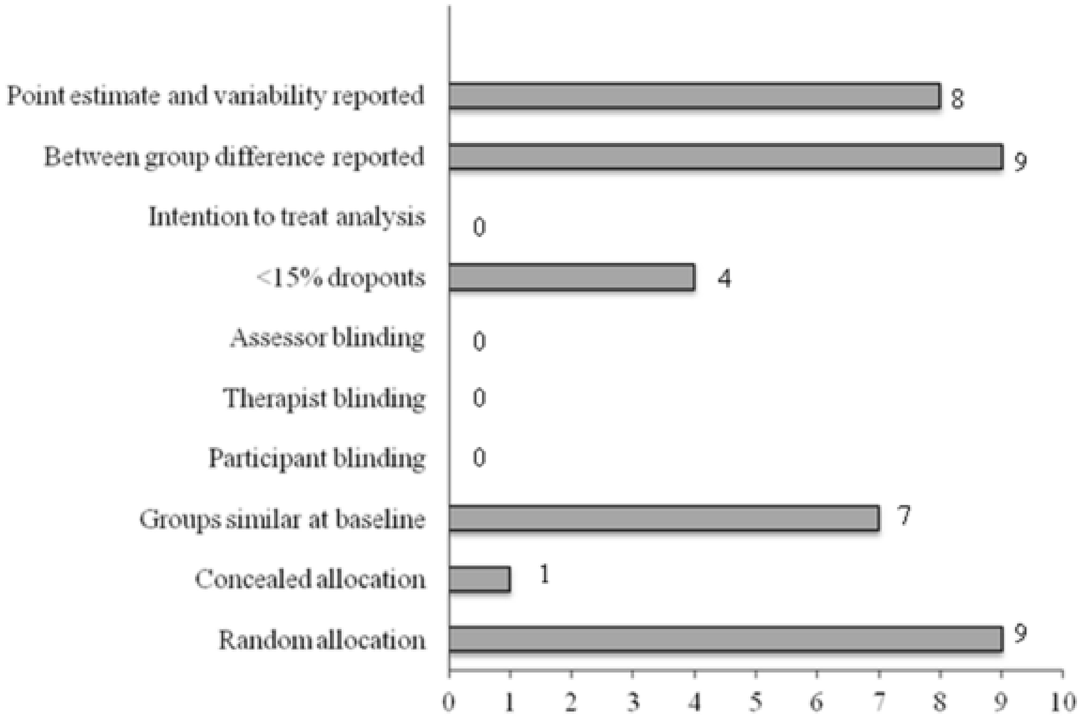

Fig.2 Number of trials for each PEDro criteria

The nine eligible studies were published between 2007 [9] and 2015 [16]. These studies comprised a total of 169 participants (male, n=141; female=28). The health conditions of the participants, the level of exercise, fluctuated between physically active and athletes.

The studies were from Australia [2,17,18,21], the United Kingdom [9,16,22] and USA[19,20]. All were randomized controlled trial type studies, while six were parallel group trials [9,16,19–22], and three used a cross-over design [2,17,18]. Exercise protocols consisted primarily of exercises that required high physical ability with possible subsequent onset of pain, such as shuttle running [9,16], downhill running [19], Australian football match and training [17,21], high intensity intervals [2,18] and counter-movement jumps [22].

Interventions were varied. Water temperature ranged from 5 [19] to 15°C [2] and immersion time varied between 5 [18] and 20 [19] minutes. All studies used passive recovery in which participants had to remain seated with minimal movement. Immersion depth ranged from immersion of the lower limbs [9,19,22] to immersion of the whole body, excluding only the head and neck [18]. It was observed that six [2,9,16,17,19–21] of eight studies that evaluated delayed effect on pain found peak pain at 24 hours post-exercise, and only one [22] found peak pain at 48 hours post-exercise.

The characteristics of the included studies are summarized in Table 1.

Table 1. Characteristics of the included studies

Study, year	Study design	Characteristics of participants	Exercise protocol	CWI group	Control group	Pain assessment	Time of assessment	Time of analysis	PEDro Score
Leeder, 2015[16]	Parallel groups	N=24 male; well trained 21±3 years	Intermittent shuttle running	14°C; 14 minutes; n=8 TI: Immediately post-exercise WL: DNR	Remained seated 14 minutes; n=8	VAS=0-200mm Squat at 90° knee flexion	24, 48, 72 hours post-exercise	24 hours post-exercise	6
Crystal, 2013[19]	Parallel groups	N=20 male 21.2±2.3 years	Downhill run	5±2°C; 20 minutes; n=10 TI: DNR WL: Up to top of the thigh	Position: DNR; n=10	VAS= 0-100mm Leg soreness while walking down the stairs	Immediately, 1, 6, 24, 48 e 72 hours post-exercise	1 and 24 hours post-exercise	4
Getto, 2013[20]	Parallel groups	N=23 13 male; 10 female Age: DNR	Exhaustive exercise session	10°C; 10 minutes; n=7 TI: Immediately post-exercise WL: Up to level of chest	Remained seated 10 minutes; n=8	VAS= 0-60 Calves, quadriceps, hamstrings, hip adductors, hip abductors and low back	Immediately post-exercise and immediately and 24 post-intervention	Immediately post-intervention and 24 hours post-exercise	3
Elias, 2013[21]	Parallel groups	N=24 male; Australian football players 19.9±2.8 years	Australian football match	12°C; 14 minutes; n=7 TI: Within 12 minutes post-exercise WL: Up to xiphoid process	Remained seated 14 minutes; n=8	VAS= 0-100mm DNR	Immediately, 1, 24, 48 hours post-exercise	1 and 24 hours post-exercise	4
Elias, 2012[17]	Cross-over	N=14 male; Australian football players 20.9±3.3 years	Australian football training	12°C; 14 minutes; n=14 TI: Within 12 minutes post-exercise WL: Up to xiphoid process	Remained seated; 14 minutes; n=14	VAS=0-100mm DNR	Immediately, 1, 24, 48 hours post-exercise	1 and 24 hours post-exercise	5
Stanley, 2012[23]	Cross-over	N= 18 male; cyclist 27±7 years	High intensity interval session	14,2±0,6°C; 5 minutes; n=18 TI: 20 minutes post-exercise WL: Body excluding head and neck	Remained seated 10 minutes; n=18	VAS=1-10 Leg soreness	Immediately post-intervention	Immediately post-intervention	5

Brophy-Williams, 2011[2]	Cross-over	N= 8 male; well trained 20.9±1.2 years	High intensity interval session	15±1°C; 15 minutes; n=8 TI: Immediately post-exercise WL: Up to mid-sternum	Remained seated 15 minutes; n=8	VAS=0-7 DNR	24 hours post-exercise	24 hours post-exercise	4
Jakeman, 2009[22]	Parallel groups	N=18 female; athletes 19.9±0.97 years	Counter-movement jumps	10±1°C; 10 minutes; n=9 TI: Within 10 minutes post-exercise WL: Up to level of the superior iliac crest	Remained seated 10 minutes; n=9	VAS=0-10 Unweighted squat at 90° knee flexion (2 s)	1, 24, 48, 72, 96 hours post-exercise	1 and 48 hours post-exercise	3
Bailey, 2007[9]	Parallel groups	N=20 male; healthy 22.3±3.3 years	Intermittent shuttle running	10±0,5°C; 10 minutes; n=10 TI: Immediately post-exercise WL: Up to level of iliac crest	Remained seated 10 minutes; n=10	VAS=1-10 General whole-body soreness; palpation of major muscle group	Immediately, 1, 24, 48, 168 hours post-exercise	1 and 24 hours	4

TI: time of immersion; WL: water level; DNR: Data not reported; VAS: Visual Analog Scale; °C: degrees Celsius

3.1 Analysis of water temperature

Seven studies [9,17–22] provided data related to the immediate effects of cold water immersion. The subgroup analysis of the pooled results is shown in Figure 3. A general analysis of the immediate effects shows a significant pooled effect for cold water immersion (WMD=0.290, 95% CI [0.037, 0.543]; p=0.025). When subgroups were analyzed, it was observed that studies using a water temperature of between 11-15°C (moderate cold) produced better results than those using water between 5-10°C (severe cold). Therefore, temperatures higher than 10°C present the best results for immediate effect on pain (Severe cold: WMD=0.144, 95% CI [-1.299, 1.526], p=0.875]; Moderate cold: WMD=0.273, 95% CI [0.107, 0.440], p=0.001).

Eight studies [2,9,16,17,19–22] were included in the analysis of water temperature on delayed effects, with pooled results showing a tendency similar to immediate effect results (Figure 4). Overall pooled results, independent of water temperature, showed a statistically significant difference in favor of cold water immersion (WMD=0.315, 95% CI [0.048, 0.581], p=0.021). Analysis of subgroups revealed that water at temperatures of between 11-15°C showed the best results (Severe cold: WMD=0.057, 95 % CI [-1.483, 1.598], p=0.942]; Moderate cold: WMD=0.317, 95% CI [0.102, 0.532], p=0.004).

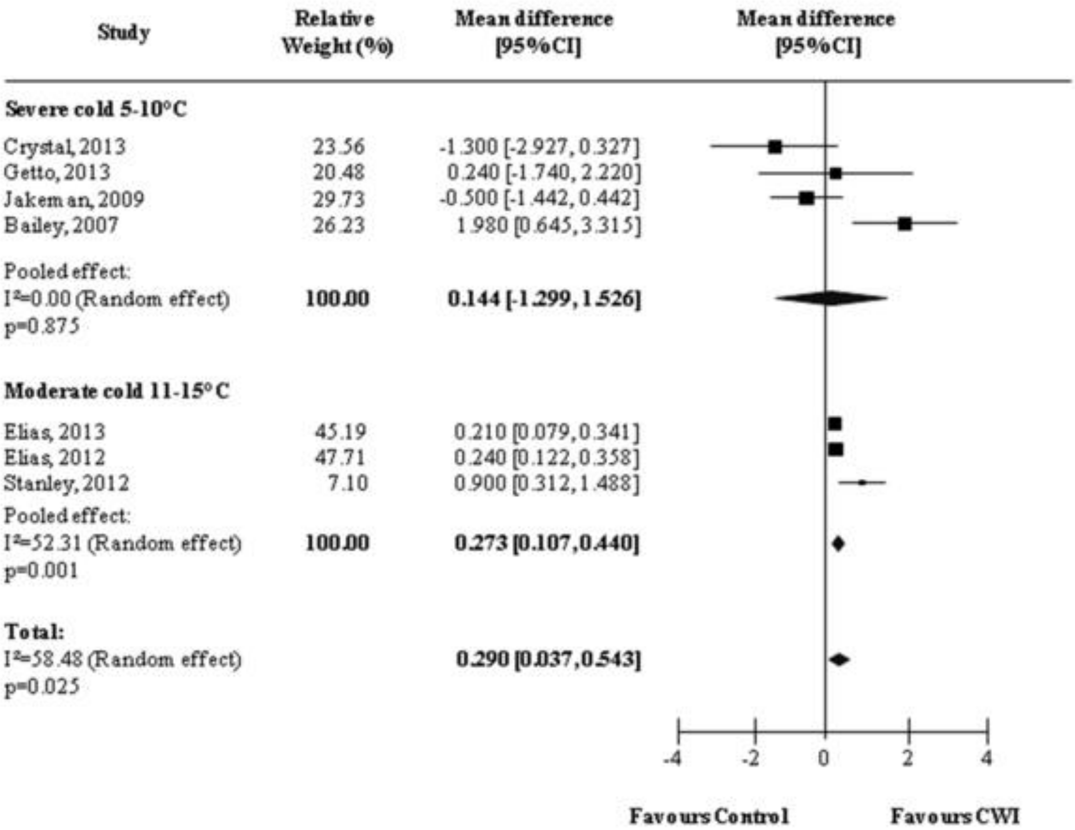

Fig.3 Forest plot of comparison: passive recovery and CWI. Subgroup: water temperature. Time point: immediate effect.

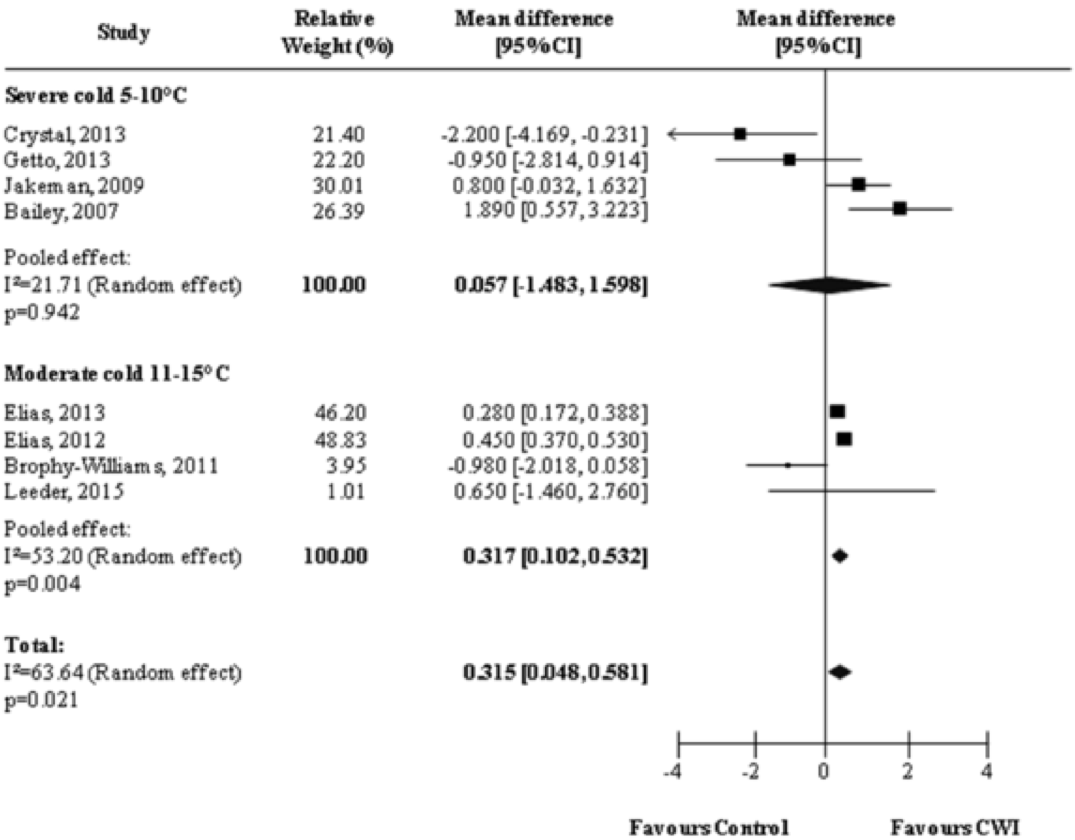

Fig.4 Forest plot of comparison: passive recovery and CWI. Subgroup: water temperature. Time point: delayed effect.

3.2 Analysis of immersion time

Figure 5 shows the results of analysis of immediate effect in relation to immersion time. Overall, CWI, was more effective than the control condition (WMD=0.290, 95% CI [0.037, 0.543]; p=0.025). Three categories were used for subgroup analysis: short, medium and longer immersion. The medium immersion category, which had duration of between 10-

15 minutes, was responsible for the best results in terms of immediate effects. Although there is only one study featuring 'longer immersion' [19] it was observed no effect for this category (Short immersion: WMD=0.646, 95% [-0.360, 1.652], p=0.208; Medium immersion: WMD=0.227, 95% [0.139, 0.314], p=0.000; Longer immersion: WMD=-1.300 [-2.927, 0.327], p=0.117).

In terms of delayed effects, the overall pooled effects of CWI described in the eight studies analyzed were positive (WMD = 0.315, 95% CI [0048, 0581], p = 0.021) (Figure 6). As with the immediate effects, an immersion time of between 11-15 minutes produced the best results (Short immersion: WMD=0.728, 95% [-0.561, 2.017], p=0.268; Medium immersion: WMD=0.317, 95% [0.102, 0.532], p=0.004; Longer immersion: WMD=-2.200 [-4.169, -0.231], p=0.029).

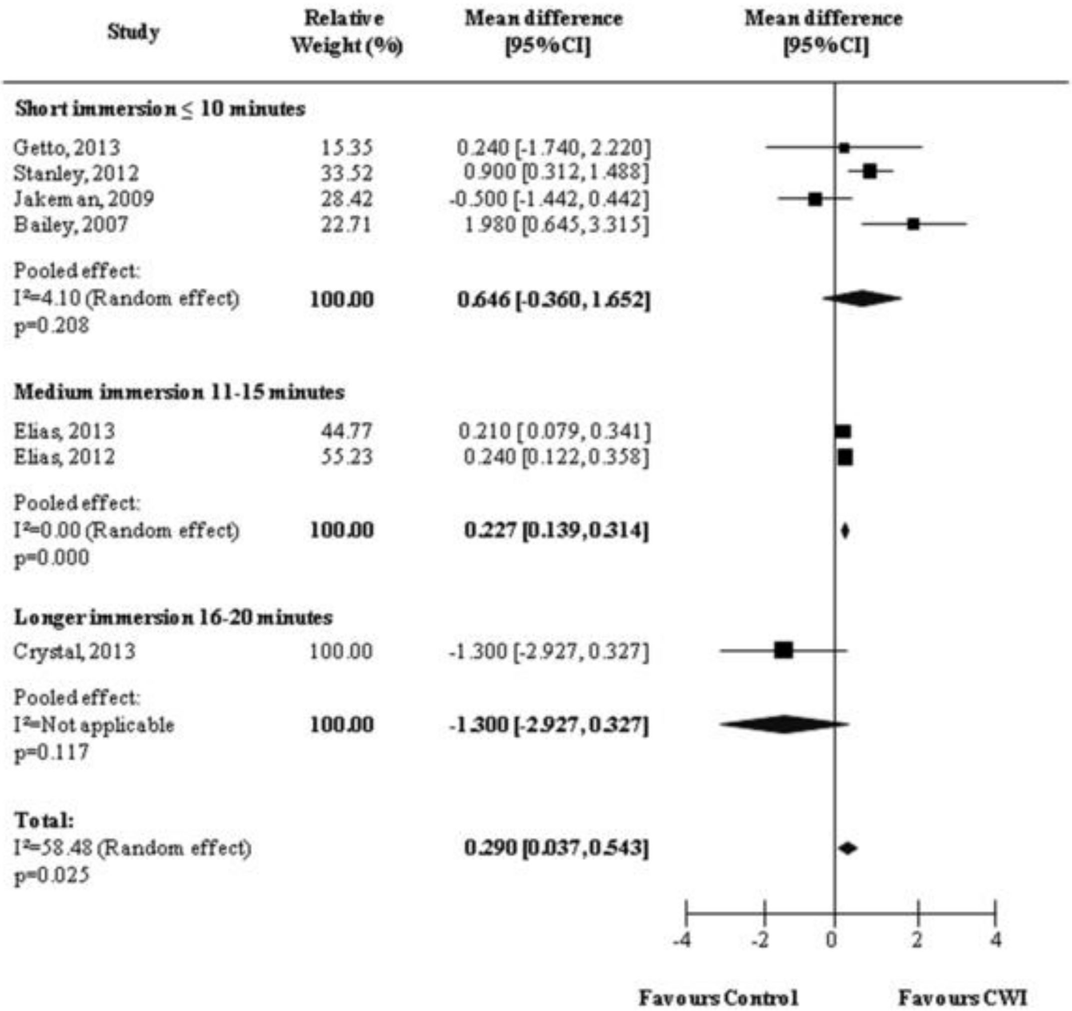

Fig.5 Forest plot of comparison: passive recovery and CWI. Subgroup: immersion time. Time point: immediate effect.

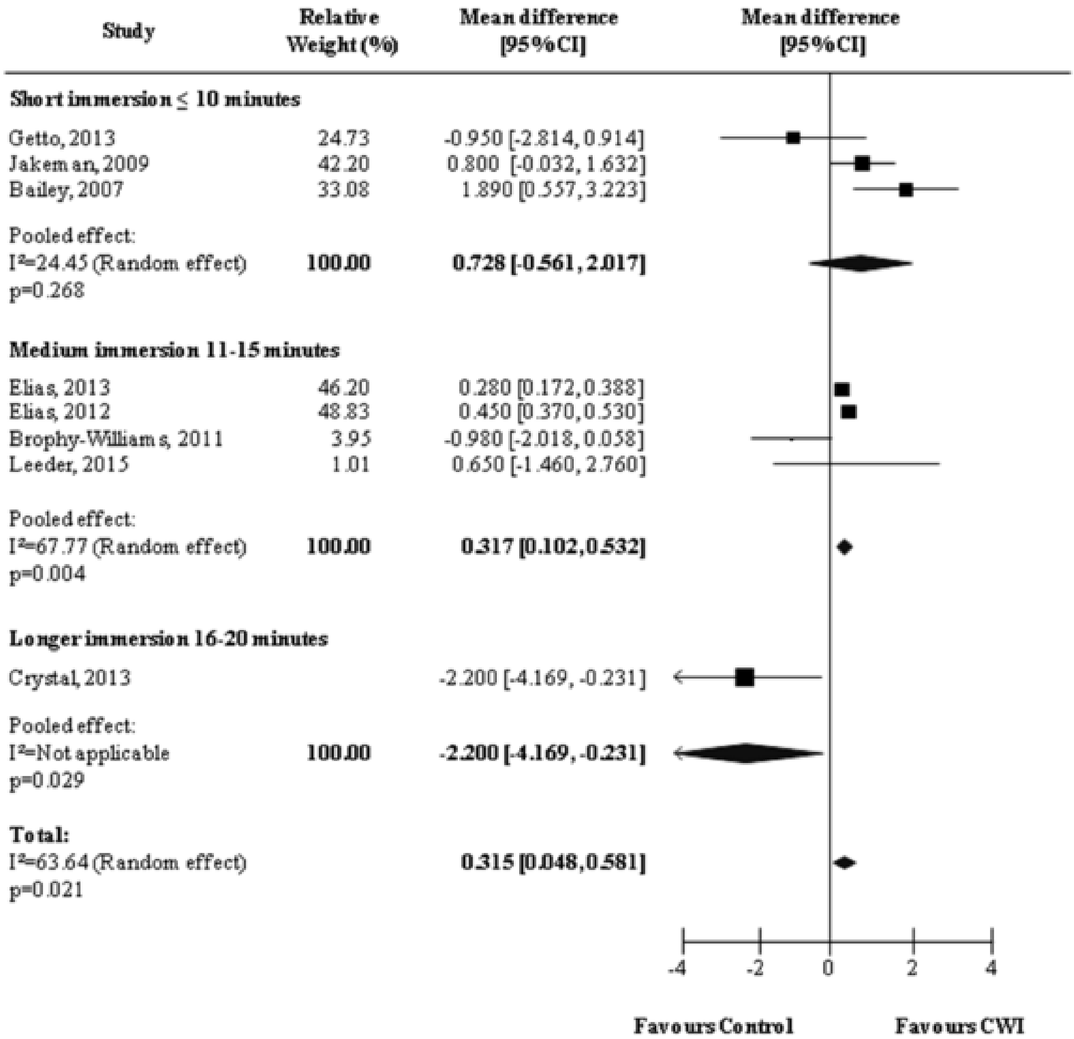

Fig.6 Forest plot of comparison: passive recovery and CWI. Subgroup: immersion time. Time point: immediate effect.

4. DISCUSSION

The results of meta-analysis of CWI as a post-exercise recovery technique and reliever of muscle soreness were consistent, and revealed the following findings: 1) independent of time and temperature, CWI produces generally positive results in terms of both immediate and delayed effects; 2) immersion in water at temperatures between 11-15°C appeared to produce a greater reduction of muscle soreness after exercise; 3) 11-15 minutes appeared to be the optimal immersion time for the relief of muscle soreness caused by exercise.

The findings regarding CWI, independent of immersion temperature and time, are in accordance with previous reviews, such as the studies by Leeder et al. [8] and Bleakley et al. [12]. The authors claim that the technique is capable of altering blood flow, thereby causing vasoconstriction and redirection of the blood. The real effects of CWI have not been fully elucidated [4], but it has been speculated that this technique is able to reduce lymphatic and capillary cell permeability [24], resulting in vasoconstriction and consequent reduction of the inflammatory process caused by exercise [6]. The technique also can reduce nerve transmission and muscle spasm. The reduction of pain can therefore be explained by these factors, together with analgesia, which occurs in response to the reduction of the pain-spasm cycle [25].

While the effects of CWI have been widely investigated, opinions vary with regard to method of application, immersion time and water temperature [13]. One hypothesis is that outcomes may differ depending on the recovery strategy used. The variance in effects caused by temperature change observed in this review revealed that CWI was more effective in terms of both immediate and delayed effects when temperatures were in the 'moderate cold' category. The mean temperature of this category in studies was 12.7° C for immediate effect and 13.2° C for delayed effect.

The benefits of 'moderate cold' temperatures have not been discussed in clinical studies. However, it has been shown that immersion in very low temperatures can cause adverse effects, interpreted by the body as noxious stimuli, and that peak pain appears around

3°C [26]. This may explain the generally negative effects described in the study by Crystal et al. [19], which featured CWI at 5°C.

A study by Getto et al. [20] claims that short immersions are less efficient at lessening muscle pain caused by exercise, due to limited muscle temperature reduction [5]. Such statement confirms the findings of this study, which indicate that medium immersions of between 11 and 15 minutes produce better results than short immersions (≤10 minutes). Additionally, during the immediate effect, there is the presence of the category 'longer immersion', responsible for the worst results. Although pooled results were not available for this category due to an insufficient number of studies (n=1), it compared unfavorably with passive recovery. The study in question [19] considered the use of a very low temperature (5°C) for 20 minutes. Davis et al. [27] claimed that for CWI to produce harmful stimulation and pain, an application of ten seconds at low temperatures was required. Such effects can be exacerbated during long immersion conditions [28,29].

Accordingly, it is important to analyze studies by subdivisions of water temperature and immersion time. The limited number of studies, however, does not allow the implementation of closed protocol comparisons. The relationship between the two variables could allow objective inferences about the most effective recovery model to be used.

As Crystal et al. [19], other studies produced results that compared unfavorably with passive recovery. Getto et al. [20] used a scale that involved six different pain points, including the low back, to analyze pain. This type of evaluation considers a larger number of pain points than other studies, and can result in participant confusion in relation to the effects of CWI. Jakeman et al. [22] found that results of immediate effects of CWI compared unfavorably with control following countermovement jumps. Goodall et al. [30] and Howatson et al. [31] used similar exercise procedures and observed a reduction of pain in the

CWI group only after 24 hours post-exercise. These adverse results can be explained by the type of muscle stress and pain magnitude [32].

Overall, the studies selected for this review show similar models of inducing stress, represented by physical activities featuring high intensity of effort. This factor is relevant to data interpretation, as different types of stress provide different outcomes, as previously explained. For example, the characteristics of injuries induced in localized eccentric exercise can differ from those sustained during sporting activities, and respond differently to the application of CWI [7,32].

To the authors' knowledge this is the first systematic review and meta-analysis to investigate the effects of different CWI procedures, namely variations in water temperature and immersion time. The strengths of this systematic review relate mainly to the rationale of the study, which aims to analyze the dose-response relationship, which is still poorly investigated in studies of this nature. One of the limitations of the study is the poor methodological quality of the studies included, as assessed by PEDro Scale. Future trials should be attentive to the criteria for the development of a high quality study, which would result in surveys with greater scientific evidence. Another limitation is that the research focused only on pain. Although it is a key outcome in recovery of an athlete, further studies should consider the dose-response effect of CWI on other markers of muscle damage, in order to identify the best CWI recovery strategy based on different factors.

5. CONCLUSION

The findings of the present study suggest that CWI is more effective than passive recovery in management of pain. The results also demonstrate the presence of a dose-response relationship, indicating that CWI provides the most effective results at temperatures between

11 and 15ºC, for 11 to 15 min. The low quality of the included studies should be considered. Higher quality studies are needed to investigate whether the dose-response relationship of the results can be reliably reproduced.

The findings of the study allow athletes using CWI to have a better understanding of the technique, resulting in a better dynamic in training and competition, leading to less aggressive and painful immersion. For those applying CWI, it will allow the use of improved logistics and therefore result in lower costs, due to the most effective use of immersion time and water temperature.

ACKNOWLEDGMENTS

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Appendix **Table 1. Search strategy**

MEDLINE (up to 21 January, 2015)

1. (randomized controlled trial) OR (controlled trial) OR (controlled clinical trial) OR (clinical trial)
2. (pain) OR (soreness) OR (muscle soreness) OR (delayed onset muscle soreness)
3. (cryotherapy) OR (cold water immersion) OR (cold-water immersion) OR (ice water immersion) OR (ice-water immersion) OR (ice bath) OR (ice-bath) OR (hydrotherapy)
4. (recovery) OR (post-exercise) OR (post exercise) OR (postexercise)
5. (animal) OR (animals)
6. 1 AND 2 AND 3 AND 4 NOT 5

EMBASE (up to 21 January, 2015)

1. (randomized controlled trial) OR (controlled trial) OR (controlled clinical trial) OR (clinical trial)
2. (pain) OR (soreness) OR (muscle soreness) OR (delayed onset muscle soreness)
3. (cryotherapy) OR (cold water immersion) OR (cold-water immersion) OR (ice water immersion) OR (ice-water immersion) OR (ice bath) OR (ice-bath) OR (hydrotherapy)
4. (recovery) OR (post-exercise) OR (post exercise) OR (postexercise)
5. 1 AND 2 AND 3 AND 4

SportDiscus (up to 21 January, 2015)

1. (randomized controlled trial) OR (controlled trial) OR (controlled clinical trial) OR (clinical trial)
2. (pain) OR (soreness) OR (muscle soreness) OR (delayed onset muscle soreness)
3. (cryotherapy) OR (cold water immersion) OR (cold-water immersion) OR (ice water immersion) OR (ice-water immersion) OR (ice bath) OR (ice-bath) OR (hydrotherapy)
4. (recovery) OR (post-exercise) OR (post exercise) OR (postexercise)
5. (animal) OR (animals)
6. 1 AND 2 AND 3 AND 4 NOT 5

The Cochrane Library (up to 21 January, 2015)

1. (randomized controlled trial) OR (controlled trial) OR (controlled clinical trial) OR (clinical trial)
2. (pain) OR (soreness) OR (muscle soreness) OR (delayed onset muscle soreness)
3. (cryotherapy) OR (cold water immersion) OR (cold-water immersion) OR (ice water immersion) OR (ice-water immersion) OR (ice bath) OR (ice-bath) OR (hydrotherapy)
4. (recovery) OR (post-exercise) OR (post exercise) OR (postexercise)
5. (animal) OR (animals)
6. 1 AND 2 AND 3 AND 4 NOT 5

Filter: trial

PEDro database (up to 21 January, 2015)

Abstract and title:

1. Pain
2. Soreness
3. Muscle soreness
4. Delayed onset muscle soreness

Therapy: hydrotherapy, balneotherapy
Subdiscipline: Sports
Method: clinical trial
*1, 2, 3, 4 were individually searched with the same therapy, subdiscipline and method.

Appendix Table 2. Physiotherapy Evidence Database Scores of Included Studies

Study	Random allocation	Concealed allocation	Groups similiar at baseline	Participant blinding	Therapist blinding	Assessor blinding	<15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimates / variability reported	Score (0-10)
Leeder, 2015	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6/10†
Crystal, 2013	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10*
Getto, 2013	Yes	No	No	No	No	No	No	No	Yes	Yes	3/10†
Elias, 2013	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10*
Elias, 2012	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10*
Stanley, 2012	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10*
Brophy-Willians, 2011	Yes	No	No	No	No	No	Yes	No	Yes	Yes	4/10†
Jakeman, 2009	Yes	No	Yes	No	No	No	No	No	Yes	No	3/10*
Bailey, 2007	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10*

* Trials assessed and listed on the PEDro Database
† Trial assessed by the 2 independent raters

Appendix: Registration PROSPERO. Available:

http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42015016573#.VO99aPnF9bc

UNIVERSITY of York
Centre for Reviews and Dissemination

NHS
National Institute for Health Research

PROSPERO International prospective register of systematic reviews

The influence of different protocols of cold water immersion on pain: a systematic review and meta-analysis

Aryane Machado, Aline Almeida, Jéssica Micheletti, Paulo Ferreira, Carlos Marcelo Pastre

Citation

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Review question(s)

The purpose of this systematic review was to determine the efficacy of cold water immersion in management of pain compared with control interventions (passive recovery).

We also aimed to identify which dosage of application can provide the best results, focusing on the water temperature and the duration of immersion.

Searches

Studies were selected after searching five databases (MEDLINE, EMBASE, SPORTDiscus, PEDro and The Cochrane Library) from the earliest record to January 21, 2015. The terms and keywords used to search optimization were related with randomized controlled trials; cold water immersion and post-exercise recovery (see details in the accompanying PDF). Electronic searches were supplemented by hand searching the reference list of eligible clinical trials. No language restrictions were applied.

Link to search strategy

http://www.crd.york.ac.uk/PROSPEROFILES/16573_STRATEGY_20150106.pdf

Types of study to be included

Randomized controlled trials

Condition or domain being studied

Studies should involve treatment with cold water immersion (CWI) in human participants and should assess pain or muscle soreness at immediate and/or delayed effect. CWI was defined as immersion in water temperature <= 15°C.

Participants/ population

To be eligible, studies had to be:

1) randomized controlled trial, comparing cold water immersion and control conditions (passive recovery) post-exercise;

2) studies that used a single session of exercises;

3) CWI applied within one hour post-exercise;

4) only one immersion on the first day.

Studies using intermittent immersions or more than one immersion in subsequent days were excluded.

Intervention(s), exposure(s)

Studies should involve treatment with cold water immersion in human participants vs control conditions (passive

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recovery)

Comparator(s)/ control

Non-exposed control group / passive recovery

Outcome(s)

Primary outcomes

Muscle soreness

Secondary outcomes

None

Data extraction, (selection and coding)

Outcome data including mean scores, SDs (final values) and sample size were extracted by two review authors (AFM, JKM). The data extraction process was performed using a standardized form that also included details as characteristics of participants, exercise protocol, cold water immersion protocols, outcome measures and methodological characteristics. Disagreements between authors regarding data extraction were resolved by consensus.

Some studies included multiple observations, therefore we extracted data at clinically relevant time point: immediate effect (up to 24 hours post-exercise) and delayed effect (after 24 hours post-exercise). For delayed effect, we considered the peak pain of control group, in order to minimize interference caused by the intervention. Pain scores were converted to a common 0-10 scale.

Risk of bias (quality) assessment

All studies included will be assessed for methodological quality. This process will be performed by two independent reviewers (AFM and JKM) using the PEDro Scale14,15. Each study will be assessed for random allocation, concealed allocation, baseline comparability, blinding participants, therapists and assessors, adequate follow-up, intention-to-treat, between-group comparison and point estimates and variability. A score greater or equal to 7 will be considered 'high quality', a score of 5 or 6 will be considered 'moderate quality' and less than or equal to 4, 'poor quality'. If trials are already assessed and listed on the PEDro database, we will adopt these scores. Methodological quality was not an inclusion criteria.

Strategy for data synthesis

The analysis will be based on temperature and duration of immersion of each study. For this, it will be necessary to establish cutoff points for each of these covariates. In water temperature analysis two categories will be used: severe cold, with water temperature between 5-10°C; and moderate cold, 11-15°C. In duration of immersion, three categories: short immersion, immersions of 10 minutes or less; medium immersion, 11-15 minutes; and longer immersion, with immersion between 16-20 minutes.

Analysis of subgroups or subsets

Comprehensive Meta-Analysis software, version 2.2.04 (Biostat, USA) will be used to conduct all analyses and the pooled estimates will be calculated using random-effects model. Data will be pooled in meta-analyses and described as weighted mean differences (MD) with 95% confidence intervals (CI). The immediate and delayed effects will be calculated in order to analyze the cold water immersion effect, independent of water temperature and duration of immersion. In cases of more than one intervention group for study, the group used will be that which represented the lowest effect size.

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Anticipated or actual start date
01 July 2014

Anticipated completion date
31 March 2015

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Conflicts of interest
None known

Language
English

Country
Australia, Brazil

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Humans; Pain; Water

Stage of review
Ongoing

Date of registration in PROSPERO
09 February 2015

Date of publication of this revision
09 February 2015

Stage of review at time of this submission	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	Yes
Data extraction	Yes	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Immediate and delayed effects of cold water immersion with different dosages after eccentric exercise-induced muscle damage: a randomized controlled trial

Cold water immersion with different dosages after eccentric exercise

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ABSTRACT

Purpose: To compare the effects of two strategies of cold water immersion (CWI), using different water temperatures, with passive recovery post-exercise, in the management of markers of muscle damage and to observe whether any of the techniques used caused deleterious effects on performance.

Materials and Methods: 60 healthy male participants performed an eccentric exercise protocol to induce muscle damage and were then randomized to one of three groups (CWI1: 15 min at 9°C; CWI2: 15 min at 14°C; CG: control group). Levels of creatine kinase, muscle soreness, pain threshold, perception of recovery and maximal voluntary isometric contraction were monitored up to 96 hours post-exercise.

Results: Regarding the immediate effect, cold water immersion, independent of water temperature, presented an earlier recovery for soreness and the CWI2 group presented an early recovery for performance ($P<0.05$). It was observed that there were no deleterious effects and no evidence was found to suggest a dose-response relationship.

Conclusions: The use of CWI is recommended as a post-exercise recovery technique and the application for 15 min at 14°C is considered the best dosage when the aim is early performance recovery; however the application should be appropriate to the specific intended outcome.

Keywords: recovery of function; cryotherapy; immersion; muscle soreness; muscle strength.

1. BACKGROUND

Intense, eccentric or unaccustomed exercise has been commonly documented as exercise able to produce delayed onset muscle soreness (DOMS) and alter various markers of muscle damage [1–5]. Responses such as a decrease in muscle function can also be related to muscle damage [6], demonstrating that these types of exercises can influence the performance and recovery of athletes [2]. Different scenarios of recovery strategies are currently being investigated in order to minimize performance decrements, such as massage, active recovery, contrast water therapy and cryotherapy [6, 7, 8].

Cold water immersion (CWI) is one recovery technique which is commonly used by athletes post-exercise to promote the restoration of body systems to baseline conditions and establish the physiological system to a pre-exercise state [9, 10]. The effects of CWI such as cooling the body tissues, reducing lymphatic, capillary and cellular permeability and decreasing nerve conduction velocity, muscular spindle activity and spasticity, have been discussed in several studies [2, 11, 12]. Despite these responses, the specific mechanism of CWI is unknown [12] and can change according to the type of exercise performed prior to the CWI and the methodology adopted for immersion [13], presenting specific evidence after exercise-induced muscle damage (EIMD) [2,11,12].

Several clinical trials and systematic reviews have compared the effects of CWI with other post-exercise recovery strategies [1-3; 5-10; 14-17]. Recent reviews found that, compared to control interventions and other traditional techniques of recovery, CWI is a more effective technique to reduce pain after a range of exercises [8, 18]. Nevertheless, studies that use different methodologies for the application of CWI, such as water temperature, duration of immersion and type of CWI, for example continuous or intermittent immersion [14] and the dose-response relationship of this technique have not yet been fully investigated.

Bleakley *et al*., 2012 [4] claimed that there are still insufficient studies available to determine the best method of CWI. From this statement, it can be is understood that conclusions about the effects of CWI are not well elucidated and require further research, including studies which approach the dose-response relationship. The purpose of this study was to analyze the immediate and delayed effects of CWI as a mode of post-exercise recovery on the management of some markers of muscle damage. The primary objective was to compare the effects of two strategies of CWI, using different water temperatures, with passive recovery post-exercise. Furthermore, from these findings, to observe whether any of the techniques used caused deleterious effects on performance on subsequent days post-exercise. Considering the positive results of previously cited studies, the hypothesis of this study was that CWI would present better results when compared with passive recovery. Moreover, considering that CWI is more efficient than other modalities for reducing neural conduction velocity [19], together with the knowledge that reduction in performance is proportional to muscle cooling [20, 21], another hypothesis was that CWI may have a negative influence on performance, related to the deleterious effects, especially when applied at 9°C.

2. METHODS

2.1 Participants

Sixty young, healthy male participants (aged 18-25 years, height 1.74±0.06 m, body mass 74.4±11.1 kg and body mass index 24.4±4.1 kg . m $^{-2}$) participated in this study, as show in the flowchart (Fig. 1). To be included, the participants were required to report the absence of anemia, inflammation, diabetes, cardiovascular diseases and muscle injuries in the lower limbs and/or spine in the previous six months. Participants were required to abstain from anti-inflammatory and analgesic drugs and not perform any exercise during the study.

Prior to data collection, a medical evaluation was performed to ensure that the participants were fully able to participate in the study.

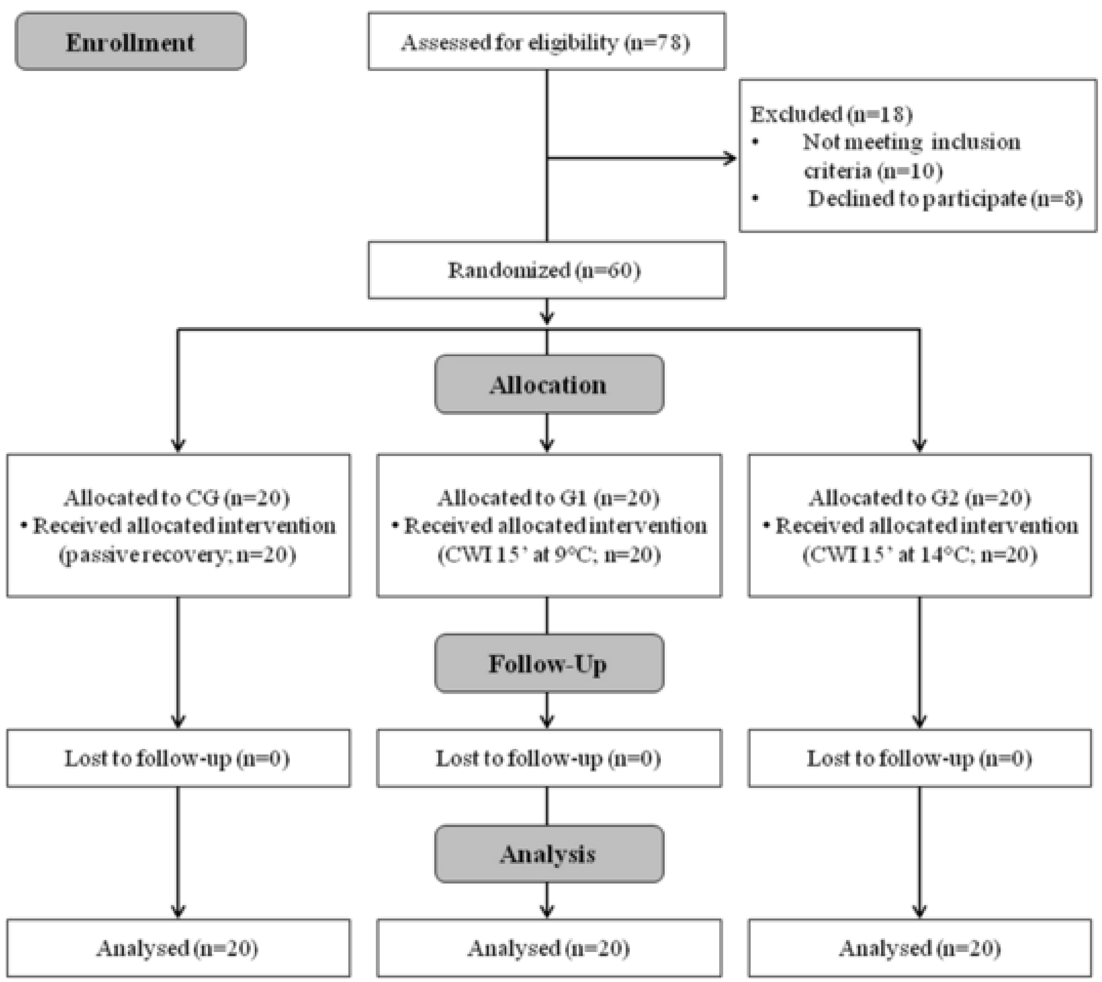

Fig 1. Flowchart of participants

To define the sample size a priori knowledge was used, based on the findings of Bailey *et al*., 2007 [2] for concentration of creatine kinase (SD=200 U/L). A sample size of twenty participants per group was stipulated by a test of hypothesis (two-tail), with a 5% level of significance and 80% power. Thus, a randomization sequence was created using software (Microsoft Office Excel 2007) and a computer-generated random list was used for allocation.

The participants were allocated into three groups: control group (CG: passive recovery for 15 minutes) and two intervention groups (CWI1 – 15 minutes at 9±1°C and CWI2 – 15 minutes at 14±1°C). During the study, the participants received no information about which intervention was considered therapeutic.

2.2 Ethics statement

The study had been previously approved by the Ethics Committee in Research of the Univ. Estadual Paulista (Faculty of Science and Technology – UNESP; protocol number: 2013/396.666). The participants received oral and written instructions and signed a Consent Form agreeing to the research procedures.

2.3 Study design

The study procedure was carried out between January and April 2014 at the Centre for Studies and Treatment in Physical Therapy and Rehabilitation – UNESP. All procedures were performed in standardized conditions (temperature: 21-23°C; relative humidity: 40-60%) [22].

Each participant attended the laboratory on five consecutive days. Prior to the procedures, the participants were assessed for anthropometric characteristics using a scale (*Tanita BC 554, Iron Man/Inner* - Illinois, USA) and a stadiometer (*Sany – American Medical do Brasil*, São Paulo, Brazil) (Table 1). The baseline assessment, eccentric exercise-induced muscle damage (EIMD), intervention and immediate assessment were performed on the first day. Subsequent visits were performed 24, 48, 72 and 96 hours after the EIMD, relating to the delayed effect. An overview of the study is presented in Fig 2.

Table 1. Comparison of sample characteristics (mean ± SD)

	CG (*n*=20)	CWI1 (*n*=20)	CWI2 (*n*=20)	*P-value*
Age (years)	20.4 ± 1.8	21.2 ± 2.0	20.85 ± 2.5	0.491
Height (m)	1.76 ± 0.0	1.74 ± 0.0	1.73 ± 0.0	0.355
Body mass (kg)	76.7 ± 10.0	71.5 ± 8.8	74.9 ± 13.7	0.260
Body mass index ($kg . m^{-2}$)	24.6 ± 3.1	23.6 ± 3.0	25.0 ± 5.7	0.599

CWI: cold water immersion; SD: standard deviation

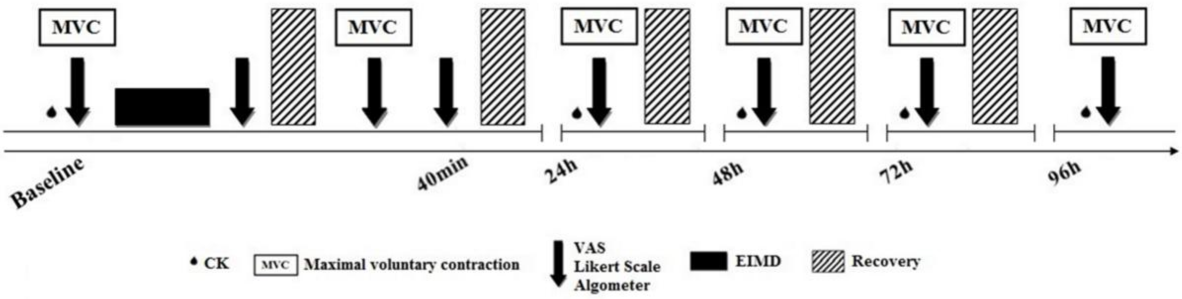

Fig 2. Study design. VAS: Visual Analogue Scale; EIMD: Exercise induced muscle damage; CK: Creatine Kinase.

2.4 Procedures

2.4.1 Eccentric exercise-induced muscle damage protocol (EIMD)

For the eccentric protocol [23], muscle injury was induced in the dominant knee extensors using an isokinetic dynamometer (*Biodex System 4 Pro*, New York, USA). Prior to the protocol, the participants were familiarized with the eccentric exercise. The familiarization consisted of five sub-maximal eccentric contractions of knee extension. Before each repetition, the participant's dominant leg was positioned at 30° knee flexion (starting from 90° flexion). The participant was instructed to perform a knee extension while the dynamometer, with its resistance, returned the leg to 90° flexion (starting position), at a speed of 60° . s –1 (1.04 rad . s –1), performing a range of motion of 60° (30-90° knee flexion).

The protocol started five minutes after the familiarization and the participant was required to perform 75 maximal eccentric contractions of knee extension, divided into five sets of 15 repetitions, separated by a rest period of 30s. The velocity and range of motion were similar to the familiarization.

2.4.2 Creatine kinase (CK)

Creatine kinase concentration was obtained from capillary blood, collected by finger-prick (32 µL). The blood sample (total blood) was analyzed using a *Reflotron Plus* reader (*Roche Diagnostics*, Mannheim, Germany) in 37°C.

2.4.3 Muscle soreness (VAS) and pain threshold (algometer)

The participants were instructed to assess the soreness in their leg (induced by the damage), using a Visual Analogue Scale (VAS) ranging from 0 “no soreness” to 10 “extreme soreness” [2]. During the assessment, the participant performed a maximal isometric contraction on an isokinetic dynamometer with the knee flexed at 60° during the assessment.

Pain threshold was assessed using a pressure algometer (*FPX 50/220, Wagner Instruments,* Greenwich, USA). The participant indicated specific painful points during the isometric contraction (60º knee flexion). The algometer was then applied to the indicated point until the participant reported discomfort. The pain threshold was defined in Kgf and did not exceed 2.55 Kgf, as suggested by Jönhagen *et al.*, 2009 [24]. The assessment was performed with the leg at 60º knee flexion, with muscles relaxed.

2.4.4 Perception of recovery (Likert Scale)

Perception of recovery was obtained using a 10-point Likert Scale, with a rating of 1 indicating the feeling “not recovered” and a rating of 10 the feeling “fully recovered” [25]. The participant was asked the following question to assess muscle function: “If you had to perform the MVIC now, how recovered do you feel?

2.4.5 Maximal Voluntary Isometric Contraction (MVIC)

Prior to the assessment of muscle function, the participants performed a warm-up consisting of 10 concentric repetitions of knee flexion-extension at 180°. s^{-1} (3.14 rad . s^{-1}) throughout the range of motion, as suggested by Baroni *et al.*, 2010 [23].

Muscle function was determined as the highest torque value of three repetitions of 5 seconds of MVIC at 60° knee flexion (0º corresponding to the maximal extension). The repetitions were separated by a rest interval of 2 minutes to minimize possible effects of fatigue. The participants were instructed to perform maximal isometric contractions and were verbally encouraged by the researcher throughout the assessment.

2.4.6 Recovery strategies

Immediately following the EIMD protocol (post-exercise), the participants from the intervention groups were immersed in water for 15 minutes, up to the height of the iliac crest at temperatures of 9±1°C or 14±1°C, controlled by a thermometer of 0.1°C with an accuracy of 0.1°C. During this period, the control group participants remained seated for passive recovery.

The same recovery strategies were performed at the end of each visit, including the following moments after the eccentric protocol (40 minutes, 24, 48 and 72 hours post-exercise) to minimize the potential effects caused by stress during MVIC.

2.4.7 Statistical analysis

We used SPSS (version 18; SPSS Inc, Chicago, IL) to conduct the analysis. Initially, sphericity of the data was tested by Mauchly's test. In case of violation of the sphericity assumption, the Greenhouse-Geisser corrections were used. Thus, the mean and standard deviation were considered. Data were analyzed using Repeated Measures Analysis of Variance (Bonferroni's test was performed when required), which provide information of time, group and interaction effects. All statistical analysis assumed a significance level of 5%.

3. RESULTS

Values of Table 2 are presented as mean and standard deviation values and shows a significant effect for time for all outcomes ($P<0.001$). There were no significant group and interaction (Group*time) effects.

Creatine kinase activity had increased significantly at 24 hours and continued increasing until 96 hours post-exercise ($P<0.05$). The CK peak occurred between 72 and 96 hours post-exercise.

The exercise protocol resulted in severe muscle soreness that peaked immediately after the protocol and 48 hours post-exercise. Both intervention groups demonstrated reduced ratings of muscle soreness immediately post-recovery and 40 minutes post-exercise. All groups reported a reduced rating of soreness at 72 hours post-exercise ($P>0.05$). Ratings of perception of recovery decreased significantly post-exercise ($P<0.05$) and began to increase at 72 hours post-exercise.

All groups presented reduced MVIC post-recovery ($P<0.05$). However, significant muscle function losses were recorded 24 hours post-exercise for the control and CWI 1 groups, while the CWI 2 demonstrated recovered values and presented no difference to baseline after the first day (Fig 3).

Table 2. Creatine kinase activity, muscle soreness, pain threshold, perception of recovery and maximal voluntary isometric contraction. Values are presented as mean±SD.

		Follow up							
	Baseline	**EIMD**	**Recovery**	**40min**	**24h**	**48h**	**72h**	**96h**	**Summary of effects**
Creatine Kinase (U/L)									
Control group	145.4±28.2	n/a	n/a	n/a	549.5±448.4*	807.6±516.7*	843.90±540.2*	822.4±549.0*	Time (*p*=0.001)
15 min at 9°C	143.6±39.7	n/a	n/a	n/a	538.8±499.6*	786.7±564.8*	881.4±588.6*	896.6±661.5*	Group*time (*p*=0.270)
15 min at 14°C	142.0±46.7	n/a	n/a	n/a	420.0±317.2*	860.2±543.3*	1118.0±549.6*	1015.6±555.7*	Group (*p*=0.784)
Muscle soreness (VAS)									
Control group	1.3± 1.8	5.7±2.5*	4.5±2.2*	3.4± 2.5*#	3.3±1.7*	4.3±2.9*	2.7±2.6	1.4±1.6#	Time (*p*=0.001)
15 min at 9°C	1.5±2.2	5.5±2.7*	2± 2.5#	2.6±2.6#	3.1±1.9#	4.6±2.9*	2.2±2.1#	0.6±0.8#	Group*time (*p*=0. 257)
15 min at 14°C	1.7±2.1	6.0±2.7*	2.7±2.2#	3.4±2.6#	3.9±1.7*	4.8±2.4*	2.9±2.5#	1.7±1.6#	Group (*p*=0.299)
Recovery (Likert Scale)									
Control group	10±0	3.1±1.5*	4.8±1.7*	4.4±1.4*#	5.9±1.7*#	4.9±2.8*	5.7±2.5*#	7.0±2.1*#	Time (*p*=0.001)
15 min at 9°C	10±0	3.7±2.5*	4.1±2.2*	5.0±2.1*	5.6±2.2*	5.7±3.1*	7.0±2.5*#	8.4±1.8*#	Group*time (*p*=0.319)
15 min at 14°C	10±0	3.4±1.8*	4.0±2.4*	5.3±1.9*#	5.8±2.2*#	5.1±2.9*	6.9±2.5*#	7.1±2.2*#	Group (*p*=0. 495)
MVIC (N . m)									
Control group	285.2± 46.9	n/a	234.6±68.9*	n/a	249.3±69.8*	247.3±95.1	252.5±95.5	264.3±84.1	Time (*p*=0.001)
15 min at 9°C	284.9±44.8	n/a	230.0±58.6*	n/a	250.1±58.7*	250.0±67.9	260.0±59.6	269.9±45.5	Group*time (*p*=0.980)
15 min at 14°C	281.6±51.1	n/a	227.9±44.5*	n/a	248.3±59.9	243.1± 69.9	246.1±56.5	257.2±47.5	Group (*p*=0.931)

n = 20 per group
n/a: not applicable
EIMD: Exercise induced-muscle damage; MVIC: Maximal voluntary isometric contraction; Recovery: immediately post-recovery.
* Statistically significant difference (*P*<0.05) from baseline
# Statistically significant difference (*P*<0.05) from EIMD

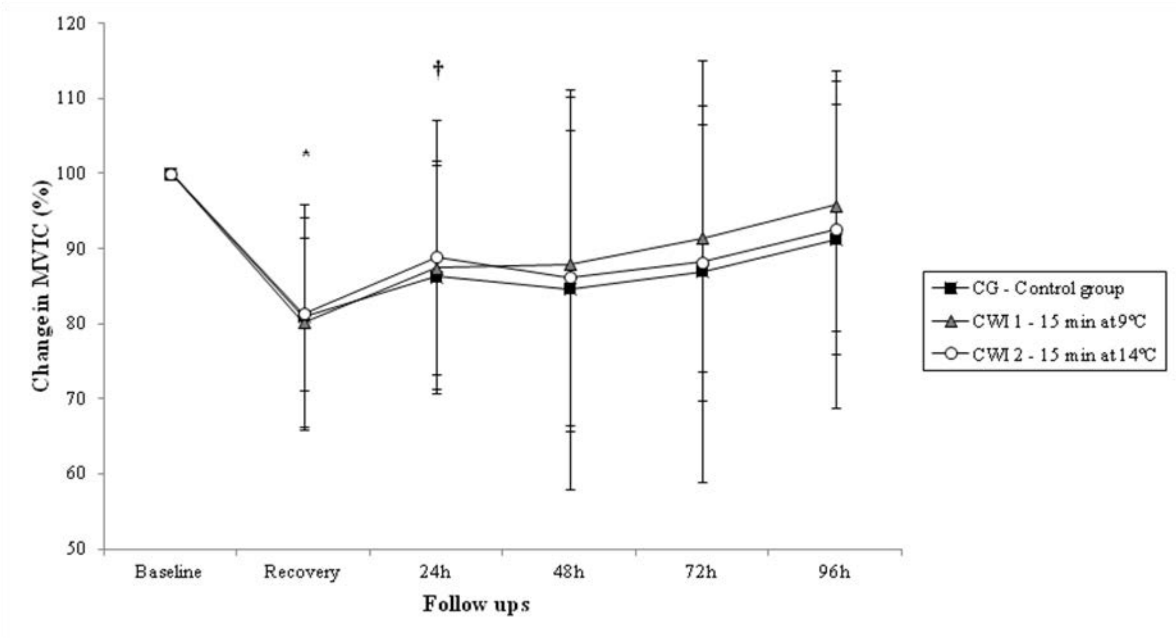

Fig 3. Change in maximal voluntary isometric contraction (%; mean and SD). *Statistically significant difference (*P*<0.05) from baseline for all groups; †Statistically significant difference (*P*<0.05) from baseline for control group and CWI 1 (15 min at 9±1°C).

4. DISCUSSION

The present study aimed to compare the immediate and delayed effects of two CWI strategies, at different water temperatures, on the management of some markers of muscle damage after eccentric exercise and to examine the possible deleterious effects on subsequent days post-exercise. The main findings of this study were that all recovery strategies acted in a similar way concerning creatine kinase activity and pain threshold and the CWI groups acted more efficiently for soreness and muscle function. The findings regarding soreness demonstrated that the CWI groups presented lower ratings immediately post-recovery. For the delayed effects, all groups reported a decrease in perception of pain at 72 hours post-exercise. For muscle function, the application of CWI for 15 minutes at 14°C presented earlier recovery compared with other CWI and control conditions.

Severe changes in markers of muscle damage corroborate the findings of Baroni et al., 2010 [23] who used the same protocol. These changes provide evidence that the objective of causing muscle damage through this exercise protocol was successful. Different protocols have been used to induce damage such as high intensity and eccentric exercise [8]. Baroni *et al.*, 2010 [23] claimed that the intensity of exercise, number of repetitions, velocity and range of motion can influence the magnitude of damage. Glasgow *et al.*, 2014 [1] used a protocol based on 3 sets of eccentric exercises which resulted in a considerably lower soreness peak than that found in the present study. This may explain the small differences found between the CWI groups and control condition.

The ratings of soreness increased after the eccentric exercise protocol and presented peaks post-exercise and at 48 hours for all groups. Crystal *et al.*, 2013 [3] also found a double peak; however, the second peak occurred at 24 hours post-exercise. An interesting finding is the soreness reduction after CWI. These findings could be due to the analgesic effect of CWI and inhibition of muscle damage [2, 26]. Analgesia is present in the short term, but the precise time is still uncertain [2, 17]. It is speculated that this period can vary from between 3 minutes to 3 hours [26], which may explain the immediate effect results. The improvement in ratings of soreness found in the CWI when compared with the control condition immediately post-recovery and 40 minutes post-exercise is similar to a previous study [27], yet demonstrated no significant differences. The delayed effects are in agreement with other studies of the same nature, demonstrating the attenuation of soreness after 48 hours post-exercise [3, 6, 17]. In addition, in accordance with a previous study, Crystal *et al.*, 2013 [3] found improvement in soreness for all groups at 72 hours post-exercise compared with pre-exercise. No effects were observed for pain threshold, which corroborates with Sellwood's study [11].

Perception of recovery has been presented as an important tool for evaluating the effectiveness of different techniques and plays a crucial role in the adaptive process [28, 29]. The improvement in perception of recovery has a direct relationship with the benefits of CWI [13, 25, 28, 30]. No evidence of an improvement in the perception of recovery in the immediate effects, unlike the studies of Parouty *et al.* [30] and Buchheit *et al.* [25]. Some authors [28, 31] have pointed out that there is a contribution from the psychological mechanism and athletes often present better performances when they believe they have received a beneficial treatment, which was not observed in this study.

Another commonly employed marker of muscle damage is the blood concentration of creatine kinase. It was observed that all groups similar responses in this respect and that the period of 96 hours post-exercise was not sufficient for recovery to baseline concentration levels, demonstrating a time effect as in the studies of Glasgow et al. [1] and Ingram et al. [32]. Eston and Peters, 1999 [33] claimed that the actual mechanisms involved in the alterations of CK are still unclear and some researchers have questioned whether CK levels accurately assess the severity of muscle damage [32-34]. Warren and Lowe and Armstrong, 1999 [34] further claimed that CK levels are dissociated from histological signs of damage and suggest, as do Morton *et al.*, 2005 [35], that the assessment of maximal voluntary contraction is a more relevant marker.

The possible effects of the techniques on muscle function were also verified. Studies claim that the electrical activity of the muscle is considerably lower after cooling techniques, although the relationship between muscle cooling and subsequent performance remains unclear [20]. Crowe et al., 2007 [36] claim that decreases in blood flow after the application of CWI can be detrimental to performance when the athlete needs to compete again and a decrease in muscle temperature has been related to a decrease in muscle power and strength [30, 36-39]. However, the hypothesis that CWI can worsen performance was not upheld in this study and, in fact, contradictorily, the findings reflected performance improvements in the time function for CWI applied for 15 minutes at 14°C, indicating recovery at 24 hours, while the other groups recovered from 48 hours post-exercise. As previously cited, performance reduction after CWI is proportionally dependent on the temperature at which the muscle is cooled [21], supporting the findings and demonstrating that lower temperatures (CWI applied at 9°C), which further reduced the muscle temperature, were not able to more efficiently restore the isometric contraction values.

The current study presents high methodological quality due to being a randomized controlled trial with parallel groups and allocation concealment. As stated previously, we ensured that the participants were not informed about the benefits of each technique [1]. However, it is not possible to fully blind the participants due to the control condition. Despite its widespread use and the large body of research involving CWI, there are few studies reporting the effects of different methodologies of CWI on immediate and delayed responses, the dose-response and deleterious effects of CWI. From the findings of the present study, no dose-response relationship was observed for any outcome based on the application of the temperatures used. Nevertheless, it was observed that CWI for 15 minutes at 14°C was the most appropriate dosage of application, represented by the early recovery of MVIC, which contradicts many studies. A potential limitation of the present study was the characteristics of the participants. Although the study sample consisted of young, healthy participants, it was not possible to ensure the exercise specificity of each participant, such as level or type of exercise, which could have influenced the responses. Therefore, we suggest further investigations which consider dose-response and a wider range of temperatures and durations of immersion, in addition to investigating the responses of high performance athletes.

5. CONCLUSIONS

From the findings of the present study, the application of CWI, independent of water temperature, presents an earlier recovery for soreness at immediate effect. It was noted that CWI for 15 minutes at 14°C represented the best dosage when the aim was performance recovery, presenting an anticipated recovery for maximal voluntary isometric contraction. However, no evidence was found to suggest a dose-response relationship for any outcome. It was also observed that there were no deleterious effects on performance after application of CWI.

Thus, the use of CWI is recommended as a post-exercise recovery technique; however the application should be appropriate to the specific intended outcome.

ACKNOWLEDGMENTS

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Appendix: Registration REBEC (Registro Brasileiro de Ensaios Clínicos). Available:

http://www.ensaiosclinicos.gov.br/rg/RBR-2bz8rj/

Ensaios Clínicos

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Efeitos imediatos e tardios da crioimersão após protocolo de exercício excêntrico

Data de registro: 5 de Set. de 2013 às 10:52

Last Update: 23 de Jan. de 2015 às 11:48

Tipo do estudo:

Intervenções

Título científico:

PT-BR	EN
Efeitos imediatos e tardios da crioimersão após protocolo de exercício excêntrico	Immediate and delayed effects of cold water immersion after eccentric exercise protocol

Identificação do ensaio

Número do UTN: U1111-1147-6348

Título público:

PT-BR	EN
Efeitos da imersão em água fria após exercício	Effects of cold water immersion after exercise

Acrônimo científico:

Acrônimo público:

Identificadores secundários:

Número do parecer: 396.666

Órgão emissor: Comitê de Ética em Pesquisa - Universidade Estadual Paulista "Júlio de Mesquita Filho"

CAAE: 22229913.0.0000.5402

Órgão emissor: Plataforma Brasil

Patrocinadores

Patrocinador primário: Universidade Estadual Julio de Mesquita Filho

Patrocinadores secundários:

Instituição: Universidade Estadual Julio de Mesquita Filho

Instituição: Faculdade de Ciências e Tecnologia - UNESP

Fontes de apoio financeiro ou material:

Instituição: Fundação de Amparo à Pesquisa do Estado de São Paulo

Condições de saúde

Condições de saúde ou problemas:

PT-BR	EN
Lesões músculo esqueléticas da perna	Leg's musculoskeletal injuries

Descritores gerais para as condições de saúde:

PT-BR	ES	EN
C05: Doenças musculoesqueléticas	**C05:** Enfermedades musculoesqueléticas	**C05:** Musculoskeletal diseases
C26: Ferimentos e lesões	**C26:** Heridas y traumatismos	**C26:** Wounds and injuries

Descritores específicos para as condições de saúde:

PT-BR	ES	EN
C26.558: Traumatismos da Perna	**C26.558:** Traumatismos de la Pierna	**C26.558:** Leg Injuries
A02.633.567: Músculo Esquelético	**A02.633.567:** Músculo Esquelético	**A02.633.567:** Muscle, Skeletal

Intervenções

Categorias das intervenções

Other

Intervenções:

PT-BR

Os participantes serão divididos em 3 grupos, sendo 2 grupos intervenção (G1 e G2) e um grupo controle (GC). Cada grupo contará com 20 participantes.

Serão os grupos:
Crioimersão - G1 (15 minutos; 9±1ºC)
Crioimersão - G2 (15 minutos; 14±1ºC)
Controle (15 minutos; sentado)

Imediatamente após o protocolo de exercício excêntrico, os participantes do grupo intervenção serão imersos até a altura da crista ilíaca por 15 minutos à temperatura de 9±1°C ou 14±1°C. Durante esse período, os participantes do grupo controle permanecerão sentados para recuperação passiva.
A temperatura da água será controlada por meio de um termômetro de 0.3° de acurácia. As mesmas estratégias de recuperação ocorrerão no final de cada visita (40 minutos, 24, 48 e 72 horas pós-exercício) a fim de minimizar os potenciais efeitos causados pelo estresse durante a contração voluntária máxima.

EN

The participants will be divided into 3 groups: 2 intervention groups (G1 and G2) and control group (CG). Each group will have 20 participants.

Groups:
Cold water immersion - G1 (15 minutes; 9±1ºC)
Cold water immersion - G2 (15 minutes; 14±1ºC)
Control - CG (15 minutes; setead)

Immediately after the eccentric exercise protocol, participants in the intervention group will be immersed to the level of the iliac crest for 15 minutes at a temperature of 9±1°C or 14±1°C. During this period, participants in the control group will remain seated for passive recovery. Water temperature is controlled by a thermometer accuracy of 0.3 °. The same recovery strategies will occur at the end of each visit (40 minutes, 24, 48 and 72 hours post-exercise) in order to minimize the potential effects caused by stress during maximal voluntary contraction.

Descritores para as intervenções:

PT-BR	ES
E02.258: Crioterapia	**E02.258:** Crioterapia
E05.466: Imersão	**E05.466:** Inmersión
D01.455.900.400: Gelo	**D01.455.900.400:** Hielo

Recrutamento

Situação de recrutamento: Recruitment completed

País de recrutamento

Brazil

Data prevista do primeiro recrutamento: 2013-09-20

Data prevista do último recrutamento: 2013-12-10

Tamanho da amostra alvo:	Gênero para inclusão:	Idade mínima para inclusão:	Idade máxima para inclusão:
48	M	18 Y	30 Y

Critérios de inclusão:

PT-BR	EN
Sexo masculino; aparentemente saudáveis; fisicamente ativos	Male; apparently healthy; physically active

Critérios de exclusão:

PT-BR	EN
Ser etilista; consumir drogas; fumo ou medicamentos anti-inflamatórios de forma crônica; apresentar anemia; processo inflamatório, diabetes; doença cardiovascular; problemas no fígado; episódio de lesão músculo-tendínea ou osteoarticular nos membros inferiores e/ou coluna nos últimos seis meses.	Be alcoholics; drug use; smoking or anti-inflammatory medications chronically; present anemia; inflammation; diabetes; cardiovascular disease; liver problems; injury episode musculotendinous osteoarticular or lower limbs and / or spine in the last six months.

Tipo do estudo

Desenho do estudo:

PT-BR	EN
Ensaio Clínico de tratamento, randomizado, factorial, aberto, com três braço	Clinical trial treatment, randomized, factorial, open, with 3 arms

Programa de acesso expandido	Enfoque do estudo	Desenho da intervenção	Número de braços	Tipo de mascaramento	Tipo de alocação	Fase do estudo
False	Treatment	Factorial	3	Abrir	Randomized-controlled	N/A

Desfechos

Desfechos primários:

PT-BR	EN
Desfecho esperado: Redução da dor muscular, avaliada por meio de uma Escala Visual Análoga de Dor (EVA). Considerou-se o valor respondido compreendido entre 0 – 10. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício.	Expected outcome: Reduction of muscle soreness, assessed by a visual analog scale of pain (VAS). It was considered the value between 0 - 10. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h post-exercise.
Desfecho encontrado: Redução da dor muscular, avaliada por meio de uma Escala Visual Análoga de Dor (EVA). Considerou-se o valor respondido compreendido entre 0 – 10, durante a contração voluntária máxima. Foi realizada análise comparativa entre os grupos e entre os momentos. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício.	Outcome found: Reduction of muscle soreness, assessed by a visual analog scale of pain (VAS). It was considered the value between 0-10, during maximal voluntary contraction. Comparative analysis was performed between groups and between times. Assessment in moments: Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h post-exercise.

Desfechos secundários:

PT-BR	EN
Desfecho esperado (1): alteração de sensibilidade, avaliada por meio do algômetro de pressão, dado em Kgf. Considerou-se o valor de mínimo desconforto sentido. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício. Desfecho esperado (2): Análise da concentração de creatina quinase, avaliada por meio do Reflotron Plus. Avaliação nos momentos: basal, 24h, 48h, 72h e 96h após exercício. Desfecho esperado (3): diminuição da força muscular, avaliada por meio do dinamômetro isocinético, na condição isométrica em 3 tentativas de 5 segundos cada. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício. Desfecho esperado (4): percepção de recuperação, avaliada por meio de uma escala Likert. Considerou-se o valor respondido compreendido entre 0 – 10. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício.	Expected outcome (1): sensitivity alteration, assessed by pressure algometer given in kgf. It was considered the minimum discomfort value. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise. Expected outcome (2): Analysis of creatine kinase concentration, assessed using the Reflotron Plus. Time points to evaluation: baseline, 24h, 48h, 72h and 96h after exercise. Expected outcome (3): decreased muscle strength, evaluated by means of isokinetic dynamometer, in isometric condition in 3 repetition of 5 seconds. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise. Expected outcome (4): perception of recovery evaluated using a Likert scale. It was considered the value between 0 - 10. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise.
Desfecho encontrado (1): alteração de sensibilidade, avaliada por meio do algômetro de pressão, dado em Kgf.	Outcome found (1): sensitivity alteration, assessed by pressure algometer given in kgf. It was considered the minimum

Considerou-se o valor de mínimo desconforto sentido no membro inferior com o músculo relaxado. Foi realizada análise comparativa entre os grupos e entre os momentos. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício. Desfecho encontrado (2): Análise da concentração de creatina quinase, avaliada fitas de CK no Reflotron Plus, por meio de punção digital. Foi realizada análise comparativa entre os grupos e entre os momentos. Avaliação nos momentos: basal, 24h, 48h, 72h e 96h após exercício. Desfecho encontrado (3): diminuição da força muscular, avaliada por meio do dinamômetro isocinético, na condição isométrica. O valor foi dado pela melhor das 3 tentativas de 5 segundos cada. Foi realizada análise comparativa entre os grupos e entre os momentos. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício. Desfecho encontrado (4): percepção de recuperação, avaliada por meio de uma escala Likert. Considerou-se o valor respondido compreendido entre 0 – 10, sendo 10 totalmente recuperado. Foi realizada análise comparativa entre os grupos e entre os momentos. Avaliação nos momentos: basal, 40 minutos, 24h, 48h, 72h e 96h após exercício.

discomfort value in the lower limb with the relaxed muscle. Comparative analysis was performed between groups and between times. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise. Outcome found (2): Analysis of creatine kinase concentration evaluated CK tapes in Reflotron Plus, by a finger prick . Comparative analysis was performed between groups and between times. Time points to evaluation: baseline, 24h, 48h, 72h and 96h after exercise. Outcome found (3): decreased muscle strength, evaluated by means of isokinetic dynamometer, in isometric condition. The value given was the best of three repetition of 5 seconds each. Comparative analysis was performed between groups and between times. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise. Outcome found(4): perception of recovery evaluated using a Likert scale. It was considered the value answered between 0-10, 10 being fully recovered. Comparative analysis was performed between groups and between times. Time points to evaluation: baseline, 40 minutes, 24h, 48h, 72h and 96h after exercise.

Contatos

<u>Contatos para questões públicas</u>

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FCT/UNESP

Contatos para informação sobre os centros de pesquisa

Nome completo: Aryane Flauzino Machado

Endereço: Rua Felipe Carnevale, 150

Cidade: Presidente Prudente / Brazil

CEP: 19060-220

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E-mail: aryfmachado@yahoo.com.br

Filiação: Universidade Estadual Paulista
FCT/UNESP

Anexos

http://www.ensaiosclinicos.gov.br/static/attachments/parecer-comite-de-etica_3.pdf (Parecer - Comitê de Ética em Pesquisa Documento gerado pela Plataforma Brasil)

Links adicionais:

Download no formato ICTRP

Download no formato XML OpenTrials

Appendix: Ethical approval – Human Research Ethics Committee

Available: http://www.ensaiosclinicos.gov.br/static/attachments/parecer-comite-de-etica_3.pdf

FACULDADE DE CIÊNCIAS E TECNOLOGIA - UNESP/ CAMPUS DE PRESIDENTE

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: EFEITOS IMEDIATOS E TARDIOS DA CRIOIMERSÃO APÓS PROTOCOLO DE EXERCÍCIO EXCÊNTRICO

Pesquisador: Aryane Flauzino Machado

Área Temática:

Versão: 1

CAAE: 22229913.0.0000.5402

Instituição Proponente: UNIVERSIDADE ESTADUAL PAULISTA JULIO DE MESQUITA FILHO

Patrocinador Principal: FUNDACAO DE AMPARO A PESQUISA DO ESTADO DE SAO PAULO

DADOS DO PARECER

Número do Parecer: 396.666

Data da Relatoria: 13/09/2013

Apresentação do Projeto:

O projeto apresenta boa revisão literatura. É assunto relevante e importante para as lesões musculares advindas de atividades físicas e a recuperação da lesão muscular. Os protocolos estão bem explicados e fundamentados e não ferem a ética com relação aos sujeitos do estudo.

Objetivo da Pesquisa:

O objetivo do presente estudo será analisar e comparar o efeito da crioimersão após protocolo de exercício excêntrico a partir de diferentes

temperaturas sobre aspectos clínicos (percepção de dor, de recuperação e alteração de sensibilidade), bioquímicos (creatina cinase) efuncionais

Avaliação dos Riscos e Benefícios:

os sujeitos poderão apresentar algum desconforto após protocolo de contração excentrica e recuperação mas receberão cuidados e orientações de profissional médico.

Comentários e Considerações sobre a Pesquisa:

nada a relatar

Considerações sobre os Termos de apresentação obrigatória:

Estão apresentados e adequados

Endereço: Rua Roberto Simonsen, 305
Bairro: Centro Educacional **CEP:** 19.060-900
UF: SP **Município:** PRESIDENTE PRUDENTE
Telefone: (18)3229-5315 **Fax:** (18)3229-5353 **E-mail:** cep@fct.unesp.br

Recomendações:

nada relatar

Conclusões ou Pendências e Lista de Inadequações:

Diante de toda apresentação de documentos e a forma apresentada do projeto de pesquisa e a declaração de profissional na realização e acompanhamento do estudo o projeto será conduzido adequadamente respeitando éticamente os sujeitos da pesquisa

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

O Comitê de Ética em Pesquisa aprovou ad referendum em 16/09/2013

PRESIDENTE PRUDENTE, 16 de Setembro de 2013

Assinador por:
Edna Maria do Carmo
(Coordenador)

Endereço: Rua Roberto Simonsen, 305
Bairro: Centro Educacional **CEP:** 19.060-900
UF: SP **Município:** PRESIDENTE PRUDENTE
Telefone: (18)3229-5315 **Fax:** (18)3229-5353 **E-mail:** cep@fct.unesp.br

A partir da pesquisa realizada pode-se concluir que os resultados da aplicação da imersão em água fria sobre os marcadores de dano muscular ainda não estão plenamente elucidados, variando quanto aos desfechos analisados. Entretanto, ambos os estudos apontam uma dose de aplicação similar.

Ainda que a revisão sistemática seja composta por artigos de baixa qualidade metodológica, a meta-análise realizada sugere uma aplicação com água à temperatura em torno de 11 a 15°C com o tempo de imersão variando entre 11 e 15 minutos. Corroborando os achados, o ensaio clínico randomizado, apresenta uma melhor dose quando aplicada a 14°C por 15 minutos, ainda que seja para recuperação antecipada da *performance*. Sob outro enfoque, conclui-se também que ambos os estudos apontam que a imersão em água fria, quando não produz efeitos que minimizam os marcadores de dano muscular, também não provoca efeitos deletérios.

1. Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. Br J Sports Med. 2010 Feb;44(3):179–87.

2. Brophy-Williams N, Landers G, Wallman K. Effect of immediate and delayed cold water immersion after a high intensity exercise session on subsequent run performance. J Sports Sci Med. 2011 Jan;10(4):665–70.

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4. Sellwood KL, Brukner P, Williams D, Nicol A, Hinman R. Ice-water immersion and delayed-onset muscle soreness: a randomised controlled trial. Br J Sports Med. 2007 Jun;41(6):392–7.

5. 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 Feb;29(3):217–25.

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7. Pournot H, Bieuzen F, Duffield R, Lepretre P-M, Cozzolino C, Hausswirth C. Short term effects of various water immersions on recovery from exhaustive intermittent exercise. Eur J Appl Physiol. 2011 Jul;111(7):1287–95.

8. Ingram J, Dawson B, Goodman C, Wallman K, Beilby J. Effect of water immersion methods on post-exercise recovery from simulated team sport exercise. J Sci Med Sport. 2009 May;12(3):417–21.

9. Glasgow PD, Ferris R, Bleakley CM. Cold water immersion in the management of delayed-onset muscle soreness: Is dose important? A randomised controlled trial. Phys Ther Sport. 2014 Jan 29.

10. Getto CN, Golden G. Comparison of Active Recovery in Water and Cold-Water Immersion After Exhaustive Exercise. Athl Train Sport Heal Care. 2013 Jul 2;5(4):169–76.

11. Jakeman JR, Macrae R, Eston R. A single 10-min bout of cold-water immersion therapy after strenuous plyometric exercise has no beneficial effect on recovery from the symptoms of exercise-induced muscle damage. Ergonomics. 2009 Apr;52(4):456–60.

12. Wilcock IM, Cronin JB, Hing WA. Physiological Response to Water Immersion A Method for Sport Recovery? Sports Med. 2006;36(9):1–18.

13. Eston R, Peters D. Effects of cold water immersion on the symptoms of exercise-induced muscle damage. J Sports Sci. 1999 Mar;17(3):231–8.

14. Andrews JR, Harrelson GL, Wilk KE. Reabilitação física nas lesões desportivas. 2.ed. Guanabara Koogan, 2000.

15. Pastre CM, Bastos FN, Netto Junior, J, Vanderlei LCM, Hoshi RA. Métodos de Recuperação Pós-exercício: uma Revisão Sistemática. Rev Bras Med Esporte. 2009;15:138–44.

Instructions for Author – Sports Medicine

Types of papers

The word counts given below do not include the abstract, references, figure legends or table captions.

- Systematic Review. Word count up to 10,000. Collates all empirical evidence that fits pre- specified eligibility criteria to answer a specific research question. It uses explicit, systematic methods that are selected with a view to minimizing bias, thus providing reliable findings from which conclusions can be drawn and decisions made. Please refer to Integrity of Research and Reporting below for more information on reporting requirements.

Manuscript Submission

Manuscript Submission

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all coauthors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

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Authors should submit their manuscripts online. Electronic submission substantially reduces the editorial processing and reviewing times and shortens overall publication times. Please follow the hyperlink “Submit online” on the right and upload all of your manuscript files following the instructions given on the screen.

Internal Review by Editorial Staff

The journal editor will perform an initial appraisal of each manuscript. If your paper has been peer reviewed by another journal as part of a prior submission, the journal editor will also assess any previous editorial/referee comments and how these have been dealt with as part of the appraisal process. If your manuscript is considered unsuitable for the journal to which it has been submitted, it may be assessed for suitability for publication in other Adis journals by appropriate editors. However, it will not be progressed to external peer review for an alternative journal without your permission.

Title page

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)

- The email address, telephone and fax numbers of the corresponding author

Abstract

Please provide an abstract of 150 to 250 words. The abstract should not contain any undefined abbreviations or unspecified references. For manuscripts reporting the results of a systematic review with or without a meta-analysis, the abstract should be structured as described in the PRISMA statement. For these types of manuscripts the abstract length can be increased from the 250 word limit to allow full compliance with PRISMA / CONSORT.

Text Formatting

Manuscripts should be submitted in Word.

- Use a normal, plain font (e.g., 10point Times Roman) for text.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Headings

Please use the decimal system of headings with no more than three levels.

Abbreviations

Abbreviations should be defined at first mention and used consistently thereafter.

Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lowercase letters (or asterisks for significance values and other statistical data).

Footnotes to the title or the authors of the article are not given reference symbols.

Always use footnotes instead of endnotes.

Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full.

References

Citation

Reference citations in the text should be identified by numbers in square brackets. Some examples:

1. Negotiation research spans many disciplines [3].
2. This result was later contradicted by Becker and Seligman [5].
3. This effect has been widely studied [13,7].

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

The entries in the list should be numbered consecutively.

- Journal article: Smith JJ. The world of science. Am J Sci. 1999;36:234–5.
- Article by DOI: Slifka MK, Whitton JL. Clinical implications of dysregulated cytokine production. J Mol Med. 2000; doi:10.1007/s001090000086
- Book: Blenkinsopp A, Paxton P. Symptoms in the pharmacy: a guide to the management of common illness. 3rd ed. Oxford: Blackwell Science; 1998.
- Book chapter: Wyllie AH, Kerr JFR, Currie AR. Cell death: the significance of apoptosis. In: Bourne GH, Danielli JF, Jeon KW, editors. International review of cytology. London: Academic; 1980. pp. 251–306.
- Online document: Doe J. Title of subordinate document. In: The dictionary of substances and their effects. Royal Society of Chemistry. 1999. http://www.rsc.org/dose/title of subordinate document. Accessed 15 Jan 1999.

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see ISSN.org LTWA

Tables

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.

- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lowercase letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Artwork and illustrations guidelines

Electronic Figure Submission

- Supply all figures electronically.
- Indicate what graphics program was used to create the artwork.
- For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MSOffice files are also acceptable.
- Vector graphics containing fonts must have the fonts embedded in the files.
- Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.

Line Art

- Definition: Black and white graphic with no shading.
- Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.
- All lines should be at least 0.1 mm (0.3 pt) wide.
- Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.
- Vector graphics containing fonts must have the fonts embedded in the files.

Halftone Art

- Definition: Photographs, drawings, or paintings with fine shading, etc.
- If any magnification is used in the photographs, indicate this by using scale bars within the figures themselves.
- Halftones should have a minimum resolution of 300 dpi.

Combination Art

- Definition: a combination of halftone and line art, e.g., halftones containing line drawing, extensive lettering, color diagrams, etc.
- Combination artwork should have a minimum resolution of 600 dpi.

Color Art

- Color art is free of charge for online publication.
- If black and white will be shown in the print version, make sure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent.
- If the figures will be printed in black and white, do not refer to color in the captions.
- Color illustrations should be submitted as RGB (8 bits per channel).

Figure Lettering

- To add lettering, it is best to use Helvetica or Arial (sans serif fonts).

- Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12 pt).
- Variance of type size within an illustration should be minimal, e.g., do not use 8pt type on an axis and 20pt type for the axis label.
- Avoid effects such as shading, outline letters, etc.
- Do not include titles or captions within your illustrations.

Figure Numbering

- All figures are to be numbered using Arabic numerals.
- Figures should always be cited in text in consecutive numerical order.
- Figure parts should be denoted by lowercase letters (a, b, c, etc.).
- If an appendix appears in your article and it contains one or more figures, continue the consecutive numbering of the main text. Do not number the appendix figures, "A1, A2, A3, etc." Figures in online appendices (Electronic Supplementary Material) should, however, be numbered separately.

Figure Captions

- Each figure should have a concise caption describing accurately what the figure depicts. Include the captions in the text file of the manuscript, not in the figure file.
- Figure captions begin with the term Fig. in bold type, followed by the figure number, also in bold type.
- No punctuation is to be included after the number, nor is any punctuation to be placed at the end of the caption.

- Identify all elements found in the figure in the figure caption; and use boxes, circles, etc., as coordinate points in graphs.
- Identify previously published material by giving the original source in the form of a reference citation at the end of the figure caption.

Figure Placement and Size

When preparing your figures, size figures to fit in the column width.

For most journals the figures should be 39 mm, 84 mm, 129 mm, or 174 mm wide and not higher than 234 mm.

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- Authors
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- Introduction

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- Books: Bates B. Bargaining for life: A social history of tuberculosis. 1st ed. Philadelphia: University of Pennsylvania Press; 1992.

- Book chapters: Hansen B. New York City epidemics and history for the public. In: Harden VA, Risse GB, editors. AIDS and the historian. Bethesda: National Institutes of Health; 1991. pp. 21-28.

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- New media (blogs, websites, or other written works): Allen L. Announcing PLOS Blogs. 2010 Sep 1 [cited 17 March 2014]. In: PLOS Blogs [Internet]. San Francisco: PLOS 2006 - . [about 2 screens]. Available: http://blogs.plos.org/plos/2010/09/announcing-plos-blogs/.

- Masters' theses or doctoral dissertations: Wells A. Exploring the development of the independent, electronic, scholarly journal. M.Sc. Thesis, The University of Sheffield. 1999. Available: http://cumincad.scix.net/cgi-bin/works/Show?2e09.

- Databases and repositories (Figshare, arXiv): Roberts SB. QPX Genome Browser Feature Tracks; 2013. Database: figshare [Internet]. Accessed: http://figshare.com/articles/QPX_Genome_Browser_Feature_Tracks/701214.

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