Moderate cryotherapy by immersion: an alternative in the treatment of muscle damage induced by exercise

ORIGINAL ARTICLE

Crioterapia moderada por imersão: uma alternativa no tratamento da lesão celular induzida pelo exercício físico

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ABSTRACT: *Objective*: to analyze the effect of moderate immersion cryotherapy (15ºC) in muscular inflammatory responses, in biochemical and neuromotor variables, after a session of eccentric exercise. *Methods:* 18 healthy men (aged 18-25 years), non-practitioners of physical exercise who participated in the survey on a voluntary basis were recruited. Initially, they were randomized into three groups: Control group (CG), Exercise Group (EX) and Exercise + Cryotherapy Group (EX + CT). After randomization, volunteers took: a) biochemical test (creatine kinase-CK), b) neuromotor test (range of motion – ANGLE), c) test of pain scale – PAIN, and d) maximum isometric strength test. Then, the experimental groups performed a series of maximal eccentric actions (seated calf raise) for the anterior and posterior region of the leg. CK, ANGLE and PAIN were analyzed 24, 48, 72, 96 and 120 hours after the session. The subjects on EX + CT received cryotherapy treatment immediately after the session and 12, 24 and, 36 hours thereafter. *Results:* In comparison to resting the CK, PAIN and ANGLE values showed significant increase after the sessions in the experimental groups. The EX exhibited significantly higher values than those of EX + CT in all variables analyzed. *Conclusion*: Cryotherapy indicate to be a viable alternative in the treatment for myopathy and delayed onset muscle soreness.

KEYWORDS: Cryotherapy; Exercise; Analgesia.

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RESUMO: *Objetivo:* analisar o efeito da crioterapia moderada com imersão (15º celsius - C), nas respostas inflamatórias musculares, nas variáveis bioquímicas e neuromotoras após uma sessão de exercício de força excêntrico. *Procedimentos Metodológicos:* 18 homens (18-25 anos) saudáveis, não praticantes de exercício físico e que participaram voluntariamente da pesquisa foram recrutados. Inicialmente foram randomizados em três grupos: Grupo Controle (GC), Grupo Exercício (GE) e Grupo Exercício + Crioterapia (EX + CT). Após a aleatorização, os voluntários seguiram para realização de testes: a) bioquímico (Creatina Quinase - CK), b) neuromotor (amplitude de movimento - ÂNGULO), c) escala de dor - DOR e d) um teste de força isométrica máxima. Em seguida, os grupos experimentais realizaram séries de ações excêntricas máximas para região anterior e posterior da perna no exercício sentadinha. Após a sessão analisou-se CK, ÂNGULO e DOR, nos momentos 24, 48, 72, 96 e 120 horas. Os sujeitos do EX + CT receberam tratamento crioterápico imediatamente após a sessão e nos momentos 12, 24, 36 e 48 horas subsequentes. *Resultados:* Em comparação com o repouso, os valores de CK, DOR e ÂNGULO apresentaram aumento significativo após as sessões nos grupos experimentais. O GE exibiu valores significativamente superior ao EX + CT em todas as variáveis analisadas. *Conclusão*: A crioterapia mostrou-se uma alternativa viável no tratamento da miopatia do exercício e da dor muscular tardia.

DESCRITORES: Crioterapia; Exercício, Analgesia.

Part of the doctoral dissertation *Crioterapia: Efeitos na Homeostasia Muscular Após o Exercício* (Cryotherapy: effects on muscle homeostasis after exercise) by Manoel da Cunha Costa, Porto, Portugal.

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INTRODUCTION

Isotonic or isometric muscular contractions occur during exercises, causing breakage in homeostasis, which progressively promotes the development of metabolic stimuli in the skeletal muscle tissue. These exercise-induced alterations incite the creation and/or propagation of micro muscle damage, causing discomfort in the skeletal musculature, which can last up to 72 hours[1]. Thus, muscle soreness is known to occur in a greater magnitude during eccentric exercise, due to the greater proliferation of metabolites[2].

Damages in the muscle fibers usually happen in a transitory manner, when a high stress level materializes, characterized by the deterioration or damage of muscle tissue cells. This inflammatory process intensifies muscle damage significantly, changing its structure and function, besides increasing the concentration of creatine kinase (CK) stock in the extracellular medium[3].

Several alternatives can minimize the process of delayed onset muscle soreness (DOMS), and one of them is the cryotherapy. The easy and low-cost technique is characterized by the application of low temperatures in the target area. Thus, cryotherapy promotes analgesia in the region affected and decreases the local temperature, favoring physiological adjustments[4-6], such as reduction of nervous transmission and cellular metabolism, which minimizes inflammatory processes, with consequent decrease in muscular discomfort; reduction of edema formation and tissue damage[5,7].

The literature contains various proposals for the application of cryotherapy treatment, the most common ones are sprays, compresses, thermal bags, immersion in low temperature waters, and direct ice applications[8]. The techniques change according to the duration of the application (from one minute and 40 seconds to 25 minutes) and temperature setting (from zero to 29°C), but all of them aim to reduce muscular stress and the risks of worsening the musculoskeletal damage [8,9].

Among the cryotherapy treatment methods, the immersion technique is the only capable of generating greater contact between the area damaged and the cold environment, providing temperature control and ability to reduce tissue aggression[10]. However, although the technique is widely used in joint, muscle and bone rehabilitation programs, as well as in performance improvement, no consensus has been reached about the optimal time and ideal temperature required to promote therapeutic benefits in cryotherapy treatments in humans[8]. The hypothesis of this research is that moderate cryotherapy (immersion technique) at 15°C improves biochemical aspects and joint mobility in humans. Therefore, the objective of our study was to analyze the effect of moderate cryotherapy at 15°C immersion, on muscle inflammatory responses in humans, and on the biochemical and neuromotor variables after a session of eccentric exercises.

METHODS

This study is the result of the first part of a doctoral dissertation defended in 2002. It is a quasi-experimental research with a quantitative approach and random sample, held in the city of Recife, Pernambuco, Brazil. This study was approved by the Research Ethics Committee of the University of Pernambuco, protocol no. 0125.

Sample

The sample consisted of 18 healthy male university students (23.2 ± 2.3 years old), non-practitioners of exercise and without risk factors (measured by Physical Activity Readiness Questionnaire – PAR-Q), who voluntarily participated in the research. Those who did not present an injury/pain/discomfort history on the lower limb muscles and were not currently in pharmacological treatment with painkillers were included. Those who showed any damage that prevented the performance of the experimental procedure, who had not finished any study step, or started any type of exercise during data collection, were excluded.

Experimental design

First Step

Initially, the subjects received general information about the study and the procedures to be adopted in the data collection. Those who responded negatively to the PAR-Q were told to sign an informed consent form.

Then they were randomly divided into three groups: The control group (CG) n=6, Eccentric Exercise Group (EX) n=6, and Eccentric Exercise Group + Cryotherapy (EX + CT) n=6. After randomization of groups, the subjects went through a battery of tests:

Biochemical (tissue aggression CK)

To determine the CK enzyme concentration in the plasma, 32 μL of capillary blood were collected in fingerstick puncture, after the cleansing of the site with 70% alcohol swab. Then we used a self-timer lancet, and the blood was drained to a previously heparinized tube, added to a reactive CK tape and placed in the *Reflotron* system (Boehringer Roche Mannheim), for immediate analysis.

Neuromotor (motion amplitude)

The motion amplitude was determined by the difference in the ankle angle between the sum of the plantar and dorsiflexion, verified by a fleximeter (Code Research Institute) placed on the instep, while the subject was sitting with the knee flexed at 90°. Every angle was measured three times and the greatest value was considered, expressed in degrees.

Subjective perception of effort (the pain scale – no palpation)

The pain scale was measured using a numeric analogical scale (1-7), adapted by Clarkson and Hubal (2002)[10], in which "1" indicates the absence of pain (no pain) and "7" is considered the maximum pain (unbearable pain). The determination of the value in the scale was performed through a verbal response, in which the subject indicated a number on the scale, referring to the perception of pain without palpation.

Maximal Isometric Strength Test (MIST)

This test consisted to evaluate the ability to perform the maximum isometric force, by means of a load cell (Globus-ergo meter – Italy). Therefore, the percentage of the test results was subsequently used in the experimental protocol to induce muscle damage from eccentric exercise.

Second Step

Eccentric exercise was used by the experimental groups to induce muscle damage. The control group did not exercise during the study period, maintaining normal daily activities.

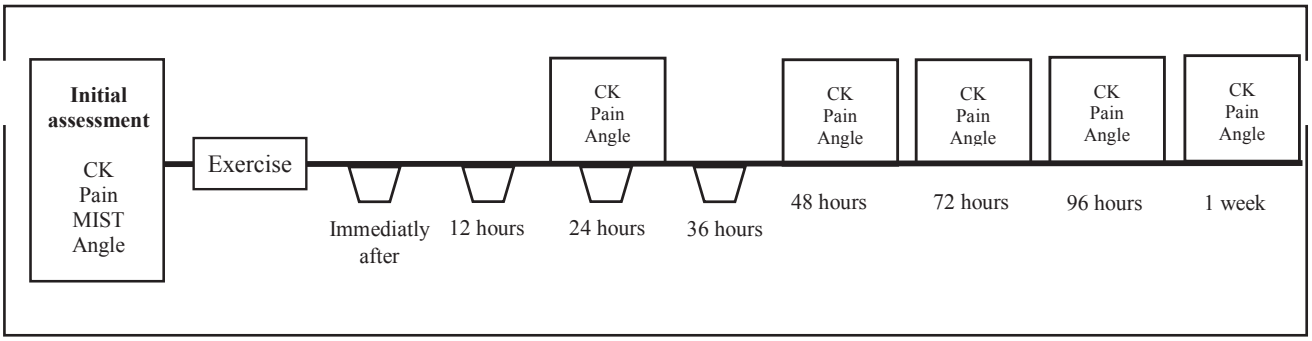
Eccentric exercise

The experimental session consisted in the performance of dynamic exercises focused on the eccentric phase. During the concentric phase, the appraisers lifted the load to avoid muscle work in this step, so that the subjects could carry the weight only at the eccentric phase of the movement. All volunteers performed five series of an eccentric exercise to failure (with a 30-second interval to work leg muscles – the soleus muscle), using a seated calf raise machine (Nippon), being applied an intensity of 85% of the maximum strength.

Each volunteer sat on the chair with the elbows flexed at 90° and the hands on the calf raise machine support, for greater accommodation of the subject to the collecting instrument. In addition, the seat height was adjusted so that the knees could remain at 90°, and the feet were positioned at the base of the calf raise machine in which the maximum isometric force test was held. EX held an exercise session, and EX + CT held an exercise session followed by periods of cryotherapy.

Cryotherapy

The moderate cryotherapy treatment was carried out with a plastic tank (340 liters), the water flowing in an open circuit adapted from a freezing device (Brastemp), which maintained a temperature of 15°C. The accepted variation in temperature was ± 1°C, and it was monitored during the whole cryotherapy process by two Incoterm brand thermometers. The subjects were kept in a sitting position beside the plastic tank, immersing the distal part of the leg (from the hallux to the patella) in the water at the controlled temperature of 15°C. The application of cold as a therapeutic element was performed as follows: four water immersion sessions in the plastic tank, with intervals of 12 hours between them, at 15°C, for 30 minutes, as Figure 1 shows.



Exercise – trial session; CK – biochemical analysis of creatine kinase; PAIN – scale assessment of pain; MIST – Maximal Isometric Strength Test; ANGLES – amplitude of motion analysis; CRYOTHERAPY – 30-minute session with the leg immersed in a reservoir at 15° C.

Figure 1 – Study design

The groups retook the batteries of tests after periods of 24, 48, 72, 96 hours, and 1 week. Therefore, in order not to change the values for the variables analyzed, subjects were told not to perform physical exercises during the assessment period.

Statistical procedures

An analysis of normality and homogeneity was conducted through the Shapiro-Wilk and Levene tests, respectively. Data are displayed in mean value and standard deviation. To verify the differences among the moments of evaluation, the repeated measures ANOVA was conducted; and the Tuckey's post-hoc test was used to verify differences between the mean values in different times, adopting a significance level of $p<0.05$.

RESULTS

Changes in Biochemical (creatine kinase – CK), neuromotor (variation of the amplitude of the movement – ANGLE) and perception of pain (PAIN) variables during evaluation are presented in Table 1.

Table 1 – Changes of CK, PAIN and ANGLE among the groups are presented as mean values ± standard deviation

	REST	24h	48h	72h	96h	1 week
CG (n=6)						
CK (U/L)	44.3 ± 13.4	44.0 ± 13.9	44.6 ± 14.0	45.0 ± 14.7	44.2 ± 13.7	44.7 ± 13.7
Pain (points)	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00	1.00 ± 0.00
Angle (°)	92.2 ± 3.7	92.0 ± 3.7	92.5 ± 3.5	92.0 ± 3.4	92,5 ± 4.0	92.5 ± 3.8
EX (n = 6)						
CK (U/L)	42.1 ± 20.5	241.4 ± 128.2*	178.7 ± 106.4*	113.5 ± 52.0	77.1 ± 33.7	48.1 ± 20.9
Pain (points)	1.00 ± 0.00	3.00 ± 1.26*	2.70 ± 1.97*	2.30 ± 1.97*	1.70 ± 0.82*	1.20 ± 0.41
Angle (°)	87.7 ± 4.9	79.2 ± 4.8*	72.5 ± 9.8*	78.7 ± 9.5*	81.8 ± 5.7*	86.5 ± 3.8
EX + CT (n = 6)						
CK (U/L)	42.8 ± 27.0	196.9 ± 98.6*	129.8 ± 70.5	102.0 ± 57.9	74.1 ± 48.5	49.0 ± 25.5
Pain (points)	1.00 ± 0.00	2.00 ± 0.89*	2.20 ± 0.98*	1.20 ± 0.41	1.00 ± 0.00	1.00 ± 0.00
Angle (°)	91.2 ± 5.3	83.3 ± 8.9	83.2 ± 5.0	84.2 ± 5.0	87.3 ± 3.2	89.0 ± 5.6

CG – control group; EX – exercise group; EX + CT – exercise + cryotherapy group; *significant difference ($p<0.05$) when compared with resting.

The CK, pain and joint angle variables were measured in six moments. In our study, the CK levels were measured from the rest until 120 hours, with 24-hour interval between measurements. Plasma concentrations of CK during evaluation, when compared with rest periods, presented higher values after exercise sessions (EX and EX + CT). However, the EX group exhibited higher values, with significant differences in 24 and 48 hours, and reductions after 72 hours. Furthermore, a significant increase was found already after 24 hours in the EX + CT group, with reductions after 48 hours. No significant differences were found in the control group.

In the pain variable, the highest values found belonged to the exercise sessions, in which significant differences were found in 24, 48, 72, and 96 hours when compared with resting in the EX group. However, it is noteworthy that in the EX + CT group there were significant differences only in the first two moments (24 and 48 hours). The CG showed no significant differences.

Regarding the angle of the joint, the lowest values were found in exercise groups, which showed significant reductions in measurements at 24, 48, 72, and 96 hours in relation to the rest period. No significant differences were found in EX + CT and CG groups.

DISCUSSION

After a training session with external loads, the skeletal muscle suffers structural changes physiologically, which will respond according to type, intensity and duration of the exercise. These changes increase the values of tissue aggression markers in the bloodstream and in the mechanical properties, such as: CK concentration, feelings of pain, and motion amplitude[1,11].

Thus, to prevent and deal with muscle changes after exercise, thermal bags and direct massage with ice are the most accessible cryotherapy techniques to the population in general, for their easy access and low cost[4,12]. In addition, it is noteworthy that, by using these methods, is not possible to determine the temperature in which the procedure is being applied between the affected area and the therapeutic agent. Thus, the subject may be adding to the skin temperatures not controlled for the treatment and aggravating injuries.

Therefore, we used in our study the immersion cryotherapy treatment, with constant temperature due to the inflow and outflow of water in the cryotherapy treatment tank (convection cooling). Thus, the protocol established, in a pioneer way, a temperature controlled at 15°C for the four 30-minute sessions (one every 12 hours). This time was enough to reduce the muscle temperature as well as excitatory impulses, acting in the prevention and treatment of muscle damage induced by the eccentric exercise. Sessions longer than 30 minutes can facilitate the process of ulceration and paralysis of the superficial nerves surrounding the treatment area[13].

After the eccentric exercise, the EX group, which did not use the cryotherapy technique, presented significant elevations in the values of blood CK 24 and 48 hours after the exercise session when compared with resting. On the other hand, the EX + CT group has exhibited increments in blood CK values only in the first 24 hours, showing thus great efficiency in the treatment of exercise-induced cellular lesion. The results found by this study were similar to Baylei et al.[10], who performed the immersion technique at 10°C for 10 minutes, and found significant changes in the levels of CK between 1 and 24 hours after exercise, returning to initial values 48 hours after induction. Vieira et al.[14], when comparing different cryotherapy temperatures (5°C and 15°C) in 20-minute immersion, immediately after the eccentric exercise session, found that the high temperature generated a better recovery profile, showing values close to resting 72 hours after the exercise. Such decrease in the values of CK can be due to the constant cooling effect on muscle, caused by moderate cryotherapy (15°C), modulating the inflammatory response[15,16].

However, the literature shows that high values of CK are closely associated with increase in pain perception between 24 and 48 hours after exercise[10,17,18]. In this study, such phenomenon also occurred after the eccentric exercise session. The group without the use of cryotherapy presented high CK levels and maintained high values of subjective pain perception, showing decrease just a week after the exercise session. A different result was found in the EX + CT group, which, 72 hours after the session, showed the values of subjective pain perception returned to those found in the rest period, demonstrating the effectiveness of cryotherapy in reducing the perception of pain. This reaction might

have occurred in response to vasoconstriction, which provides decreased blood flow and local edema, and consequently favors the reduction of CK levels and slows down the metabolic cellular action[4,6].

Regarding motion amplitude, it is noteworthy that, according to Table 1, significant decrease occurred only in the EX group 24, 48, 72 and 96 hours in relation to resting. It may be also noted that the EX + CT group showed no significant differences at any moment, maintaining normal values, presenting a behavior similar to the one found in CG, which had not exercised.

In an opposite way, the study by Isabell et al.[19], consisting of 22 healthy subjects (20.3 ± 2.1 years old) and using the technique with ice packs (uncontrolled temperature), has not found efficient results in the maintenance of the movement and in muscle inflammation at the first moments (24 and 48 hours) after exercise showing improvement in the variables analyzed only after 72 hours. Using a cryotherapy methodology different from the one used in our study, Howatson et al.[15] performed ice applications and massages directly on the area damaged after exercise, not demonstrating efficient results in CK reduction, motion maintenance, and pain sensation in 12 adults (24.8 ± 5.3 years old). Their study reported only a small decrease of muscle inflammation after 72 hours. On the other hand, the study by Macedo et al.[16] showed the application of cold water immersion cryotherapy significantly decreases the electromyographic activity of muscles in the lower limb, showing efficient reduction of inflammatory response in the skeletal muscle.

Thus, according to the results of this study, immersion cryotherapy can be used as an effective treatment in reducing exercise myopathy and DOMS, since it provides reduction in CK concentration and maintenance in the motion amplitude. A possible limitation of this study, however, was the utilization of a specific sample of young male adults. Therefore, the results cannot be extrapolated to the public in general. That would require future studies, with other populations.

CONCLUSION

Four sessions of 30 minutes (every 12 hours) of moderate cryotherapy in immersion at 15°C were a viable alternative for clinical use in the treatment of exercise myopathy and DOMS. This effect was demonstrated by the reduction of CK and non-palpation pain, and by the recovery or maintenance of motion amplitude in EX + CT.

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