









The effects of immersion cryotherapy on levels of muscle strength and power

Efeito da crioterapia de imersão sobre níveis de força e potência muscular

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RESUMO

Objetivo: Verificar a influência da crioterapia de imersão na força isométrica e potência de membros inferiores. **Métodos:** A amostra foi composta por 14 atletas utilizando o modelo de randomização cruzada. O consumo máximo de oxigênio (VO_{2MAX}) foi mensurado durante o teste de esforço. A potência de membros inferiores foi avaliada pelo teste de impulsão vertical e a força pelo pico de torque isométrico da musculatura extensora de joelhos. As avaliações de força e potência foram realizadas em três momentos: (1) em situação basal; (2) após o protocolo de fadiga; e (3) após o protocolo de recuperação: crioterapia ou controle. O protocolo de fadiga consistia em correr na velocidade correspondente a 120% do VO_{2MAX} até a falha motora. O protocolo de crioterapia foi composto pela imersão dos membros inferiores em tanque com gelo e água (10°C) por 10 minutos. Procedimento semelhante foi adotado para recuperação passiva, exceto pela não adição de água e gelo. Os dados foram analisados no *GraphPAD Prism* ($p < 0,05$). **Resultados:** Nossos dados indicam redução de 18% na altura do salto após a crioterapia (33,0±2,8 versus 27,0±2,8 cm; $p < 0,05$) e incremento de 7,1% após a recuperação passiva (32,5±6,4 versus 34,8±2,1 cm; $p < 0,05$). Em relação ao pico de torque isométrico, observou-se redução de 3,7% após a crioterapia (295±71 versus 285±68 Nm; $p < 0,05$) e de 9,6% após o repouso passivo (297±73 versus 268±72 Nm; $p < 0,05$). **Conclusão:** A crioterapia de imersão parece afetar a potência de membros inferiores e auxiliar na recuperação da força isométrica quando comparada a recuperação passiva.

Palavras-chave: Fisioterapia, Crioterapia, Recuperação de função fisiológica, Regeneração, Força muscular.

ABSTRACT

Aim: To verify the influence of immersion cryotherapy on isometric strength and lower limb power of athletes. **Methods:** The sample consisted of 14 athletes using the cross-randomization model. Maximum oxygen consumption (VO_{2MAX}) was measured during the exercise test. The power of the lower limbs was assessed by the jump test and the strength by the peak isometric torque of the knee extensor muscles. The strength and power assessments were carried out in three moments: (1) at baseline; (2) after fatigue protocol; and (3) after recovery protocol. Fatigue protocol was composed by running at a speed corresponding to 120% of VO_{2MAX} until voluntary failure. The cryotherapy protocol consisted of immersing the lower limbs in a tank with ice and water (10°C) for 10 minutes. A similar procedure was adopted for passive recovery, except for not adding water and ice. Data were analyzed using *GraphPAD Prism* ($p < 0.05$). **Results:** Our data indicate an 18% reduction in heel height after cryotherapy (33.0±2.8 versus 27.0±2.8 cm; $p < 0.05$) and an increase of 7.1% after recovery passive (32.5±6.4 versus 34.8 ± 2.1 cm; $p < 0.05$). Concerning the peak isometric torque, a reduction of 3.7% was observed after cryotherapy (295±71 versus 285±68 Nm; $p < 0.05$) and 9.6% after passive rest (297±73 versus 268±72 Nm; $p < 0.05$). **Conclusions:** Immersion cryotherapy seems to affect the power of lower limbs and assist in the recovery of isometric strength when compared to passive recovery.

Key-words: Physical therapy specialty, Cryotherapy, Recovery of function, Regeneration, Muscle strength.

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Introduction

Cryotherapy is a technique often used in sports medicine to treat musculoskeletal injuries or accelerate the athletes' recovery [1]. Immersion cryotherapy consists of submerging the whole body or body segment in a container with combined water and ice for a predetermined time. Bleakley *et al.* [2] mention that the temperature resulting from this combination can vary from 10 to 15°C, although some studies have used colder temperatures [3]. Regarding the exposure time, continuous (5 to 24 minutes) or intermittent (2 to 15 minutes) protocols are used to cool body tissues aiming to minimize inflammation in muscles and joints [1].

From a physiological point of view, the application of cold stimulates skin receptors causing the sympathetic activation of muscle fibers, reducing the hemorrhagic condition when reaching 13.8°C. The lower local blood flow stimulates the metabolic rate reduction and, consequently, the oxygen demand and cell death risk due to secondary necrosis [1,4]. Besides, Herrera *et al.* [5] hypothesized a relationship between temperature and nerve conduction, mainly in the more superficial nerves. These authors argue that the conduction speed of motor nerves has a direct relationship with tissue temperature reduction, affecting muscle strength and power production.

In this sense, Pritchard & Saliba [6] showed cryotherapy applied by small intervals does not interfere negatively in the performance of vertical jump, agility tests, and sprints. Contrarily, Douris *et al.* [7], Howatson *et al.* [8] and Sellwood *et al.* [9] observed that cryotherapy applied before strength training can decrease muscle performance and potentially increase injury risks due to longer duration of the action potential and lower impulse transmission speed, causing a reduction in muscle contraction speed. Thus, there is no consensus on whether cryotherapy before a training session would be beneficial to the athlete's performance. Therefore, this study aims to verify whether immersion cryotherapy impacts the muscle strength and power of athletes' lower limbs.

Methods

Subjects

Eighteen healthy male rugby athletes aged between 20-40 years old, with at least two years of experience in the sport were recruited. These athletes were intentionally selected by explaining the research objectives and procedures. The athletes could not be or have been injured in the six months preceding the evaluations and should be training regularly in their team.

All procedures were previously approved by the research ethics committee of the Federal University of Rio Grande do Sul (n° 21.708/2011), respecting the recommendations of Resolution 466/12 of the National Health Council. All participants received the guidelines relevant to the procedures of the research and signed the free and informed consent form.

Although our sample was selected intentionally, we use the data published by Rowsell *et al.* [10], when investigating the impact of immersion cryotherapy on the power of lower limbs in soccer players, to calculate the sample size necessary to satisfy a statistical power of 90% with 95% confidence (BioEstat 5.0, Instituto Mamirauá, Brazil). According to the sample size, the mean difference and standard deviation of lower limb power identified the minimum need for 12 subjects.

Methodological procedures

The present study is characterized as cross-sectional crossover research, using a comparative model of randomized and crossed intervention. To minimize the effects of learning in the assessments, athletes were randomized in blocks using opaque envelopes to define the order of the procedures: control or intervention (cryotherapy). All participants performed both procedures, being their control. The study design consisted of three visits to the laboratory separated for five and seven days, respectively. On the first visit, sample characterization tests were administered: anthropometric assessment, cardiopulmonary test, and food recall, in addition to the randomization process.

On the second and third visits, vertical thrust and isokinetic dynamometry tests were performed to assess the power and strength of the lower limbs in three moments: 1) in a baseline situation - before the fatigue protocol - PE; 2) after the fatigue protocol - PF; and 3) after the recovery protocol - PT: active rest (control) or immersion cryotherapy. All tests were performed in the morning by the same researcher, with a standardized interval time between the assessment procedures. Figure 1 illustrates the methodological design of the study

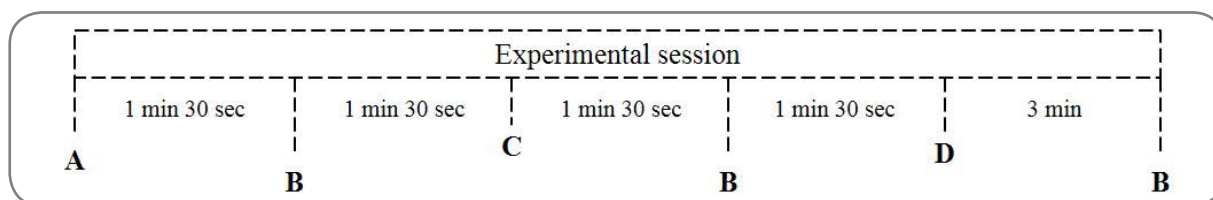


Figure 1 - Experimental session design. A: Warm-up. B: Power and strength of lower limb assessments. C: fatigue protocol. D: recovery protocol: immersion cryotherapy or active rest (control). 1min 30sec: waiting period between procedures.

Anthropometric assessment

To estimate body composition, skinfolds, bone diameters, body lengths, and perimeters were measured. For this purpose, a Harpenden scientific plicometer, a short and long caliper, a segmometer (Cescorf, Brazil), and a metal measuring tape (Sanny, Brazil), respectively, were used. All techniques followed the recommendations of the International Society for the Advancement of Kinanthropometry - ISAK [11]. An experienced anthropometrist (ISAK Level II) performed all measurements. Body mass and height were measured on a mechanical scale with a coupled stadiometer (Tânita, Brazil). Body composition was predicted by the five-component methodology [12,13].

Cardiopulmonary test

To analyze the cardiorespiratory capacity and determine the intensity of effort for the fatigue protocol, the incremental test on a treadmill (Inbramed, Brazil) with gas analysis (CPX-D, MedGraphics, Minnesota, USA) was used. The protocol started at 6 km/h, with increments of 1 km/h every minute until the participant's exhaustion or identification of the interruption criteria: 1) respiratory quotient ≥ 1.15 ; 2) heart rate $\geq 95\%$ of the predicted heart rate; or 3) presence of a plateau in oxygen consumption - $\text{VO}_{2\text{MAX}}$ [14]. Throughout the test, the slope remained fixed at 1%. Data were collected using the breath by breath method and analyzed by two experienced evaluators. Before carrying out the tests, the gas analyzer was calibrated according to the manufacturer's recommendations.

Food recall

To avoid bias caused by caloric consumption variations in the analysis, each participant was instructed to register all drinks and food consumed in the 24 hours before the tests. Meals were described with food consumed, times, quantities in homemade measures and, when necessary, the brand of the product. For proper completion, a photographic album of homemade measures was delivered, consisting of a compilation of utensils and food portions photos, based on the Photographic Album of Portions of Food [15,16].

The 24-hour recall (R24) of the first session was returned to the participants, who were instructed to repeat the same food consumption in the 24 hours prior to the second and third sessions. Participants were instructed not to consume alcoholic beverages and/or those containing caffeine in the 24 hours prior to the tests. For the analysis of R24, the software Dietwin® (Brubins, Brazil) was used.

Vertical jump test

The power of the lower limbs related to the elastic force was evaluated by the countermovement jump (CMJ) using a contact mat that recorded the flight time of each jump (Jump Test, Hidrofit, Brazil), following the protocol of Bosco *et al.* [17,18]. In short, the participants were positioned standing, with their hands on their hips and their feet parallel, shoulder-width apart. At the software signal, the subjects quickly flexed their hip, knee, and ankle joints (movement similar to the 90° squat) to jump as high as possible. At this time, they were asked not to raise their knees or bring their legs forward. The hands should remain at the waist. Each participant performed three to five jumps, with a 30-second interval. The highest value was used for analysis.

Isokinetic dynamometry

The strength of the lower limbs was assessed by the knee extensors' isometric torque peak during the maximum test, performed on the isokinetic dynamometer positioned in the extensor chair function (CYBEX 7000, Ronkonkoma, USA) [19]. Briefly, the participants were positioned seated on the equipment (85° of hip flexion and 60° of knee flexion), stabilized by belts and bands. The lateral epicondyle of the femur was aligned with the rotation axis of the dynamometer and the mechanical arm of the equipment was adjusted for each subject, to obtain the adequate distance between the knee and the lever arm. Five maximal isometric contractions of knee extension were performed to determine the maximum strength of the athletes at an angle of 60°. Standardized verbal incentives and an interval of one minute between each attempt were provided. The highest value of the peak torque was recorded.

Fatigue protocol

The protocol for fatigue induction was performed on the same treadmill used in the cardiopulmonary test. Briefly, athletes were submitted to running at an intensity 20% higher above their maximum aerobic capacity tested, that is, they needed to run at a speed related to 120% of VO_{2MAX} (maintaining the treadmill at 1 % inclination). The protocol ended when the athlete requested or when the researcher noticed motor failure.

Recovery protocol

Immersion cryotherapy was performed in a tank with a capacity of 100 liters, filled with 70% of its capacity with a combination of water and ice. The water tem-

perature was monitored using an underwater thermometer ($10 \pm 1^\circ\text{C}$). Participants entered the tank by submerging their lower limbs to the level of the gonads, remaining in the standing position for 10 minutes [20]. A similar procedure was adopted for passive recovery (placebo), inside the tank without adding water and ice.

Statistical analysis

For data analysis, GraphPAD Prism 5 (GraphPad Inc, San Diego, USA) was used. To verify the normality of the data, the Shapiro-Wilk test was performed. Analysis of variance (ANOVA) for repeated measures, followed by the Bonferroni *post hoc* test, was used to the assessment of differences between groups at different moments (pre and post-fatigue protocol, and post-therapy). Finally, the Mann-Whitney test was performed to compare the energy value of R24 between the test days. Data are expressed as mean \pm standard deviation or percentage values. The level of significance adopted was 5% ($p < 0.05$).

Results

The final study sample was composed of 14 young adults (22 ± 2 years), with good cardiorespiratory capacity ($\text{VO}_{2\text{MAX}} 44.1 \pm 6.7 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and a high percentage of fat ($27.8 \pm 4.4\%$) for high-performance sports. Four athletes had their data excluded because they were in the process of recovery (injury not resulting from the research protocol). There was no difference in caloric intake between the two evaluation days ($2,893 \pm 802$ versus $2,915 \pm 746$ kcal; $p = 0.949$).

Vertical jump test

Our data indicate a 10.9% reduction in the height of the CMJ between the PE and PF moments, approximately 8.2% between the PF and PT moments, and about 18.2% between the PE and PT moments ($p < 0.05$). Regarding active rest, a reduction of 2.2% in the height of the CMJ was observed between the PE and PF moments, an increase of 9.4% between the PF and PT moments, and a 7.1% increase between the PE moments and PT ($p < 0.05$). Figure 2 shows the performance of the CMJ in both interventions: immersion cryotherapy and active rest (control).

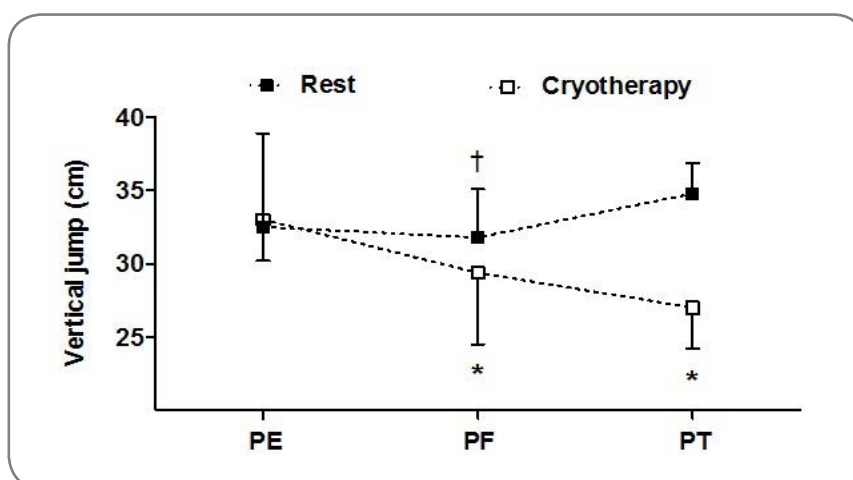


Figure 2 - Power of lower limbs after immersion cryotherapy and active rest; PE = pre-exercise; PF = post-fatigue protocol; PT = post-recovery protocol. * $p < 0.05$ versus PE (cryotherapy protocol). † $p < 0.05$ versus PE and PT (rest protocol). Bonferroni test.

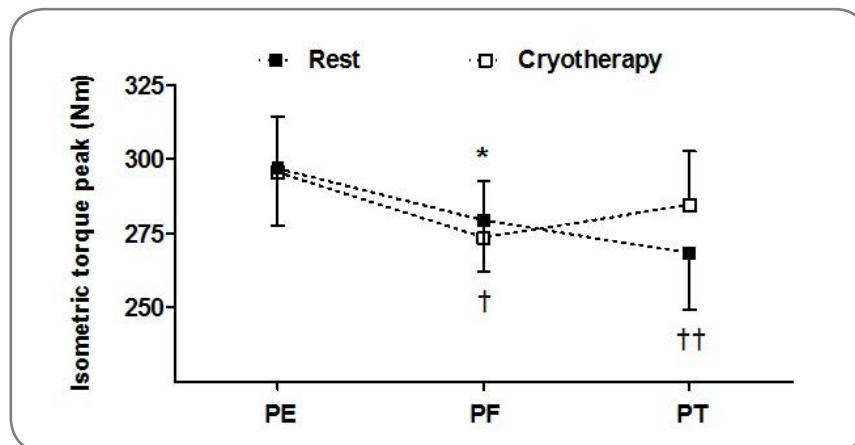


Figure 3 - Isometric torque peak after immersion cryotherapy and active rest. PE: pre-exercise. PF: post-fatigue protocol. PT: post-recovery protocol. * $p < 0.01$ versus PE (cryotherapy protocol). † $p < 0.01$ versus PE (rest protocol). †† $p < 0.05$ versus PF and PE (rest protocol). Bonferroni test.

Discussion

Our objective was to verify if immersion cryotherapy could negatively impact lower limb isometric strength or power production of athletes submitted to a muscle fatigue protocol. Interestingly, our data indicated an antagonistic behavior of these variables. Immersed cryotherapy proved to be more efficient than active rest to recover isometric strength. However, for muscle power, active rest showed better results when compared to cryotherapy. Two factors can justify these findings: 1) the lower elastic capacity in cold environments, impairing muscle power; and 2) the unintended effect of the CMJ as a warm-up for dynamometry may have helped in the re-establishment of the participants' contractile capacity.

Indeed, Pritchard & Saliba [6] had argued that there is variability in the experimental design of studies that investigated the effect of cryotherapy, generating an interpretive bias, especially regarding the waiting period for testing. Kinzey *et al.* [21] state that it is necessary to wait 15 minutes after the application of cryotherapy for the production of strength and / or muscle power to return to baseline levels. Although the waiting period for the present study was standardized and monitored (180 sec), randomization of the dependent variables was not performed, that is, the CMJ was performed before the strength test. This may partially justify the observed divergences. The unintended effect of jumping as a warm-up may have positively influenced the production of isometric strength after cryotherapy. Rhodes & Alexander [22] support this hypothesis by demonstrating a detrimental effect on test performance immediately after cryotherapy.

Similarly, Tassignon *et al.* [23] observed a reduction in the jump distance in participants who were exposed to the cryotherapy protocol at 10°C. This was not observed in the performance of the same participants when the technique was applied at a temperature of 18°C, suggesting that the treatment temperature is decisive for the desired response. Additionally, the authors observed a reduction in electromyographic activity during the isokinetic dynamometer test, which suggests lower recruitment of muscle fibers (lower speed of motor nerve conduction). Besides, Hauptenthal *et al.* [24] observed that the application of ice reduced the proprioceptive capacity of the ankle dorsiflexor muscles, inhibiting isometric strength production.

All of these factors corroborate the result found in the present study. Nevertheless, the mechanism responsible for the performance impairments when the muscle is subjected to low temperatures is not yet fully understood. Interestingly, Fuchs *et al.* [25] observed that immersion in cold water (8°C) during recovery from strength exercises reduced the muscle's ability to absorb and / or direct amino acids for the synthesis and recovery of myofibrils when compared to immersion in neutral water (30°C). Interestingly, the authors used the contralateral limb of the participant himself as a control, that is, while one member was exposed to cryotherapy the other was exposed to neutral water. To reach this conclusion, Fuchs *et al.* [25] used isotopic markers and performed muscle biopsies.

The present study's methodology limits greater inferences for lacking deeper analyzes of physiological mechanisms and focusing on dynamic responses of muscle fatigue. We speculate that the application of cold may induce vasoconstriction, reducing the metabolic rate and, consequently, the demand for cellular oxygen, corroborating findings from Fuchs *et al.* These processes reduce cell death from secondary necrosis, decreasing damage to the contractile properties of the muscle. Interestingly, the lower performance in the isometric strength after active rest could be linked to the "muscle fatigue" state, since the jump test was performed before the dynamometer.

This study has some limitations such as not having randomized the evaluation process (jumping test versus dynamometer), having used only one temperature in the cryotherapy protocol, and evaluating a population of amateur athletes, limiting extrapolation of the results to other populations.

Conclusion

Based on the results found, it can be concluded that immersion cryotherapy has a negative impact on the production of explosive strength in the lower limbs, albeit it seems to assist in the recovery of the athletes' isometric strength. Thus, immersion cryotherapy needs to be applied with caution to accelerate recovery in short intervals, such as between combat rounds and/or game intervals, as it may not improve the athlete's performance.

Potential conflict of interest

No conflicts of interest with potential potential for this article have been reported.

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Authors' contributions

Conception and design of the research: Reischak-Oliveira A, Lopes AL and Gross JS. Data acquisition: Lopes AL, Gross JS, Krüger RL, Carteri RBK, Radaelli R, Teixeira BC. Analysis and interpretation of data: Reischak-Oliveira A, Teixeira BC, Krüger RL, Ribeiro GS, Lopes AL and Gross JS. Statistical analysis: Ribeiro GS and Teixeira BC. Obtaining financing: Reischak-Oliveira A. Writing of the manuscript: Lopes AL, Gross JS, Carteri RBK, Ribeiro GS and Teixeira BC. Critical review of the manuscript for intellectual content: Reischak-Oliveira A, Lopes AL, Carteri RBK, Ribeiro GS and Teixeira BC.

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