Effect of cryotherapy on post-exercise cardiac autonomic recovery in mixed martial arts (MMA) fighters: A Randomized Clinical Trial

Efeito da crioterapia sobre a recuperação autonômica cardíaca pós-exercício em lutadores de artes marciais mistas (MMA): Um ensaio clínico randomizado

Efecto de la crioterapia en la recuperación autonómica cardíaca después del ejercicio en luchadores de artes marciales mixtas (MMA): Un ensayo clínico aleatorio

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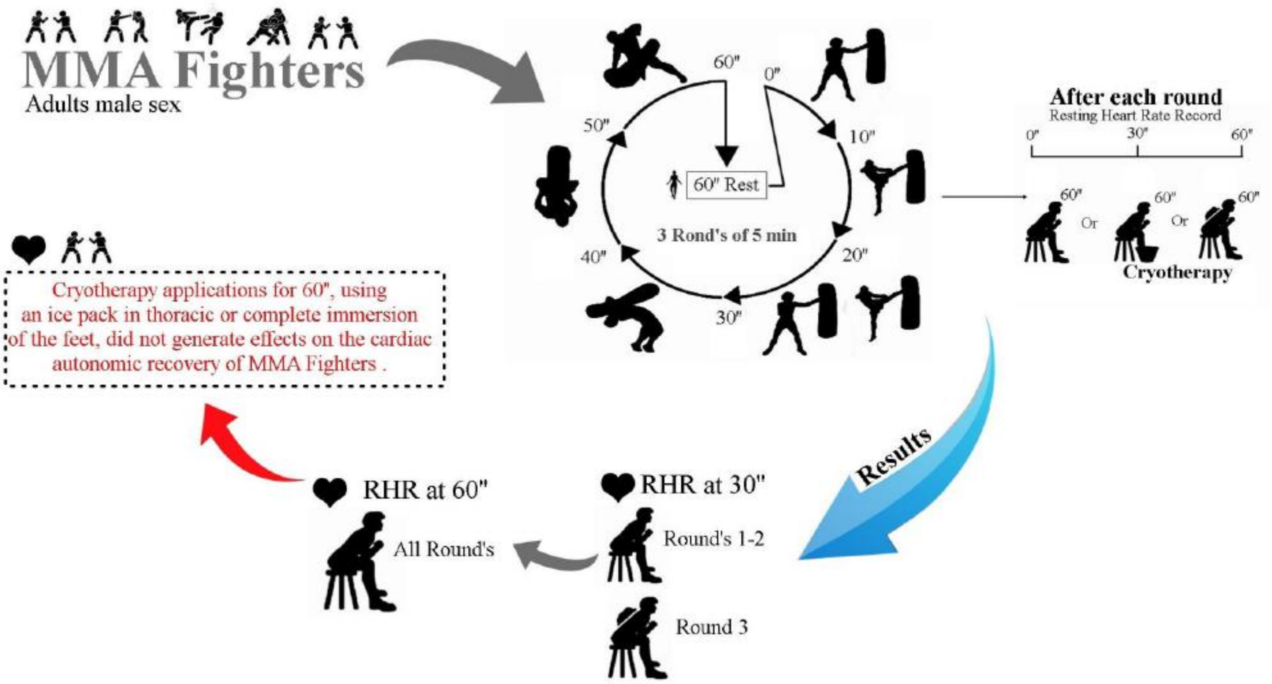
Visual Abstract. Effect of cryotherapy on post-exercise cardiac autonomic recovery in mixed martial arts (MMA) fighters: A Randomized Clinical Trial.



MMA: Mixed martial arts. RHR: Resting heart rate. Source: Authors.

Abstract

Background: Cryotherapy brings benefits for muscle recovery and reduction of lactate thresholds in fighters; however, the effect of cryotherapy on the autonomous cardiac recovery (ACR) of wrestlers is not yet defined in the scientific literature. Objective: To analyze the effect of cryotherapy on ACR after simulated combat exercise in mixed martial arts (MMA) fighters. Methods: Crossover randomized clinical trial with a sample of 17 MMA fighters (male, age >18 years). There was simulated combat of three rounds of MMA; each round lasted 5-min, there were the 60s between rounds. ACR was assessed by resting heart rate (RHR), which was monitored by a portable Polar-FT1® device. We measured RHR in the interval between the rounds at the 30s and 60s of rest in the conditions: without cryotherapy (Control), application of an ice pack in the thoracic region (TC); Immersion of feet in ice water (FC). Results: At 30-s of RHR, the control condition was better than FC to reduce RHR in rounds 1 and 2 ($p<0.05$; $\eta 2p$:0.28). At the 60s of RHR, the control condition was better than FC and TC ($p<0.05$; $\eta 2p$:0.32). The control condition had a better RHR recovery rate than the FC condition after rounds one ($\eta 2p$: 0.23), two ($\eta 2p$: 0.46), and three ($\eta 2p$: 0.27) ($p<0.05$). The TC condition did not show differences concerning the control and FC conditions. Conclusion: Cryotherapy applications in the thoracic region and by complete immersion of the feet did not generate significant effects on the ACR of MMA fighters.

Keywords: Physical education teaching; Performance; Athletes; Heart rate.

Resumo

Introdução: A crioterapia traz benefícios para a recuperação muscular e redução dos limiares de lactato em lutadores; entretanto, o efeito da crioterapia sobre a recuperação cardíaca autônoma (RCA) dos lutadores ainda não está definido na literatura científica. Objetivo: Analisar o efeito da crioterapia na RCA após simulação de exercícios de combate em lutadores de artes marciais mistas (MMA). Métodos: Ensaio clínico randomizado cruzado com uma amostra de 17 lutadores de MMA (masculino, idade>18 anos). Houve combate simulado de três rounds de MMA; cada round durou 5 minutos, houve os 60s entre os rounds. O RCA foi avaliado pela frequência cardíaca em repouso (FCR), que foi monitorada por um dispositivo portátil Polar-FT1®. Medimos a FCR no intervalo entre os rounds nos 30s e 60s de repouso nas condições: sem crioterapia (Controle), aplicação de um pacote de gelo na região torácica (TC); Imersão dos pés em água gelada (PC). Resultados: Com 30s de FCR, a condição de controle foi melhor que a PC para reduzir a FCR nas rodadas 1 e 2 ($p<0,05$; $\eta 2p$:0,28). Nos 60s de FCR, a condição de controle era melhor que a PC e TC ($p<0,05$; $\eta 2p$:0,32). A condição de controle teve uma taxa de recuperação FCR melhor que a condição PC após as rodadas um ($\eta 2p$: 0,23), dois ($\eta 2p$: 0,46) e três ($\eta 2p$: 0,27) ($p<0,05$). A condição TC não apresentou diferenças em

relação ao controle e às condições da PC. Conclusão: As aplicações de crioterapia na região torácica e por imersão completa dos pés não geraram efeitos significativos sobre o FCR dos combatentes de MMA.
Palavras-chave*:* Ensino de educação Física; Performance; Atletas; Frequência cardíaca.

Resumen
Antecedentes: La crioterapia aporta beneficios para la recuperación muscular y la reducción de los umbrales de lactato en los luchadores; sin embargo, el efecto de la crioterapia en la recuperación cardiaca autónoma (RCA) de los luchadores aún no está definido en la literatura científica. Objetivo: Analizar el efecto de la crioterapia en la RCA tras un ejercicio de combate simulado en luchadores de artes marciales mixtas (MMA). Métodos: Ensayo clínico aleatorio cruzado con una muestra de 17 luchadores de MMA (varones, edad >18 años). Se realizó un combate simulado de tres asaltos de MMA; cada asalto duró 5 minutos y hubo 60 entre asaltos. La RCA se evaluó mediante la frecuencia cardíaca en reposo (FCR), que se monitorizó con un dispositivo portátil Polar-FT1®. Se midió la RHR en el intervalo entre los asaltos a los 30 y 60 de descanso en las condiciones: sin crioterapia (Controle), aplicación de una bolsa de hielo en la región torácica (TC); inmersión de los pies en agua helada (PC). Resultados: A los 30-s de FCR, la condición control fue mejor que la FC para reducir la FCR en las rondas 1 y 2 ($p<0,05$; $\eta 2p$:0,28). A los 60-s de FCR, la condición de control fue mejor que la PC y la TC ($p<0,05$; $\eta 2p$:0,32). La condición controle tuvo una mejor tasa de recuperación de la FCR que la condición PC después de las rondas uno ($\eta 2p$: 0,23), dos ($\eta 2p$: 0,46) y tres ($\eta 2p$: 0,27) ($p<0,05$). La condición TC no mostró diferencias respecto a las condiciones controle y PC. Conclusión: Las aplicaciones de crioterapia en la región torácica y por inmersión completa de los pies no generaron efectos significativos en el RCA de los luchadores de MMA.
Palabras clave: Enseñanza de la educación física; Rendimiento; Atletas; Ritmo cardíaco.

1. Introduction

Post-exercise recovery has been extensively investigated in the scientific scenario; in this context, the heart rate (HR) plays a fundamental role. It is known that the stress imposed by exercise promotes changes in the cardiac autonomic system, which among biological responses, will increase HR, which remains elevated during the post-exercise period and gradually decreases to baseline levels with the reactivation of the parasympathetic system and the deactivation of the sympathetic system (Almeida et al., 2016; Peçanha et al., 2017). In this sense, the recovery HR (RHR) is a variable that can be used to monitor the cardiac autonomous recovery in athletes of several sports modalities, especially in modalities that require a short-term recovery for a next stimulus (Peçanha et al., 2017).

In this way, fight sports are characterized by being intermittent, maintaining high intensities in short periods of activity, presenting anaerobic (70 to 80%) and aerobic (from 20 to 30%) characteristics (Davis et al., 2018). In the competitive context, the fights show an average work/rest interrelationship of three rounds lasting from three to five minutes, with a one-minute break for recovery between rounds (Finlay; Greig & Page, 2018). According to Imai et al. (1994) cardiac autonomic recovery is accompanied by a significant reduction in RHR, and for RHR, the parasympathetic effect is significant in the first 30 seconds after a submaximal exercise without sympathetic effect during this same period. This parasympathetic effect is also visible for 60 seconds post-maximum exercise. Therefore, despite being a short period, there are possibilities to achieve significant results in cardiac autonomic recovery; therefore, it is important to choose a method that provokes rapid acute responses concerning the cardiac autonomic system (Almeida et al., 2016; Imai et al., 1994).

Cryotherapy has been widely used in different scenarios, especially in aspects involving the recovery of athletes (Jinnah et al., 2019). The application of cryotherapy on an area of the skin causes a reflex activation, or depolarization, of several sympathetic adrenergic nerve fibers, such depolarization of the fibers causes a release of the neurotransmitter norepinephrine on the smooth muscle receptors that involve the blood vessels, with this, it occurs potent reflex vasoconstriction. After vasoconstriction, the body promotes dilation of the vascular system and increases blood flow in the affected regions to promote possible repairs caused by vasoconstriction, which enhances recovery in the region (Rose et al., 2017).

In this context, benefits of cryotherapy in the recovery of muscle strength and endurance and reduction of lactate thresholds in wrestlers have already been observed (César; Júnior & Francisco, 2021), as well as it has been verified that in soccer players, the isolated use of cryotherapy has greater chances of promoting recovery from heart rate variability and blood lactate reduction (Micheletti et al., 2019). However, the investigation of cryotherapy in the autonomic cardiac recovery of fighters is still a gap to be filled in the scientific literature (Jinnah et al., 2019; César et al., 2021).

Given the assumptions, this study brings the hypothesis that the use of cryotherapy for 60 seconds will promote cardiac autonomic recovery in mixed martial arts (MMA) fighters. In this sense, we aimed to analyze the effect of cryotherapy on cardiac autonomic recovery after simulated combat exercise in male MMA fighters.

2. Methods

A randomized clinical trial with crossover design (Thomas; Nelson & Silverman, 2009) with a sample of 17 male MMA athletes chosen randomly in two fight academies located in Great Natal (Brazil). The sample size was calculated a priori using the "T" statistic in the G* Power® software (Version 3.0; Berlin, Germany) (Kang et al., 2021), considering an $\alpha < 0.05$ and a $\beta = 0.80$. Thus, we consider the effects of 0.56 for metabolic parameters and 0.63 for autonomous parameters found in the study by Micheletti et al. (2019) Therefore, a minimum sample size of 12 subjects was appointed with an estimated power of 0.82 for metabolic parameters and 0.83 for autonomous parameters.

Initially, an explanation was given to the research volunteers about the study procedures, addressing the risks and benefits, then there was the signing of the free and informed consent form (FICF), then the selection of participants was made. Volunteers linked to the state MMA federation, with a minimum experience of 6 months in national level competitions in the middleweight category were included, those who made use of caffeine and ephedrine supplements, beverages, and foods were excluded from the sample, as well as those who were using any anabolic steroid or any ergogenic resource were excluded.

Ethics

This study was previously approved and registered by the Ethics and Research Committee of the Federal University of Sergipe - Brazil (ID: 01723312.2.0000.0058), following all the protocols of Resolution 466/12 of the National Health Council on 12/12/2012 (Campos, 2020), strictly respecting the national and international ethical principles contained in the Declaration of Helsinki (Johannes; Van Delden & van der Graaf, 2017). Furthermore, the present study complied with all the requirements and international standards of the CONSORT checklist for experimental studies (Pandis et al., 2019).

Procedures related to Cryotherapy.

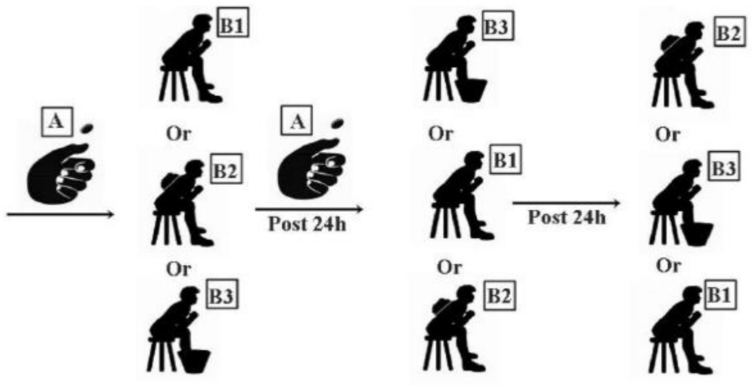
We determined two regions for the application of cryotherapy, the thoracic region, due to the location of the central cardiovascular system and the foot region. It is known that the biological reactions of the autonomic nervous system occur in a cephalocaudal way (i.e., descending: from head to toe); thus, reactions to stimuli from the external environment can also use the same flow of communication in reverse caudal-brain (i.e., ascending: from toe to head) (Snyder et al., 2018). In this sense, when using cryotherapy in the feet region, the autonomic nervous system likely responds to external stimuli, promoting the regularization of RHR.

Thus, cryotherapy was applied with the standard ice water temperature in the bucket being kept between 4 and 10 °C (Lindsay et al., 2018). The temperature was measured using a skewer-type food thermometer (Elitech ®, São Paulo, Brazil). For cryotherapy in the thoracic region, we maintained a similar temperature and used ice in chunks, 0.5 mm thick plastic bags (ziplock ®, São Paulo, Brazil). We emphasize that we used RHR to infer the post-exercise cardiac autonomous recovery; thus, during cryotherapy conditions, RHR was monitored and measured at 30 and 60 seconds. We monitored RHR with a portable heart rate monitor (Polar-FT1®, São Paulo, Brazil).

Randomization

The order of performance of the conditions was randomized (by drawing lots) (Vickers, 2006): (i) Control (without cryotherapy); (ii) Cryotherapy using an ice pack in the thoracic region; (ii) Cryotherapy with the complete immersion of the feet in ice water. All subjects went through all conditions in different orders (according to randomization), and each condition occurred 24 hours apart (See figure 1).

Figure 1. Flowchart of the randomization of study conditions.



A: Draw to randomize according to study conditions. B1: Control condition (no cryotherapy). B2: Cryotherapy condition in the thoracic region. B3: Cryotherapy condition in the feet. Source: Authors.

Experimental Protocol

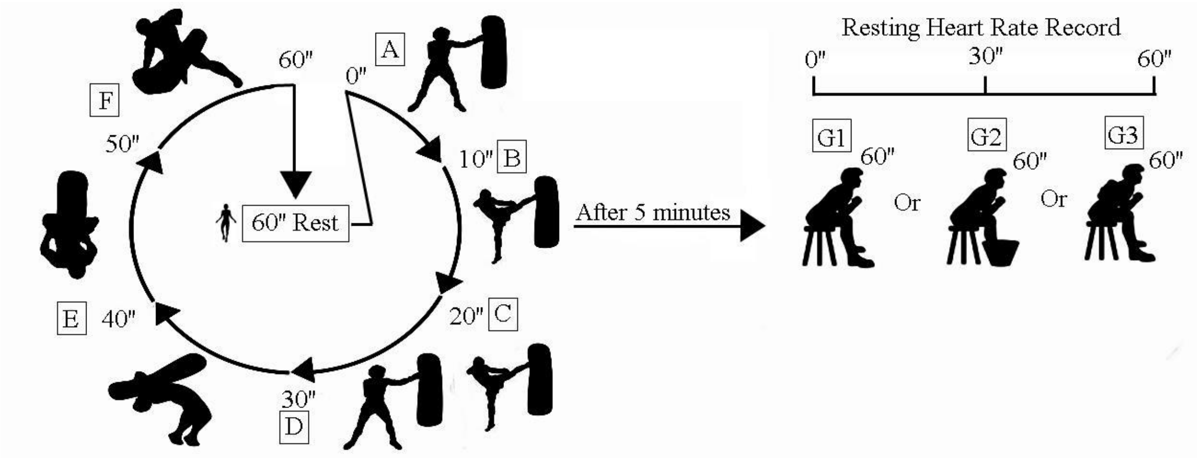
The evaluation site was kept at room temperature (24°C), a fixed mat made of rubber fibers covered with a vacuum canvas was used. All assessments were performed at 7 pm. The experimental protocol consisted of simulating MMA rounds using punch bags (Petrorian®, Rio de Janeiro, Brazil) weighing 40 kg, 150 cm in length, and 60 cm in diameter. Two bags were used, one for the use of punches and kicks and the other for simulating projections and isometry on the ground in the closed leg guard position (performing the isometry of the thigh adductors).

The simulation consisted of a circuit performing movements from the fights such as punches, kicks, knees, falls and isometry of thigh adductors simulating the closed leg guard. A time was set for each of the movements mentioned. The round was subdivided into three active rounds interspersed with 60 seconds of active rest, in which the participant performed “jumps” at a low height without leaving the place (totaling 5 minutes per round). Thus, at the end of each 5-minute round, 60 seconds of one of the conditions were performed: control, cryotherapy in the thoracic region, or cryotherapy with the total immersion of the feet. In this sense, three rounds of 5 minutes were performed, interspersed for 60 seconds, totaling 18 minutes of simulation for each randomized condition (See Figure 2).

Preceding the combat simulation, we conducted a familiarization period in which participants performed a full round of the simulation. After familiarization, participants were instructed not to perform strenuous physical activities and not to consume stimulant foods (with caffeine, taurine, ephedrine) during the next 24 hours. The next day, evaluations began. In the evaluations of each condition, a 10-minute body warm-up was performed, using multi-joint exercises with the body weight (squats, push-ups, sprints, and walks). Then, the heart rate monitor was positioned on the participant, who was instructed to “do their best” during the simulation. In addition, to stimulate the participant, verbal stimulation was provided throughout the simulation.

Each participant was analyzed individually by the research team, consisting of three evaluators, in which evaluator one conducted the experiment and provided verbal stimuli to the participant, evaluator two conducted the cryotherapy procedures, and evaluator three wrote down information regarding frequency peak heart rate and rest at moments 30 and 60 seconds of the conditions: control, cryotherapy in the feet and cryotherapy in the thoracic region.

Figure 2. Experimental study protocol.



A: 10 seconds of punches. B: 10 seconds of kicks. C: 10 seconds alternating punches and kicks. D: 10 seconds projecting the punching bag (standard technique: grabbing the bag and throwing it to the ground towards the back). E: 10 seconds of thigh adductor isometry simulating the closed leg guard. F: 10 seconds of downward punch with one knee resting on the punching bag. G1: 60 seconds control condition (without cryotherapy). G2: 60 seconds cryotherapy condition in the feet. G3: 60 seconds cryotherapy condition in the thoracic region. Source: Authors.

Measurement of the RHR recovery index

The RHR recovery index of the 60s was calculated using the mathematical model presented by Buchheit et al., (2006; 2007) which consists of:

RHR 60-s recovery index = HR peak – HR 60-s after physical exercise

RHR: Resting Heart Rate. HR: Heart Rate. -s: Seconds.

Statistical Analysis

Data normality was verified by Shapiro-Wilk (González-Estrada & Cosmes, 2019) and Z-Score (Hopkins & Weeks, 2990) tests for asymmetry and kurtosis (-1.96 to 1.96). Comparisons were performed using the Two-Way ANOVA test (Fujikoshi, 1993), checking the effect of time (from round 1 to 3) and conditions (control, cryotherapy in the thoracic region, and cryotherapy in the feet). The effect size was verified by partial squared eta ($\eta 2p$), adopting the following magnitude (Norouzian & Plonsky, 2018): Small $\eta 2p \leq 0.10$ to 0.23; Average $\eta 2p$ from 0.24 to 0.34; Large $\eta 2p$ from 0.35 to 0.44; Very large $\eta 2p \geq 0.45$. To identify specific differences, Tukey's post-hoc (Ruxton & Beauchamp, 2008) was used. All statistical analyzes were performed using open-source R software (Version 4.1.1; R Foundation for Statistical Computing®, Vienna, Austria) (Matloff, 2011) considering $p<0.05$.

3. Results

The sample was of 17 male MMA athletes of the middleweight category (from 77.1 to 83.9 kg) aged between 18 and 35 years. For intra- and between-condition comparisons, no significant differences were found concerning peak heart rate during the 3 rounds (Table 1). Furthermore, there was no significant effect of time ($\eta 2p$: 0.03), suggesting that the athletes were able to maintain similar intensities throughout the experiment in the three conditions (control, thoracic cryotherapy, and cryotherapy in the feet). All results were confirmed with Tukey's Post-hoc test.

Table 1. Comparisons of peak heart rate behavior for each round under different conditions.

Moments	Control	Thoracic Cryotherapy	Feet Cryotherapy	$F_{(2.0)}$	p
Round 1	188.9 ± 5.6	189.8 ± 9.8	189.2 ± 8.5	2.3	0.3
Round 2	194.5 ± 3.93	192.1 ± 8.0	191.2 ± 6.3	1.7	0.5
Round 3	191 ± 7.5	192.1 ± 6.7	191.2 ± 6.6	1.9	0.1

Statistical tests used: One-way ANOVA followed by Tukey's post-hoc. Source: Authors.

For RHR measured at 30 seconds, the control condition was better than the foot cryotherapy condition in reducing RHR in the first and second rounds (η2p:0.28), while cryotherapy in the thoracic region was more effective than cryotherapy in the feet to reduce RHR in the third round (η2p:0.23). In addition, for cryotherapy in the thoracic region, there was a significant effect of time (η2p: 0.25). For the RHR measured at 60 seconds, the control condition was more effective than the cryotherapy in the feet and the thoracic cryotherapy conditions (η2p: 0.32). Furthermore, there was no significant effect of time (η2p: 0.0). For both RHR measurements (30 and 60 seconds), there were no significant differences between control and thoracic cryotherapy conditions. All results were confirmed with Tukey's Post-hoc test.

Table 2. Comparisons of resting heart rate behavior at 30 and 60 seconds under conditions without cryotherapy, thoracic cryotherapy, and foot cryotherapy.

Moments	Control	Thoracic Cryotherapy	Feet Cryotherapy	$F_{(2.0)}$	p
		RHR at 30 seconds			
Round 1	147.9 ± 8.8*	155.5 ± 7.8	157.3 ± 10.8	3.2	<0.001
Round 2	151.2 ± 4.6 *	156.4 ± 6.1	158.9 ± 7.7	1.0	<0.001
Round 3	149.1 ± 7.4	147.7 ± 4.7 *	158.1 ± 8.1	2.3	0.04
		RHR at 60 seconds			
Round 1	132.7 ± 7.8*	136.6 ± 7.7	140.1 ± 10.1	3.0	<0.001
Round 2	135.7 ± 5.2*	137.7 ± 6.1	143.5 ± 8.2	0.9	0.0009
Round 3	134.4 ± 5.9*	138.3 ± 5.3	142.0 ± 9.1	0.5	0.001

Statistical tests used: One-way ANOVA followed by Tukey's post-hoc. *: Statistical difference concerning the cryotherapy condition in the feet. RHR: Resting Heart Rate. Source: Authors.

Table 3 shows the RHR heartbeat recovery index, showing that the control condition recovered more heartbeats than the cryotherapy condition in the feet after round 1 (η2p: 0.23), round 2 (η2p: 0.46), and round 3 (η2p: 0.27). Regarding thoracic cryotherapy, there were no significant differences between the control and cryotherapy conditions in the feet. There was no significant effect of time (η2p: 0.01). All results were confirmed with Tukey's Post-hoc test.

Table 3. Comparisons of resting heart rate recovery rate in each round under different conditions.

Moments	Control	Thoracic Cryotherapy	Feet Cryotherapy	$F_{(2.0)}$	p
Round 1	56.1 ± 3.8*	52.5 ± 4.3	49.6 ± 6.2	7.5	0.001
Round 2	58.8 ± 4.8*	53.5 ± 2.8	48.5 ± 5.7	20.8	<0.001
Round 3	56.6 ± 2.8*	52.9 ± 3.7	50.0 ± 6.2	9.0	<0.001

Statistical tests used: One-way ANOVA followed by Tukey's post-hoc. *: Statistical difference concerning the cryotherapy condition in the feet. Source: Authors.

4. Discussion

This study aimed to analyze the effect of cryotherapy on cardiac autonomic recovery after simulated combat exercise in MMA fighters. Thus, the main findings indicated: (i) Athletes were able to maintain themselves at similar intensities throughout the experiment in the three conditions, with no effect of time on peak heart rate. (ii) Not performing cryotherapy in the interval between rounds was more effective in reducing HR compared to cryotherapy applied to the feet and thoracic region. (iii) The effect of time for cryotherapy applied to the thoracic region was pointed out, suggesting that the method only had a significant effect on the reduction of HR measured 30 seconds after exercise from the 3rd round (after 15 minutes).

In our results, there was no change in RHR peak during the simulated MMA rounds in the control, foot immersion cryotherapy, and thoracic cryotherapy conditions. This result suggests that the athletes were able to maintain the intensity during the experiment, keeping them in zones of similar intensity throughout the experiment. It is known that different intensity zones during physical exercise will promote different responses concerning the cardiac autonomic system (Peçanha et al., 2017). Thus, performing the maintenance of the intensity zone during an exercise protocol performed in scientific research optimizes the results, allowing a fair comparison between different conditions analyzed (Peçanha et al., 2017; Lederer et al., 2019).

The present study identified that the control condition (without cryotherapy) was more effective than the cryotherapy conditions with foot immersion and thoracic cryotherapy in promoting autonomous cardiac recovery. Michelletii et al. (2019) among their methods, investigated the probabilities of cryotherapy to promote better RHR recovery. These authors submitted 64 soccer athletes to the control condition (passive recovery for 15 minutes) and cryotherapy (partial immersion: 13±1°C for 15 minutes); thus, it was concluded that, in isolation, cryotherapy has greater chances of promoting recovery of heart rate variability, however, when analyzing the group effect, there are no differences between cryotherapy and passive rest.

It is noteworthy that the present study used the ice temperature between 4 and 10 °C and Michelletii et al. (2019) at approximately 13 °C. Louis et al. (2020) performed an intervention that tested different temperatures of cryotherapy with whole-body immersion in forty healthy men. The authors divided the sample by interventions considering the temperature of the cryotherapy procedure (- 110 °C, - 60 ° C, -10 °C, control temperature ≃ 24 °C) and followed the groups for five days. The results suggested that a cryotherapy exposure of -110 °C is necessary to stimulate modulations in the autonomic nervous system monitored by heart rate variability. In a similar objective, Fonda et al. (2014) examined the thermal and cardiovascular responses after the 90s, 120s, 150s and 180s of whole-body cryotherapy in a cryogenics booth (temperature between – 130ºC and -170ºC) in twelve individuals of the sex male (age 23.9 ± 4.2 years). Thermal response, heart rate, and blood pressure were measured before, immediately after, 5 min after, and 30 min after the session. Skin temperature differed significantly between different durations, except between 150 and 180-s, while there was no significant difference in heart rate and blood pressure. In contrast, Zalewski et al. (2014) evaluated 25 healthy men with a mean age of 30.1 ± 3.7 years. Each subject was exposed to cryotherapeutic temperatures in a cryogenic chamber for 3 min (approximately - 120 °C). The results showed that there were significant changes in autonomic balance that are induced by changes in central and peripheral blood volume. Cryostimulation has been associated with significant changes in heart rate and baroreceptor sensitivity. A decrease in HR was observed immediately after cryotherapy, with subsequent stabilization at the pretreatment level three and six hours later.

Piras et al. (2019) verified the effect of cryotherapy with partial immersion (3 min) using temperature at −160 °C in nine rugby players in the conditions of strength training and interval running. The authors found that in interval running, RHR was 3.5% lower after cryotherapy, and the same result was observed for oxygen consumption (4.9% lower) and ventilation (6.5% lower). The energy cost measured after cryotherapy was 9.0% lower than after passive recovery. Thus, they concluded that cryotherapy at -160 °C with partial immersion promotes a significant acute effect in the reduction of cardiorespiratory and metabolic parameters.

The present study showed an effect of time for thoracic cryotherapy, suggesting that the method only had a significant effect on the reduction of RHR measured at 30 seconds after exercise from the 3rd round (after 15 minutes). In a systematic review study, Jinnah et al. (2019) analyzed research published between 1950 and 2018; the authors concluded that cryotherapy has a more beneficial effect on recovery in the first 24 hours after exercise than immediately after recovery, suggesting that monitoring must be carried out for several moments during the 24 hours after the application of the cryotherapy protocol.

In this sense, based on the discussion, the present study brings as a strong point the fact that it demonstrates that not performing cryotherapy at a temperature between 3 and 10 °C with the full immersion of the feet or with an ice pack in the thoracic region is a strategy more practical and that promotes better response in the autonomous cardiac recovery of MMA fighters. Thus, we suggest that further studies repeat the present research experiment considering a cryotherapy ice temperature equal to or less than -110 °C and that, in addition to evaluating the acute effect, evaluate the chronic effect within 24 hours after the application of cryotherapy.

Despite the importance of the findings, the present study has among its methodological limitations the fact that it used only male athletes from the medium weight category. In this sense, in female athletes or from other weight categories, the results may differ from those found in our study.

5. Conclusion

Cryotherapy applications (between 4 and 10 °C) for 60 seconds, using an ice pack in the thoracic region and complete immersion of the feet in a container with water and ice after simulated combat, did not generate significant effects on the cardiac autonomic recovery of martial arts fighters mixed (MMA). Thus, the condition without cryotherapy proved to be more efficient in the homeostasis of resting heart rate after simulated combat exercise in MMA fighters. We suggest that as was done in the present study, that future studies examine the effect of cryotherapy on cardiac autonomic recovery in the following ways: (1) In female MMA athletes. (2) In male MMA athletes of different weight and age categories. (3) Using lower temperatures than used in the present study. (4) Using a longer time interval than that used in the present study. (5) Investigating the effect of cryotherapy in different combat sports.

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