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EFFECTS OF ISCHEMIC PRECONDITIONING ON STRENGTH AND INTERMITTENT PERFORMANCE

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Anderson Luiz Rodrigues

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ABSTRACT

In sports competitions, enhancement in the smallest details may cause a significant difference in the final performance. Thus, sports scientists and coaches are always seeking for lawful competition-day interventions that may improve performance. In this context, a maneuver called ischemic preconditioning (IPC) has emerged. The IPC consists in repeated bouts of muscular ischemia followed by reperfusion performed on the proximal limbs (i.e., arms or thigh) before an exercise event. Despite several studies testing the IPC-induced effects on exercise performance in different types of exercise, the beneficial effects of IPC are still debatable. Even meta-analyses show heterogeneous conclusions, showing that more studies are necessary. Therefore, the aim of our study was to evaluate the effect of IPC on: a) high-intensity intermittent exercise and (b) maximal strength. In the first study fifteen players (15.5 ± 0.5 yrs) attended four trials separated by seven days in a counterbalanced randomized cross-over design: IPC (4 × 5-min occlusion 220 mmHg/reperfusion 0 mmHg) in each thigh; SHAM (similar to the IPC protocol but "occlusion" at 20 mmHg); IPC-A and SHAM-A similar to the IPC and SHAM, but with a moderate aerobic activity (70% of HRmáx) on reperfusion phases. After 6-min of each trial, the players performed the YoYo Intermittent Endurance Test level 1 (YoYoIE1). In the second study, fifteen recreational weight-lifters participated in a randomized cross over design, involving two sessions (IPC and SHAM), consisted of three cycles of 5 minutes of occlusion at 170 mm Hg of pressure (IPC) or 20 mmHg (SHAM), alternated by 5 minutes of reperfusion at 0 mm Hg. Ten minutes after, participants performed an 1-RM test on bench press. Our data didn’t found any effect of IPC on intermittent exercise and a slightly increase (~2.4%) on maximal strength, suggesting that IPC can possibly be an ergogenic aid for strength athletes.

Key-words: Ischemia. Reperfusion. Vascular occlusion. Intermittent exercise. Resistance training. Performance. Ergogenic aid.

RESUMO

Em competições esportivas, o aprimoramento nos menores detalhes pode causar uma diferença significativa no desempenho final. Assim, cientistas e técnicos do esporte estão sempre buscando intervenções legais em dias de competição que possam melhorar o desempenho. Nesse contexto, surgiu uma manobra denominada pré-condicionamento isquêmico (PCI). O PCI consiste em episódios repetidos de isquemia muscular seguidos de reperfusão realizada nas regiões proximais dos braços ou da coxa antes de um exercício físico. Apesar de vários estudos terem avaliado os efeitos induzidos pelo IPC no desempenho em diferentes tipos de exercício físico, os efeitos benéficos do IPC ainda são discutíveis. Mesmo metanálises mostram conclusões heterogêneas, mostrando que mais estudos são necessários. Portanto, o objetivo do nosso estudo foi avaliar o efeito do PCI sobre: a) exercício intermitente de alta intensidade e (b) exercício de força máxima. No primeiro estudo, quinze jogadores (15,5 ± 0,5 anos) participaram de quatro sessões separadas por sete dias em um desenho cruzado randomizado contrabalançado: IPC (4 × 5 min oclusão 220 mmHg / reperfusão 0 mmHg) em ambas as coxas; SHAM (semelhante ao protocolo IPC, mas "oclusão" a 20 mmHg); IPC-A e SHAM-A semelhantes ao IPC e SHAM, mas com atividade aeróbia moderada (70% da FCmáx) nas fases de reperfusão. Após 6 minutos de cada tentativa, os jogadores realizaram o Yo-Yo Intermittent Recovery Test Level I (YoYoIR1). No segundo estudo, quinze levantadores de peso recreativos participaram de um desenho cruzado randomizado, envolvendo duas sessões (IPC e SHAM), consistindo em três ciclos de 5 minutos de oclusão a 170 mm Hg de pressão (IPC) ou 20 mmHg (SHAM), alternado por 5 minutos de reperfusão a 0 mm Hg. Dez minutos depois, os participantes realizaram um teste de 1-RM no supino. Nossos dados não encontraram nenhum efeito do IPC no teste de exercício intermitente e um ligeiro aumento (~ 2,4%) na força máxima, sugerindo que o IPC pode possivelmente ser um auxílio ergogênico para atletas de força.

Palavras-chave: Isquemia. Reperfusão. Oclusão vascular. Exercício intermitente. Treinamento resistido. Performance. Recurso ergogênico.

SUMMARY

1 INTRODUCTION

Ischemic preconditioning (IPC) involves the use of repeated bouts of ischemia induced in skeletal muscle through the use of a cuff or tourniquet on upper or lower limbs, interspersed with periods of reperfusion (MAROCOLO et al., 2019). Murry et al. (MURRY C E; JENNINGS R B; REIMER K A, 1986) introduced the term, in 1986, after publishing first results that confirmed that brief episodes of ischemia and reperfusion were able to protect dog´s myocardium against further occurrence of permanent ischemia. Later, in 1993, Przyklenk et al. (PRZYKLENK et al., 1993) introduced the term “local remote preconditioning”, after notice a remote effect of IPC in which transient non-lethal ischemia and reperfusion applied to a remote organ or its part, protects another organ against further episode of lethal ischemia and reperfusion injury. However, just in 1997, Birnbaum et al. (BIRNBAUM; HALE; KLONER, 1997) was the first to describe myocardial protection by partial reduction of blood flow to a stimulated peripheral muscle in rabbit after a 30-minute 55 to 65% reduction of artery blood flow plus stimulation of the gastrocnemius muscle.

Regarding sports and exercise sciences, the physiological mechanisms underlying a potential ergogenic effect from IPC may be explained through three main pathways: systemic response, neuronal and humoral pathways (CARU et al., 2019). IPC is related to a higher local vasodilation at moderate-intensity exercise (HORIUCHI; ENDO; THIJSSEN, 2015), which may contribute to blood supply and optimize the delivery of oxygen and nutrients to the peripheral tissue, and muscle deoxygenation kinetics during exercise (KIDO et al., 2015). The increasing in blood flow and muscle oxygenation (BARBOSA et al., 2015; PARADIS-DESCHÊNES; JOANISSE; BILLAUT, 2016) would result in improved oxygen consumption (BEAVEN et al., 2012; TAPURIA et al., 2008) and better performance in endurance exercises. Furthermore, Rassaf et al. (RASSAF et al., 2014), found an increase in the levels of nitric oxide (NO) in the human blood after remote IPC (via shear stress on endothelial wall). Enhanced NO levels (via dietary supplementation) reduces local and systemic muscular oxygen cost during exercise by improving energy efficiency in the mitochondria (BAILEY et al., 2012; LARSEN et al., 2011), enhances muscle contractile efficiency during knee-extensor exercise (BAILEY et al., 2010) and improves exercise tolerance and performance during high-intensity constant work rate (JONES; VANHATALO; BAILEY, 2013). Increases in muscle activation following IPC suggests positive alterations on central nervous system (CRUZ et al., 2015). Crisafully et al (CRISAFULLI et al., 2011) suggests that IPC can affect a complex mechanism on central nervous system known to control the skeletal muscle recruitment, increasing the neural drive and the number of motor units recruited. However, more research is necessary to elucidate the mechanisms of IPC on exercise performance, since results are still debatable (MAROCOLO et al., 2019).

Although some research of exercise performance after a period of occlusion (MAROCOLO et al., 2016) have been documented since 50´s, just in 1998 the first study using the traditional protocol of IPC (minutes of occlusion interspersed with periods of reperfusion) on exercise performance was conducted (LIBONATI et al., 1998). Since then, lots of researchers has studied IPC as an ergogenic aid to improve performance in a wide variety of activities, such as swimming (JEAN-ST-MICHEL et al., 2011; MAROCOLO et al., 2015), cycling (CRISAFULLI et al., 2011; DE GROOT et al., 2010; FOSTER et al., 2011; PAIXÃO; DA MOTA; MAROCOLO, 2014), running (BAILEY et al., 2012; JAMES et al., 2016), and resistance exercise (MAROCOLO et al., 2016a; PARADIS-DESCHÊNES; JOANISSE; BILLAUT, 2016). However, inconsistent results have been reported (DA MOTA; MAROCOLO, 2016; INCOGNITO; BURR; MILLAR, 2016; MAROCOLO et al., 2016b). It is difficult to explain why the findings are inconsistent, but the variety of activities (i.e., exercise protocol tested), IPC protocols (i.e., time of occlusion/reperfusion, number of cycles, timing prior exercise, cuff placement, size of the cuff, pressure of the cuff, bilateral or unilateral limb occlusion, local or remote IPC, etc), the fitness level and the individual responsiveness could be part of such inconsistency (MAROCOLO; BILLAUT; DA MOTA, 2018). Also, a placebo effect from IPC benefits on exercise performance should be considered (MAROCOLO et al., 2015). This lack of consistent results, makes more difficult to elucidate the mechanism behind IPC (MAROCOLO et al., 2019).

Although several types of exercise have been tested for a potential ergogenic effect from IPC, there is limited evidence about the IPC effect on maximal strength and on intermittent exercises involving acceleration, deceleration, and changes of direction. A better maximal strength, as well as a superior intermittent ability to run, might generate relevant practical applications on sports like powerlifting and team sports, respectively. Therefore, we performed two separate studies, aiming a) to evaluate the effects of IPC on maximal voluntary dynamic strength performance and b) maximal intermittent ability performance. We had scientific reasons to expect a benefit from IPC for those physical abilities, which we hope to make clearer on our introductions of the two papers presented in this dissertation.

2 PRODUCED ARTICLES

2.1 ARTICLE 1

TRADITIONAL AND ACTIVE ISQUEMIC PRE-CONDITIONING EFFECTS ON HIGH-INTENSITY INTERMITTENT EXERCISE

ABSTRACT

This study evaluated the acute effect of traditional ischemic preconditioning (IPC) and an “active” protocol of ischemic preconditioning (IPC-A) on a high-intensity intermittent exercise performance and physiological indicators in amateur team-sport players. Fifteen players (15.5 ± 0.5 yrs) attended four trials separated by seven days in a counterbalanced randomized cross-over design: IPC (4 × 5-min occlusion 220 mmHg/reperfusion 0 mmHg) in each thigh; SHAM (similar to the IPC protocol but "occlusion" at 20 mmHg); IPC-A and SHAM-A similar to the IPC and SHAM, but with a moderate aerobic activy (70% of HRmáx) on reperfusion phases. After 6-min of each trial, the players performed the YoYo Intermittent Endurance Test level 1 (YoYoIE1). The distance covered in the YoYoIE1 IPC (917.3 ± 204.2); IPC-A (930.7 ± 210.8); SHAM (968 ± 201.3); SHAM-A (933.3 ± 203.8), was not different among trials (p = 0.46), furthermore, lactate concentration did not differ (P=0.3675) among protocols. There were also no significant differences in either mean heart rate (P=0.0133) or peak HR (p =0.0005) for both IPC and SHAM compared to control. Therefore, we conclude that acute IPC does not influence high-intensity intermittent exercise performance in team-sports players and that physiological indicators do not differ between the interventions.

Keywords: Physical training, Ischemia, Skeletal Muscle, Aerobic capacity, Ergogenic.

INTRODUCTION

Isquemic-preconditioing (IPC) involves the use of repeated bouts of ischemia induced in skeletal muscle through the use of a cuff or tourniquet on upper or lower limbs, interspersed with periods of reperfusion (MAROCOLO et al., 2019). IPC has gained high visibility on sports medicine and sports sciences journals, due its potential as a legal, non-invasive and feasibility ergogenic aid to enhance exercise performance. The exact IPC-induced mechanisms which could support improvements on exercise performance are still uncertain. However, IPC is related to a higher local vasodilation at moderate-intensity exercise (HORIUCHI; ENDO; THIJSSEN, 2015), which may contribute to blood supply and optimize the delivery of oxygen and nutrients to the peripheral tissue, and muscle deoxygenation kinetics during exercise (KIDO et al., 2015). The increasing in blood flow and muscle oxygenation (BARBOSA et al., 2015; PARADIS-DESCHÊNES; JOANISSE; BILLAUT, 2016) would result in improved oxygen consumption (BEAVEN et al., 2012; TAPURIA et al., 2008) and better performance in endurance exercises.

Despite several studies testing the IPC-induced effects on exercise performance in different types of exercise, the beneficial effects of IPC are still debatable. Even meta-analyses show heterogeneous conclusions (DA MOTA; MAROCOLO, 2016; INCOGNITO; BURR; MILLAR, 2016; MAROCOLO et al., 2016b). For example, Salvador et al., concluded that IPC may enhancement performance on aerobic and anaerobic exercise (SALVADOR et al., 2016). On the other hand, Marocolo et al concluded that overall the IPC has minimal or nonsignificant impact on exercise performance especially considering the fitness level of the individuals and different statistical methodologies, such as P values, effect sizes and the smallest worthwhile change (MAROCOLO et al., 2019). Such disagreement provokes us to think about different approaches (i.e., components of the IPC protocol). Indeed, probably the optimal IPC protocol per si (e.g., amount and duration of cycles of occlusion–reperfusion, time to start the exercise) has not been found yet (MAROCOLO et al., 2019).

Although the standard IPC protocol is carried out at rest (MAROCOLO et al., 2019; SALVADOR et al., 2016), research groups (CRISAFULLI et al., 2011; SLYSZ; BURR, 2018) have tried to ally IPC with exercise to potentiate the stimulus. The rationale for this combination (IPC plus exercise) aims to induce (or amplify) the hypoxic and metabolic preconditioning stimulus of IPC (e.g., adenosine, bradykinin and opioids), which could trigger a cascade of reactions superior than standard IPC (i.e., at rest) isolated, promoting an enhanced metabolic environment for improving performance (CRISAFULLI et al., 2011; SLYSZ; BURR, 2018). Additionally, the exercise *per si* is also capable to reduce the damage incurred by ischemia-reperfusion injury (POWERS; QUINDRY; KAVAZIS, 2008). Two studies attempted to combine IPC with exercise. Slysz and Burr (2018) concluded that walking exercise combined with restricted leg muscle blood flow or electrical muscle stimulation (EMS) improved performance in a maximal aerobic test, but standard IPC (i.e., isolated) no. However, the validity of their conclusions is questionable (MAROCOLO; MEIRELES; DA MOTA, 2019), once the authors did not have “controls/placebo” for EMS and walking isolated to exclude a possible advantageous effect from EMS/walking “only” (i.e., no IPC). Besides, walking exercise with leg blood flow restriction is not IPC, once “IPC” is applied before the exercise, not during. Another study applied the exercise (5 min of submaximal cycling) just before the IPC aiming to increase metabolite accumulation for muscle metaboreflex activation (CRISAFULLI et al., 2011). However, the authors did not equalize the cycles of occlusion/reperfusion between IPC standar vs. IPC active (IPC-A). The authors had one cycle of 3-min conclusion after exercise vs. 3 cycles of 5 min occlusion/5 min reperfusion (CRISAFULLI et al., 2011). Thus, to the best of our knowledge, there is no study investigating the effect of IPC combined with exercise on any exercise test performance.

Although the physical demands in team-sports (e.g., soccer and basketball) are complex and involve several aspects (MOTA et al., 2016), the high-intensity intermittent exercise is similar to the activity observed in the games. Surprisingly, only one study (MAROCOLO et al., 2017) out of 45 (~2%) analyzed in a recent meta-analyze (MAROCOLO et al., 2019) tested the IPC effect on YoYo intermittent endurance test level 2. In such study, IPC showed no effect on performance. However, the IPC effect on a longer type of intermittent test (more dependent on the aerobic system) fitting the ergogenic potential from IPC is unknown. Therefore, this study investigated the acute effect of standard IPC and IPC combined with submaximal exercise (IPC active [IPC-A]) on YoYo intermittent recovery test level 1 (YYIR1) performance, perceptual and physiological indicators in team-sports players. We hypothesized that IPC-A would increase the distance covered in YYIR1, more than placebo and IPC due higher metabolic stimulus from IPC-A.

MATERIALS AND METHODS

Fifteen young basketball and soccer players (15.5 ± 0,5 year, 173 ± 6,5 cm, 65,95 ± 4,4 kg, VO_2máx = 44,53 ± 1,69 $ml.kg^{-1}.min^{-1}$) volunteered for this study. Inclusion criteria were: (a) familiarized with YYIRT1, and performed at least three times the test in the last six months, (b) no smoking history during the last year, (c) absence of any cardiovascular or metabolic disease, (d) systemic blood pressure lower than 140/90 mmHg and no use of antihypertensive medication, (e) no use of creatine supplementation, anabolic steroids, drugs or medication with potential effects on physical performance (self-reported) and (g) no recent musculoskeletal injury. This study was approved by the local institutional Ethical Committee for Human Experiments and was performed in accordance with ethical standards in sports science research (HARRISS; ATKINSON, 2015). In addition, all subjects signed an informed consent form. Based on prior research (BRADLEY et al., 2011), a sample size less than 13 (i.e., *n* between six and nine) was sufficient to detect a significant ($p < 0.05$) difference among playing positions ("group") in the YoYoIE2 (main dependent variable). Also, a study using a similar IPC protocol (independent variable) and physical test duration, reported significant statistical effects with a sample size of 12 individuals (CRUZ et al., 2015). Thus, to counteract any potential drop out, a sample of 15 subjects was included for this study.

EXPERIMENTAL DESIGN OF THE STUDY

Subjects attended the laboratory five times (with 7 days in-between), for initial screening and anthropometric measurements and for familiarization with the equipment and proceeding. Perceptual recovery status (PRS) (BANGSBO; IAIA; KRUSTRUP, 2008) and visual analogue scale of muscle soreness (DOMS) (BIJUR; SILVER; GALLAGHER, 2001) were reported as soon as the participant arrived the local of the test. From second to fifth visits, a randomized crossover assignment (IPC, IPC-A, SHAM and SHAM-A) was adopted (figure 1). The YYIRT1 was carried out after 6 min of each trial (IPC, IPC-A, SHAM or SHAM-A). One minute after test, blood was collected from the hand finger tip using a lancet of automatic retraction (ROCHE Accu-Check, Basel Switzerland), and a valid (FELL et al., 1998) portable analyzer (ROCHE Accu-Check, Basel Switzerland) was used for determination of lactate concentration. HR was monitored throughout the entire YYIRT1, by an individual RS800CX heart monitor (Polar Electro®, Kempele, Finland). All YYIRT1 tests were conducted by the same experienced researcher at the same time of the day. To prevent the possibility of a placebo (positive) effect (4,5), all subjects were informed that all conditions could improve performance. Also, in order to prevent nocebo (negative) effects, the participants were informed that IPC and SHAM would cause absolutely no harm, despite discomfort related to the maneuvers (FERREIRA et al., 2016). Additionally, the tester was blinded for which protocol (i.e., IPC, IPC-A, SHAM, SHAM-A) the subjects had undergone before. Also, the subjects were kept blinded in relation to performance and other indicators until the end of the research, i.e., no information about distance covered (the audio of speed and level of YYIRT1 was in unknown language), HR and lactate. Coffee (or caffeine products), tea, and alcohol intake was prohibited as well as strenuous exercise for 24 h before testing (INCOGNITO; BURR; MILLAR, 2016).

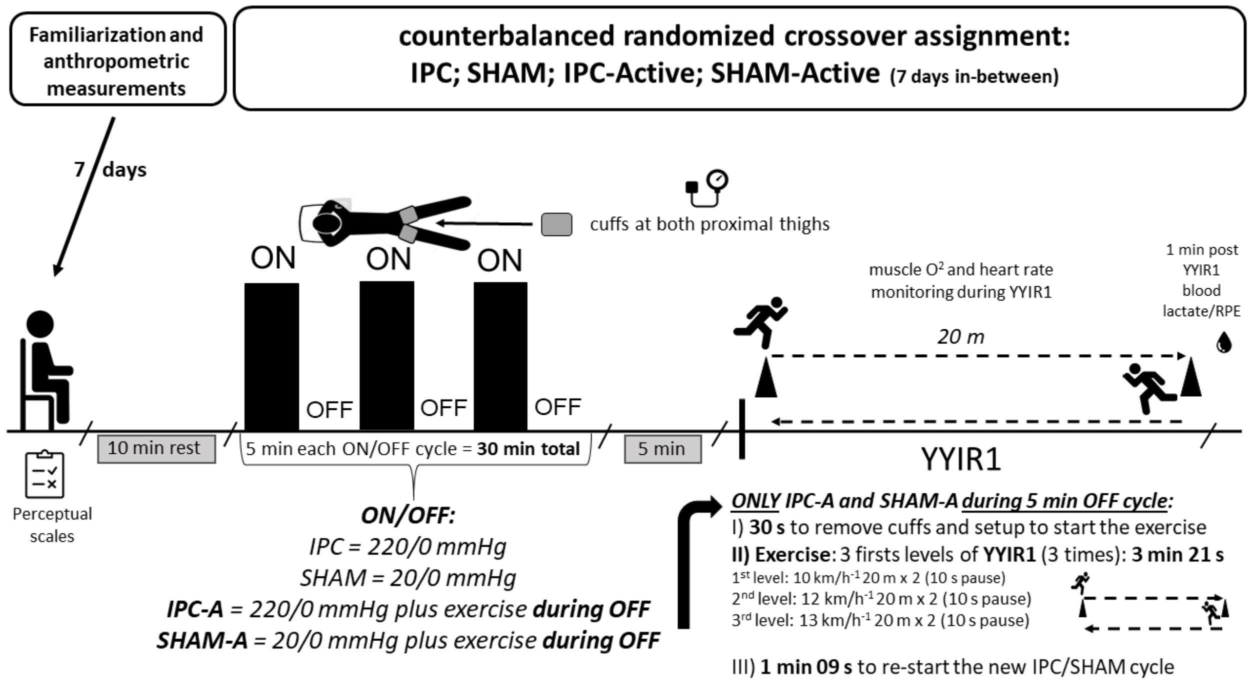

Fig. 1 Experimental design of the study. N = 15. Perceptual questions were about recovery status and delayed onset muscle soreness; IPC = ischemic preconditioning, IPC-A = active ischemic preconditioning, SHAM = placebo, SHAM-A = active placebo RPE = rating of perceived exertion.

ISCHEMIC PRECONDITIONING AND PLACEBO PROTOCOLS

In the current study, we applied four different protocols (conditions) to test our hypothesis, randomily: stardard IPC (at rest), standard SHAM (at rest), IPC-A, and SHAM-A. The IPC maneuver consisted of three cycles of 5-min occlusion (220 mmHg) and 5-min reperfusion (no pressure) in each thigh (total duration 30 min), using a pneumatic tourniquet (ITS-MC 12x86cm, Novo Hamburgo, RS, Brazil) administered at the subinguinal region of the thighs. We applied this specific IPC protocol for the following reasons: (a) several studies have successfully explored the ergogenic effects of IPC on exercise performance with the same protocol (CRUZ et al., 2015; JEAN-ST-MICHEL et al., 2011; MAROCOLO et al., 2016a; PATTERSON et al., 2015); (b) at least three ischemia-reperfusion cycles are necessary to protect against skeletal muscle infarction and endothelial dysfunction after prolonged periods of imposed ischemia (SALVADOR et al., 2016); and (c) it is considered safe and well tolerated in both patients and healthy volunteers (GONZALEZ et al., 2014). The occlusion and reperfusion phases were conducted at both thighs, at the same time, with subjects remaining lying. In the SHAM protocol, an external pressure of 20 mmHg was administered, as proposed in previous studies (FOSTER et al., 2011; MAROCOLO et al., 2016a). In orderThe IPC-A and SHAM-A was similar to IPC and SHAM, but at reperfusion phase, subjects performed three times the three first levels of YYIRT1 (heart rate around 70% of maximum, 201 seconds). IPC has shown to improve exercise performance within 45 min of the final cuff inflation (BAILEY et al., 2012; PATTERSON et al., 2015). Thus, in the current study, YYIRT1 was performed after 6 min of each trial (i.e., IPC, IPC-A, SHAM or SHAM-A).

YO-YO INTERMITTENT RECOVERY TEST LEVEL 1 (YYIRT1)

The Yo-Yo IR level 1 (Yo-Yo IR1) test focuses on the capacity to carry out intermittent exercise leading to a maximal activation of the aerobic system and is highly suggested for evaluation of physical performance in intermittent sports (BANGSBO; IAIA; KRUSTRUP, 2008). The YYIRT1 consists of a repeated 2 × 20-m shuttle run at progressively increasing speed stages (initial speed at 10 km.h-1), guided by specific audio (10-s to recovery in a marked 5 m area behind the finishing line). Cessation of the test was assessed by failure to reach the finish line by the tone on two occasions (BRADLEY et al., 2011).

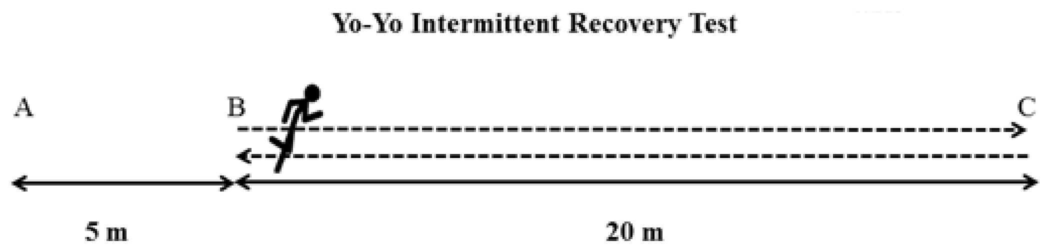

FIG. 2 – YO-YO INTERMITTENT RECOVEY TEST 1.

STATISTICAL ANALYSIS

The Shapiro–Wilk test was applied to verify the normal distribution of the data. For between- protocol analysis, one-way analysis of variance (ANOVA) for repeated measures was conducted, followed by post-hoc Tukey's test or nonparametric ANOVA (Friedman test) followed by a post-hoc Dunn's test was performed. Only for the distances covered in the YoYoIE1 we calculated the effect size (ES; Cohen d) to determine the meaningfulness of the difference (practical relevance), classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0) as recommended (BATTERHAM; HOPKINS, 2006). The significance level was set at 0.05. The software used for data analysis was GraphPad® (Prism 6.0, San Diego, CA, USA).

RESULTS

Table 1 shows the score of each group at the beginning of the session. As shown, there were no significant difference ($p < 0,05$) on the recovery status or on the delayed onset muscle soreness on the tests.

Table 1 Varaibles of recovery at the beggining of the tests.

	IPC	IPC-A	SHAM	SHAM-A	P
PRS	9,4±1,12	9,4±1,06	9,4±0,74	9,4±1,13	0,8797
DOMS	0,33±1,29	0,73±1,58	0,53±1,19	0,40±1,06	0,7793

Note: PRS= perceived recovery status; DOMS = delayed on-set muscle soreness.

Figure 2, shows the accumulated distance (m). No significance was found (p=0,46) between conditions: IPC (917,3 ± 204,2); IPC-A (930,7 ± 210,8); SHAM (968 ± 201,3); SHAM-A (933,3 ± 203,8).

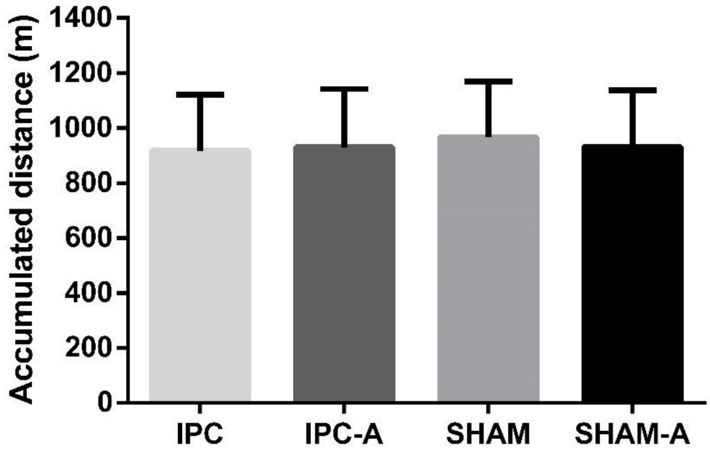

Figure 2: Accumulated distance on YYIRT1.

Individual performance on accumulated distance (m) on SHAM (control) compared to the others situations are presented on table 2 and figure 3.

Table 3 shows the heart rate during the YYIRT1 and lactate colected one minute after the end of the test. HR mean%peak represents the percentage of the HR mean from the HR maximum.

Table 2 Number of participants that improved, decreased and had neutral results compared to control (SHAM).

	IMPROVED	DECREASED	NEUTRAL
IPC	3	7	5
IPC-A	5	9	1
SHAM-A	2	11	2

Note: IPC = isquemic preconditioning; IPC-A = active isquemic pre-conditioning; SHAM-A - active placebo.

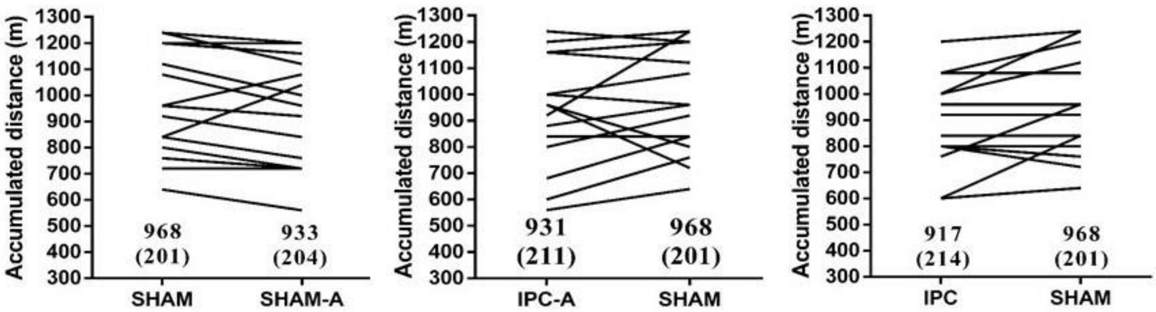

Fig.3 Individual performance on accumulated distance (m) on SHAM (control) compared to the others situations. Horizontal lines represent individual data. Values are mean (standard deviation).

Table 3 Intensity variables on YYIRT1 after different IPC protocols.

	IPC	IPC-A	SHAM	SHAM-A	P
HR minimum (bpm)	61.47 ± 5.89	62.13 ± 6.60	61.87 ± 5.55	61.8 ± 5.83	0.9243
HR mean (bpm)	169 ± 8.05	172.3 ± 7.85	170.7 ± 7.21	173.9 ± 7.63	0.0133
HR maximum (bpm)	193.2 ± 8.24	196.2 ± 8.91	193.5 ± 7.37	199.2 ± 9.34	0.0005
HR mean%peak	87.47 ± 1.49	87.85 ± 1.76	88.26 ± 1.69	87.33 ± 1.41	0.3885
Lactate (mmol/L)	9.53 ± 2.45	9.91 ± 3.01	9.53 ± 2.01	11.95 ± 3.96	0.3675

Note: HR = heart rate; bpm = beats per minute; values are mean ± standar desviation.

DISCUSSION

The aim of this study was to evaluate the effect of the traditional IPC and an "active" IPC (IPC-A), previous an intermitent maximal aerobic test (YYIRT-1) on performance and physiological indicators, such as, heart reate (HR) and lactate (LAC). Surprinsingly, neither IPC nor IPC-A increased performance comparted to SHAM on YYIRT-1. HR and LAC was also not significant different among situations. It is important to mention that in the active placebo intervention (SHAM-A) we found the most decreament on performance and on LAC values, showing that maybe this extra amount of volume (+ 720 m) was too high, even conducted in moderate intensity (~

70% HRmáx). Interestingly, on IPC-A, LAC was lesser than in the SHAM-A and almost like SHAM and IPC, showing some effect of the IPC on lactate. As shown on table 1, PRS and DOMS were not significant different among situation ($p < =0.05$), ensuring that all conditions were performed in the same status of recovery.

To quantify the maximal aerobic capacity (VO_2máx) of our participants, we used the YYIRT-1. This is a well recognized test for youth athletes on intermittent sports, such as our participants (BANGSBO; IAIA; KRUSTRUP, 2008). Our hypothesys was that they could perform better on the test, i.e. achieve a better score, since IPC was capable of improve performance on aerobic activities (CRUZ et al., 2015; DE GROOT et al., 2010; JEAN-ST-MICHEL et al., 2011), although with mixed results, with (CRISAFULLI et al., 2011; DE GROOT et al., 2010) and without (BAILEY et al., 2012; CRUZ et al., 2015; JAMES et al., 2016; PATTERSON et al., 2015) improvement on VO_2máx. A similar study from our group (MAROCOLO et al., 2017), also didn´t found any influence of IPC on distance covered (IPC 867 ± 205 m, SHAM 873 ± 212 m and control 921 ± 206 m), nor on HR, HR peak and LAC, on intermitent exercise. Different of the actual study, Marocolo et. al. (MAROCOLO et al., 2017) evaluated the acute effect of IPC on YYIRT-2, a similar test with the main difference in the starting speeds (YYIRT-1 starts at 10 km/h and YYIRT-2 starts at 13 kmh), shortening the test and being more designed for highly trained athletes, although there is a large relationship between distances between the tests (LOCKIE et al., 2017).

Beside a different type of YYIRT1, the novelty in this study compared to our another one, is the use of an “active” protocol, with the aim to evoke or amplify the hypoxic and metabolic accumulation produced by IPC at rest. To our knowledge, only one study examined the effect of IPC combined with exercise to improve performance, although their protocols were performed more in a blood flow restriction exercise (BFRE) context. In a study by Slysz and Burr (SLYSZ; BURR, 2018), twelve men, underwent on four different conditions: traditional IPC, IPC with treadmill walking (IPC+Walk), IPC with eletrical muscle stimulation (IPC+EMS) and no IPC (control). IPC+Walk and IPC+EMS. VO2máx Their hypothesys was that muscle contractions during IPC, via walking or eletro muscle stimulation, would improve the subsequet performance on the tests. The maximal watts during the VO2max increased when IPC was combined with both EMS (304 ± 38 W) and walking (308 ± 40 W) compared to traditional IPC (296±39 W) and no IPC control (293±48 W; $P = 0.02$), but there was no statistical difference in anaerobic peak power, neither on VO_2máx.

YYIRT1 consists in repeated sprints of 20x20 meters, always with 10 seconds of recovery (BANGSBO; IAIA; KRUSTRUP, 2008). Some studies failed to found any effect on sprint performance after IPC. For example, Griffin et. al. (GRIFFIN et al., 2019), didn´t found any effect on muscle oxygenation, lactate, RPE and time for local (p = 0.538) or remote (p = 0.100) IPC, taken to perform a protocol of 3 x (6 x 15+15m) shutle sprints with 20s of passive recovery between repetitions and 120s between sets. In another study (ZINNER; BORN; SPERLICH, 2017), thirteen team sports athlets (7 males and 6 females) performed 16 x 30m sprints with 15s recovery between repetitions) after a local, remote and SHAM trial. No improvement on time IPC (16.0 ± 1.8 s), IPC_{remote} (16.2 ± 1.7 s), and CON (16.0 ± 1.6 s; p = 0.50) was found. and no statistical differences in oxygen uptake, heart rate, muscle oxygen saturation of the *vastus lateralis* and *biceps brachii* between the three conditions were evident (all $p > 0.05$). Interestingly, IPC was deleterious just for the women and not to men in this study. IPC didn´t showed any effects on sprint time (p < 0.05) (GIBSON et al., 2015), even in a short duration protocol (3 x 30m with 60 seconds of recovery).

Similar with previous studies mentioned above, IPC was not capable to influence on the physiological indicators of intensity in our study, since neither heart rate (HR) nor lactate (LAC) differed among situations. This data don´t surprise us, since they corroborate with results of our another study (MAROCOLO et al., 2017). Curiously, in the presente study, LAC was slightly higher at SHAM-A compared to IPC-A, suggesting some effect of IPC on the "active" protocol.

Individual performance is shown at table 2 and figure 3. Although the score were not significant different between situations (p = 0.46), it is worth to mention that seven, nine and eleven participants decreased their performance after IPC, IPC-A and SHAM-A respectivelly compared to SHAM (control). This data corroborate with some studies that found a worse performance after an IPC protocol compared to SHAM (PAIXÃO; DA MOTA; MAROCOLO, 2014). To explain this decreament on performance, beyond the increase in volume (+ 720m) on active protocols, Griffin et. al. (GRIFFIN et al., 2019) found an increase in the sensation of muscle soreness and reduced perception of freshness on local compared to remote IPC, and this sensation could impair the performance of the participants. As we didn´t collected any data about subjective effort during the YYIRT-1, we can just speculate about the subject.

In sumary, more participants decreased their performance than increased on situations compared to control, suggesting that IPC, IPC-A and even the active protocol alone (SHAM-A) are detrimental to maximal aerobic capacity. On "active" situations, the extra volume on activities can explain the worse performance on IPC-A and SHAM-A, but mechanisms behind the worse performance are not clear on IPC. Futures studies are necessary to understand the mechanisms that could impair performance on aerobic performance.

CONCLUSION

Although the score between conditions were not significant different (p = 0.46) on YYIRT-1, the time spent to perform IPC, the increase in volume in the active protocol and, principal, the number of participants that decreased their performance on IPC, IPC-A and SHAM-A compared to control, our data can´t support the use of IPC or "active" IPC as an ergonic aid to improve maximal aerobic capacity.

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1.2 ARTICLE 2

ISCHEMIC PRECONDITIONING IMPROVES MAXIMAL STRENGTH PERFORMANCE.

ABSTRACT

Multiple studies has investigated the ergogenic properties of ischemic preconditioning (IPC) for aerobic performance, but just a few well controlled have investigated the efficacy of acute IPC for resistance exercise. The aim of the study was to determine the ergogenic potential of IPC on maximal strength performance (1-RM) on bench press exercise and on subjective perception of effort (RPE). After three sessions to test their 1-RM (third was considered control), fifteen recreational weight-lifters participated in a randomized cross over design, involving two sessions (IPC and SHAM), consisted of three cycles of 5 minutes of occlusion at 170 mm Hg of pressure (IPC) or 20 mmHg (SHAM), alternated by 5 minutes of reperfusion at 0 mm Hg. Ten minutes after, participants performed an 1-RM test on bench press. Our results showed an increase on 1-RM for IPC (115.7 ± 15.55), but not for SHAM (113.9 ± 15.77) compared to CONTROL (113.3 ± 15.9). RPE was lesser for IPC (8), but no for SHAM (9) compared to CONTROL (9). IPC improves load on 1-RM test and reduces perceived effort of male recreational resistance trained individuals. Such evidence suggests an ergogenic effect of IPC for using in competitions involving repeated maximal strength output.

INTRODUCTION

In sports competitions, enhancement in the smallest details may cause a significant difference in the final performance. Thus, sports scientists and coaches are always seeking for lawful competition-day interventions that may improve performance. Among several potential interventions, those which are feasible and simpler to be inserted in the routine might be preferable for practical reasons, such as compression garments (GIMENES et al., 2019; PAVIN et al., 2019), different types of warm-up or re-warm-up (HAMMAMI et al., 2018), cold water immersion (GARCIA; DA MOTA; MAROCOLO, 2016), etc. In this context, a maneuver called ischemic preconditioning (IPC), has emerged (CARU et al., 2019; MAROCOLO et al., 2019). The IPC consists in repeated bouts of muscular ischemia followed by reperfusion performed on the proximal limbs (i.e., arms or thigh) before an exercise event (MAROCOLO et al., 2016b, 2019; MOTA et al., 2020). Multiple studies demonstrate the ergogenic ability of

IPC for endurance exercise (BAILEY et al., 2012; CRUZ et al., 2015; DE GROOT et al., 2010; JEAN-ST-MICHEL et al., 2011; KIDO et al., 2015). In a study (BAILEY et al., 2012) 13 healthy men performed a 5-km time trial 34 seconds faster after IPC versus control. Another study showed improvements on maximal swim time for 100 m (0.7 s) after remote IPC (i.e., ischemia/reperfusion at a remote site) (JEAN-ST-MICHEL et al., 2011). Such improvement was of ~-1.1% better than the relative to personal best time, generated a significant improvement in average International Swimming Federation points (+22 points, P=0.01).

To date, just few well-controlled studies have investigated the potential of IPC to enhance resistance exercise performance (MAROCOLO et al., 2019). Marocolo et al. (MAROCOLO et al., 2016a) showed that IPC increased the number of movements performed with a resistance at 12 repetitions maximum (12-RM) compared with control. However, they found no difference between IPC (13.08 ± 2.11 repetitions) and PLACEBO (13.15 ± 0.88) conditions, suggesting that IPC and PLACEBO have small beneficial effects on repetition performance over a control condition, possibly by a placebo effect. Paradis-Deschênes et. al. (PARADIS-DESCHÊNES; JOANISSE; BILLAUT, 2016) studied ten strength-trained men performing five sets of 5 maximum voluntary knee extensions of the right leg on an isokinetic dynamometer. In short, they found IPC benefits during exercise, increasing peak force (~11.8%), and average force (~12.6%) in comparison with placebo treatment. The underlying mechanisms by which IPC may exert its ergogenic effects on resistance exercise performance are still not clear. An enhancement of adenosine triphosphate (ATP) production by phosphagen pathways (MENDEZ-VILLANUEVA et al., 2012), a higher concentration of phosphocreatine at rest and during pauses (ENKO et al., 2011), could enhance the recovery between sets of resistance exercise and, consequently, the performance. Also, IPC promotes reactive hyperemia and higher muscular reoxygenation (BILLAUT; BUCHHEIT, 2013) and less muscle damage from the eccentric phase (FRANZ et al., 2018), which could benefit repeated resistance exercise performance. Surprisingly, to the best of our knowledge, there is no study testing IPC effects on 1-RM performance, and none regarding a potential impact on repeated 1-RM performance, which could be relevant for practical application (e.g., powerlifting competitions or maximal strength training). Therefore, this study investigated the effect of IPC on maximal strength test performance on bench press exercise. We hypothesized that IPC could increase the maximum strength due to improvements in ATP production, phosphocreatine resynthesis, better muscular reoxygenation, and lower muscle damage.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

With the aim to evaluate the effect of IPC previous a traditional one repetition maximal test (1-RM) on the bench press exercise (BPE), fifteen recreational weightlifters were recruited. On the first two sessions, they performed the one repetition maximum (1-RM) test, separated by 72-houras. The values of 1-RM among the sessions were not significant different (p = 0.37; ANOVA one-way for repeated measures), then, the third session was considered as control (no cuff on the arms). Then, a randomized cross over design, involving two sessions (IPC or SHAM) were separated by at least 72h. The IPC session consisted of three cycles of five minutes of occlusion, at proximal area of both arms, with 170 mmHg of pressure alternated by five minutes of reperfusion (no external pressure, i.e., o mmHg). The SHAM session served as a placebo-controlled and was similar of the IPC session, but 20 mmHg of pressure was applied. Ten minutes after IPC (or SHAM), participants performed the 1-RM test.

SUBJECTS

Fifteen male recreational weightlifters (table 1) volunteered for this study. Inclusion criteria were: (a) familiarized with bench press for at least one year, (b) no smoking history during the last year, (c) absence of any cardiovascular or metabolic disease, (d) systemic blood pressure lower than 140/90 mmHg and no use of antihypertensive medication, (e) no use of creatine supplementation, anabolic steroids, drugs or medication with potential effects on physical performance (self-reported), (g) age from 18 to 45 years and (g) no recent musculoskeletal injury. The study procedures were approved by the local institutional ethical committee for human experiments (n. 2.250.458) and were performed in accordance with the Declaration of Helsinki. In addition, all subjects signed an informed consent form before data collection.

Table 1 Characteristics of the participants.

				Training History	
Age (y)	**Height (cm)**	**Weight (kg)**	**Body fat (%)**	**Years**	**Days per week**
29.9 ± 5.9	1.75 ± 0.1	86.2 ± 9.6	18.7 ± 5.8	8.0 ± 5.0	5.2 ± 0.7

Values are expressed in mean ± SD

EXPERIMENTAL DESIGN OF THE STUDY

Figure 1 shows a general scheme of the experimental design of this study. Participants attended the local of the test five times, with three days in-between, to ensure recovery and to minimize a possible effect of a second window effect caused by IPC (BOLLI, 2000). The visits were always at the same time of the day. At first session, initial screening and anthropometric measurements, familiarization with the equipment and proceedings (e.g. perceptual scales), and the first 1-RM test were initially assessed. At 2nd and 3rd session, 1-RM test was performed. All subjects had no significant difference (p= 0,3679) at 1-RM score between 2nd and 3rd sessions (Table 2), meaning that three sessions were enough to minimize a potential learning effect or systematic bias and guarantee reliability test results (CRONIN; HENDERSON, 2004; PLOUTZ-SNYDER; GIAMIS, 2001; RITTI-DIAS et al., 2005). In the next two sessions the participants were randomly assigned into IPC or SHAM interventions in a counterbalanced randomized crossover design (Figure 1). Also, in order to prevent nocebo (negative) effects, the subjects were informed that IPC and SHAM would cause absolutely no harm, despite discomfort related to the maneuver. To prevent the possibility of a placebo (positive) effect, all subjects were informed that all conditions could improve performance (DE SOUZA et al., 2019; MAROCOLO et al., 2016a). Additionally, the 1-RM tester was blinded for which protocol the subjects had undergone before, being IPC or SHAM applied by another researcher at an isolated room (MAROCOLO et al., 2017).

VISUAL ANALOGUE SCALE AND PERCEIVED RECOVERY STATUS

To make sure that the participant was in the same recovery condition on trials, before each session, all subjects indicated a score on a visual analogue scale (VAS) and on a perceived recovery scale (PRS). The VAS, is presented as a 100-mm ruler, from 0 to 10, where 0 is absence of pain and 10 maximum pain (BIJUR; SILVER; GALLAGHER, 2001). The PRS (LAURENT et al., 2011), is a scale from 0 ”very little recovered, feeling extremely tired” to 10 ”very well recovered, feeling with great energy”. If the participant scored less than six, or two points less of the last session on PRS and more than four on VAS, he was invited to try to perform the test on next day.

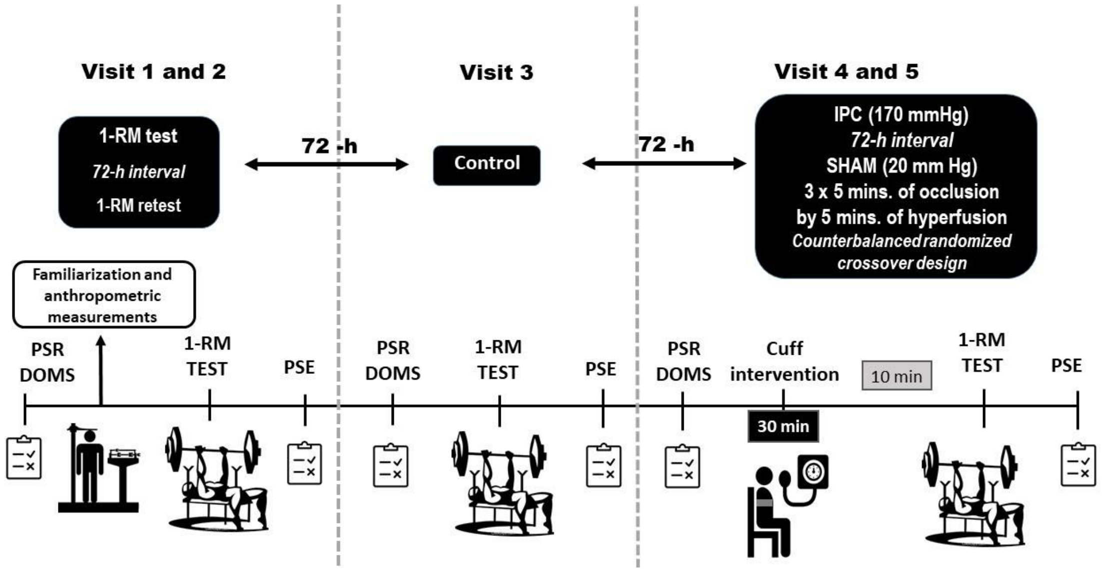

Fig.1 Experimental design of the study (N = 15). PSR = perceived recovery status; DOMS = delayed on-set muscle soreness; PSE = Perceptual of subjective effort; IPC = ischemic preconditioning; SHAM = placebo.

ISCHEMIC PRECONDITIONING PROTOCOLS (IPC)

The IPC maneuver consisted of three cycles of 5-min occlusion (170 mmHg) and 5-min reperfusion (no pressure) at the proximal area of both arms simultaneously (total duration 30 min), using a pneumatic tourniquet (ITS-MC 10x46cm, Novo Hamburgo, RS, Brazil) administered at the proximal area of the arms. In the SHAM protocol, an external pressure of 20 mmHg was administered, as proposed in previous studies (FOSTER et al., 2011; MAROCOLO et al., 2016a). This protocol has been demonstrated safe (GONZALEZ et al., 2014) and very explored by others IPC studies (CRUZ et al., 2015; JEAN-ST-MICHEL et al., 2011; MAROCOLO et al., 2016a; PATTERSON et al., 2015). 1-RM test was performed after 10 min of each intervention (i.e, IPC or SHAM).

TEST 1-RM

First participants performed ten repetitions using just the bar to review the procedures of the test. Then, after one-minute resting, they performed one set of eight repetitions with 50% 1-RM and after two minutes resting, one set of 3 repetitions with 75% 1-RM. After five minutes resting, they performed one repetition with 100% 1-RM. At next sets, always with five minutes of rest, one kilo was added to the bar until the participant could not perform properly the lift once, considering 1-RM the greatest load properly lifted by the participant. The test will follow the guidelines of the USA

Powerlifting Association (2019). To avoid muscle delayed soreness and fatigue, all participants were asked to follow an exercise protocol during the study (push, pull and legs, rest), taking the test at first on push days. Participants were informed to choose freely their exercises and training routine during the study.

MAXIMAL STRENGTH PERFORMANCE ATTEMPTS

On the sessions control (3rd visit) and randomly on 4th and 5th (IPC or SHAM) sessions the participants performed the Maximal strength performance attempts. After the warmup, the participants started with the 1RM test/retest values. If the participant lifted the 1RM load more than one repetition, the attempt was interrupted and he rested 5 min to attempt again with more 1 kg. Here there was no limit for maximal attempts. These sessions were interrupted when the participant did not lift the load once.

RATING OF PERCEIVED EXERTION (RPE)

Immediately after the 1-RM test, the participant indicated a score for his RPE via CR-10 Borg scale in order to determine the subjective intensity of the exercise. This scale ranges from 0 to 10, where 0 is “nothing at all” and 10 is “very very hard (maximal)” (LAGALLY et al., 2004).

STATISTICAL ANALYSIS

We verified the distribution of the data by the Shapiro–Wilk test. We applied a one-way analysis of variance (ANOVA) for repeated measures to check differences among interventions (IPC vs SHAM vs control), followed by post-hoc Tukey’s test. If the data were nonparametric, ANOVA (Friedman test) followed by a post-hoc Dunn’s test was performed. Only for the 1-RM values we calculated the effect size (ES; Cohen d) to determine the meaningfulness of the difference (practical relevance), classified as: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0) as recommended (Batterham & Hopkins, 2006). The significance level was set at 0.05. The software used for data analysis was GraphPad® (Prism 6.0, San Diego, CA, USA).

RESULTS

Table 2 shows the score of each group at the beginning of the session. There were no differences ($P > 0.05$) on the rating of perceived recovery status and perception of delayed onset muscle soreness on the maximal strength performance attempts.

Table 2 Variables of recovery at the beginning of the tests.

Variable	**Control**	**SHAM**	**IPC**	**p**
PRS	9.0 (1.0)	9.0 (1.0)	9.0 (1.0)	0.846
DOMS	1.0 (3.0)	1.0 (1.0)	1.0 (1.0)	0.312

N = 15; Data are median (interquartile interval: 75 – 25 percentile); PRS = perceived recovery status; DOMS = delayed on-set muscle soreness.

Table 3 shows individual maximum weight lifted at each session. There were no significant difference (p = 0.37) between the first three sessions, so 3rd session was considered control.

Table 3 Individual maximum weight lifted at each session.

PARTICIPANT	**SESSION 1**	**SESSION 2**	**SESSION 3**	**SHAM**	**IPC**
1	134	134	134	134	136 *
2	102	102	102	103	105 *
3	107	107	108	109	112 *
4	102	102	102	104 *	106 *
5	140	140	140	140	141
6	110	110	110	111	114 *
7	110	110	110	110	110
8	126	126	126	126	129 *
9	96	96	96	97	102 *
10	102	102	102	102	104 *
11	105	105	105	105	108 *
12	128	128	128	129	131 *
13	94	94	94	94	94
14	102	102	102	103	103
15	140	140	140	141	141

Note: SHAM = placebo; IPC = isquemic preconditioning;* = significant different compared to control.

Individual performance can also be seen on figure 2. We can note that 10 participants improved 1-RM on IPC and just one on SHAM condition. None participant in any condition decreased his performance.

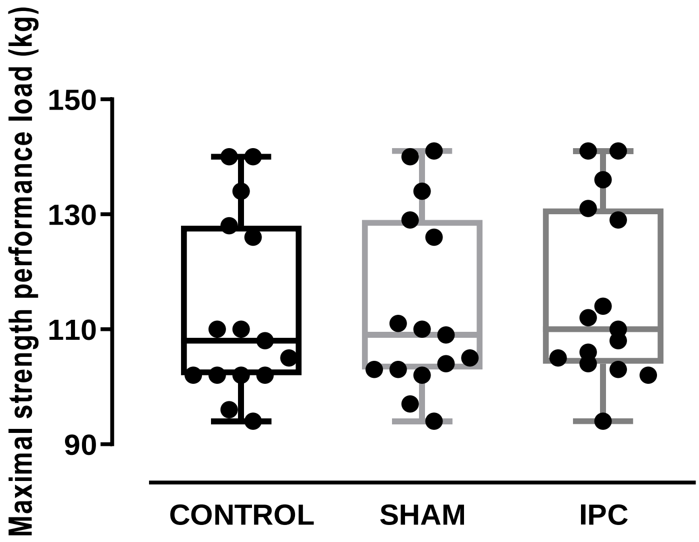

Figure 2: IPC presented higher load than CONTROL and SHAM (placebo). Dots are individuals values. Data are median and percentiles.

Table 4 shows that IPC group had a higher maximal strength performance load lifted in comparison with SHAM and control (Friedman test, p< 0.001). Also, IPC presented higher successful attempts beyond the control (SABC) and lower RPE compared to SHAM and CONTROL.

Table 4 – IPC promoted higher load and successful attempts beyond the control (SABC) on the maximal strength performance on bench press test and lower RPE than SHAM and control.

Variable	CONTROL	SHAM	IPC	P
1-RM	113.3 ± 15.9	113.9 ± 15.77	115.7 ± 15.55*	< 0.01
SABC**	-	1 (0-2)	3 (0-6)*	< 0.01
RPE	9	9	8*	< 0.01

Data are presented as mean ± standard deviation and [Lower - Upper confidence interval 95%]; n = 15 for all variables. IPC = ischemic preconditioning; SHAM = placebo; 1-RM = maximal strength performance load; SABC = successful attempts beyond the control; RPE = rating of perceived exertion.

DISCUSSION

The aim of this study was to evaluate the effect of IPC on 1-RM on bench press exercise and our main results was that IPC significantly improves the maximum voluntary dynamic force (2.2 ± 1.7%). This improvement on 1-RM is in accordance with studies showing the benefits of IPC (2-4%) in aerobic activities (CRISAFULLI et al., 2011; DE GROOT et al., 2010; JEAN-ST-MICHEL et al., 2011) and in time to failure tasks (~6%) (SALVADOR et al., 2016).

A lesser RPE was found after IPC condition (IPC = 8 and SHAM/Control = 9), meaning that at IPC participants felt a lesser subjective intensity of effort even performing the bench press with a higher load. The sum of the weight lifted by participants on IPC (1736 kg), was higher compared to SHAM (1708 kg) and CONTROL (1699 kg) conditions.

Individual performance is shown at figure 2. Ten participants of IPC had a significant improvement on performance and just one at SHAM. Consequently, the number of successful attempts beyond the control (SABC) was higher for IPC compared to SHAM (IPC = 3 [0-6], SHAM = 1 [0-2], $p<0.01$). At IPC one participant had five, four participants had three, four participants had two, one participant had one and five participants had zero SABC. At SHAM group just one participant had two more, seven participants had one and six participants had zero SABC. Maybe some participants were more responsive to IPC than others (MAROCOLO; BILLAUT; DA MOTA, 2018). Is also important to mention that neither IPC nor SHAM were detrimental to performance.

The level of recovery of the participants on the beginning of each session was important because they would perform a maximal test. As shown on table 3, the PRS and DOMS were not significant different between SHAM and IPC, inferring that all participants were tested at similar recovery states. Another worry of our group was about the 1-RM data. There is no consensus on literature (4–6) how many sessions are necessary to guarantee that a future increase on performance can be due to a period of familiarization to the test. However, as shown on table 4, there were no significant differences between 1-RM test sessions. So, 2-3 sessions were enough to calculate 1-RM on our participants.

A lesser RPE was found after IPC condition (IPC = 8 and SHAM/Control = 9). As first proposed by Crisafulli et al. (CRISAFULLI et al., 2011), this lesser RPE could have positively affected a complex mechanism on central nervous system known to control the skeletal muscle recruitment, increasing the neural drive and the number of motor units recruited, enhancing the performance (power output) of our participants. To test this hypothesis, in a study by Cruz et al. (CRUZ et al., 2015), 12 recreationally trained cyclists, performed an incremental test after IPC or SHAM. In short, an improvement of 8% after IPC was followed by an attenuation in the RPE ($p = 0.01$) and a progressive increase in the myoelectrical activity of the vastus lateralis muscle ($p = 0.04$), suggesting that this mechanism had a role on the ergogenic effects of IPC. However, this cannot be a consensus since Siegler et. al. didn´t found any effect of IPC on measures of torque, muscle contractility, or voluntary activation ad sEMG amplitude after three series of two minutes of sustained isometric leg extension (HALLEY; MARSHALL; SIEGLER, 2018) or one 135 maximal isokinetic knee extension (HALLEY; MARSHALL; SIEGLER, 2019). It is important to note that, differently of previous studies with longer periods of muscle contraction, our used a more short and explosive exercise, where could be better benefited from a possible utilization of a higher fraction of the skeletal muscle recruitment.

Although, to elucidate the mechanisms of IPC was not a goal of our study, we can speculate that some metabolics and hemodynamics responses were valuable mechanisms to improve the performance of our participants. For instance, in a study, Paradis-Deschênes (PARADIS-DESCHÊNES; JOANISSE; BILLAUT, 2016) investigated the effects of IPC on muscle haemodynamics and O2 uptake during repeated maximal contractions. Ten strength-trained men performed five sets of five maximal voluntary knee extensions of the right leg on an isokinetic dynamometer, preceded by either IPC of the right lower limb (3×5-min compression/5-min reperfusion cycles at 200 mm Hg) or sham (20 mm Hg). During exercise, peak force was almost certainly higher (11.8%; ES, 0.37; 0.27, 0.47), average force was very likely higher (12.6%; ES, 0.47; 0.29, 0.66), and average muscle O2 uptake was possibly increased (15.8%;ES,0.36;–0.07,0.79) after IPC. In the recovery periods between contractions, IPC also increased blood volume after sets 1 (23.6%; ES, 0.30; –0.05, 0.65) and 5 (25.1%; ES, 0.32; 0.09, 0.55). Blood volume at rest also increased (23%-46% higher blood volume in IPC compared with SHAM), contributing to the improvement of performance since skeletal muscle perfusion influences the development of peripheral muscle fatigue. This increased blood volume possibly accelerated ATP and phosphocreatine repletion, and probably increased the athlete recovery between sets (BILLAUT; BUCHHEIT, 2013). IPC has shown to blunts exercise-induced muscle damage and pain while maintaining the contractile properties of the muscle, before a bout of eccentric exercise of the elbow flexors (3x10 at 80% 1-RM) (FRANZ et al., 2018).

Bench press exercise (BPE) is a multi-joint exercise, where pectoralis major (PM) and triceps brachii (TB) are the principal muscles involved, with similar activity during the BPE (STASTNY et al., 2017). Protective effects against ischemia-reperfusion injury can be obtained by local or remote IPC (BARBOSA et al., 2015; MAROCOLO et al., 2016c), in this case, BPE could be affected by IPC locally on TB, since we applied IPC on both arms and/or remotely (e.g., cellular, neural, and humoral mechanisms) on PM and other muscles involved on the task and systemic variables as we can see on the drop of the RPE on IPC condition. For instance, in a study conducted by our group (MAROCOLO et al., 2016c), IPC was applied on legs or arms before an elbow flexion exercise (at scott machine) on different days, and increased performance locally (14.1±2.5 repetitions) and remotely (14.3±2.2). Interestingly, the number of repetitions significantly increased for both IPC and SHAM conditions. Similar results were found in another study conducted by our group (MAROCOLO et al., 2016a). The effect of local IPC was evaluated before a resistance exercise performance (three sets with 12-RM load) in the lower limbs. Interestingly, the number of repetitions significantly increased for both the IPC (13.08) and PLACEBO (13.15) conditions, but not for the CON (11.88) condition. Some authors have demonstrate some worry about the pressure applied on SHAM condition (20 mm Hg) because even lower pressures as ~15 mm Hg at arms could induce a ~30% redution in blood flow (MOUSER et al., 2018), or just induce a placebo effect and maybe triggering some performance benefits similar to the IPC condition (MAROCOLO et al., 2016a). However, at this study, SHAM procedure were not enough to improve performance, neither by the pressure applied, nor by motivation or a placebo effect.

CONCLUSION

IPC improves load on 1-RM test and reduces perceived effort of male recreational resistance trained individuals. Such evidence suggests an ergogenic effect of IPC for using in competitions involving repeated maximal strength output.

PRACTICAL APPLICATIONS

Our data support the use of IPC as an ergogenic aid to 1-RM on bench press exercise in recreational participants. The magnitude of the benefits from IPC to strength performance in the current study may seem small, i.e., IPC increased ~2.4 kg (~2.12%) vs. control condition. However, coaches and athletes know that in strength competitions “only” 1 kg may be decisive. Therefore, we recommend IPC application before competitions or training sessions demanding repeated maximal strength performance. Our data showed that most participants benefited from IPC (10 out of 15 performed better after IPC). Even so, we suggest individual evaluation once the effects might be worthwhile more or less depending on the unique characteristic.

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3 FINAL CONSIDERATIONS

The first study shows that ischemic preconditioning (IPC) does not influence the maximum intermittent performance and physiological/perceptual indicators, even combining with specific light (i.e., not passive IPC). We highlight our unique protocol of performing some exercise during the reperfusion phase. Although we did not find benefits, we also did not find negative effects. Future studies should refine such active protocol to check whether it can be helpful in other types of performance or exercise settings.

On the second article/study, IPC demonstrated promising results when applied ten minutes prior to a maximum dynamic strength performance in the bench press exercise, increasing the maximum load lifted, as well as a lower perception of effort. Interestingly, the placebo condition had no improvement in performance, contrary to some papers reporting positive results from IPC due to a placebo effect. The use of near-infrared spectroscopy, muscle eletromyography and pre-post muscle sample biopsies to monitor a possible increase on muscle blood volume and oxygenation, mucle activity and on ATP/PCr concentration, could help future researchs to clarify possible mechanisms underlying performance improvement after IPC.

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APPENDIX

APPENDIX I – TCLE ARTICLE 1

Título do Projeto: <u>Efeito do pré-condicionamento isquêmico ativo na capacidade aeróbia de alta intensidade.</u>

TERMO DE ESCLARECIMENTO

O senhor (a)/ seu filho (a), classificado como atleta está sendo convidado (a) a participar do estudo intitulado: "**EFEITO DO PRÉ-CONDICIONAMENTO ISQUÊMICO ATIVO NA CAPACIDADE AERÓBIA DE ALTA INTENSIDADE"**, porque queremos descobrir qual estratégia é mais eficaz nessa categoria. Os avanços na área das ciências do esporte ocorrem através de estudos como este, por isso a participação do (a) senhor (a) é importante. O objetivo do estudo é verificar o efeito de quatro protocolos de pré-condicionamento isquêmico (PCI) com diferentes pressões no desempenho do YoYo-Interminetent Recovery Test 1 (YYIRT1), um teste para medir a capacidade aeróbia e que possui uma boa correlação com o desempenho dos atletas em jogos. Caso o (a) senhor (a)/ seu (sua) filho (a) participe, serão necessários cinco encontros, com o mínimo de 3-7 dias de intervalo entre eles. Cada encontro não durará mais do que 60 minutos. A primeira sessão será para preenchimento de documentos éticos, mensuração de massa/estatura corporal e realização de familiarização com os procedimentos. Na sessão de familiarização, coletaremos informações gerais como data de nascimento e tempo de contato com a modalidade, bem como mensuraremos a massa e a estatura corporal. Na sequência, os participantes receberão explicações sobre os equipamentos, os testes e as escalas de percepção de recuperação, dor muscular de início tardio e de esforço. Logo após, irão realizar o YYIRT1. Esta sessão de familiarização servirá para enfatizar os procedimentos da pesquisa em si, como o PCI, no qual as coxas serão envolvidas com um torniquete que irá pressioná-las por algum tempo. Será sempre realizado um protocolo diferente de pré-condicionamento isquêmico previamente ao YYIRT1 nas próximas sessões.

Não será feito nenhum procedimento que traga qualquer risco à vida do (a) senhor (a)/ seu (sua) filho (a). Haverá pequenos desconfortos quando receber uma picada para colher o sangue do seu dedo e durante o momento de oclusão do PCI.

Você poderá obter todas as informações que quiser e poderá ou não participar da pesquisa; o seu consentimento poderá ser retirado a qualquer momento, sem prejuízo no seu atendimento. Pela participação do (a) senhor (a)/ seu (sua) filho (a) no estudo, você (nem seu filho – para atletas menores de idade) receberão qualquer valor em dinheiro, mas haverá a garantia de que todas as despesas necessárias para a realização da pesquisa não serão de sua responsabilidade. O seu nome/ de seu (sua) filho (a) não aparecerá em qualquer momento do estudo, pois será identificado (a) por um número ou por uma letra ou outro código.

TERMO DE CONSENTIMENTO LIVRE, APÓS ESCLARECIMENTO

Título do Projeto: Efeito do pré-condicionamento isquêmico ativo na capacidade aeróbia de alta intensidade.

Eu, ____, li e/ou ouvi o esclarecimento acima e compreendi para que serve o estudo e qual procedimento ao qual eu/ o atleta sob minha responsabilidade será submetida(o). A explicação que recebi esclarece os riscos e benefícios do estudo. Eu entendi que eu/ o atleta sob minha responsabilidade somos livres para interromper a participação na pesquisa a qualquer momento, sem justificar a decisão tomada e que isso não afetará o meu tratamento/ dele (ou dela). Sei que o meu nome/ do atleta não será divulgado, que não teremos despesas e não receberemos dinheiro por participar do estudo. Eu concordo com a minha participação/ do (a) meu (minha) filho (a) no estudo (desde que ele também concorde). Por isso eu assino este Termo de Consentimento (juntamente com o (a) filho (a) quando o atleta for menor de idade).

Uberaba, .../ ..../................

____

____

Assinatura do responsável legal — Documento de Identidade

______________________________________ ______________________________

Assinatura do menor (caso ele possa assinar) — Documento de Identidade (se possuir)

____

Assinatura do pesquisador orientador

Telefones de contato dos pesquisadores responsáveis:

Prof. Dr. Gustavo R. da Mota (34) 9102-1577 ou (34) 3318-5964/3318-5973

Prof. Anderson Luiz Rodrigues (16) 98182-5899 ou (16) 3324-2943

Em caso de dúvida em relação a este documento, você poderá entrar em contato com o Comitê Ética em Pesquisa – CEP da Universidade Federal do Triângulo Mineiro, pelo telefone 3318-5854.

APPENDIX II – TCLE ARTICLE 2

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Convidamos você a participar da pesquisa: "Efeitos do pré-condicionamento isquêmico sobre a força máxima no exercício supino reto". O objetivo desta pesquisa é avaliar o efeito do pré-condicionamento isquêmico realizado previamente a um teste de força no exercício supino reto sobre a força máxima e a intensidade subjetiva de esforço.

Sua participação é importante, pois irá contribuir com a ciência do exercício físico, especificamente, sobre um possível recurso ergogênico para o desempenho da força máxima.

Caso você aceite participar desta pesquisa será necessário responder alguns questionários e realizar pelo menos cinco testes de força no supino reto a cada 3 dias.

Os riscos desta pesquisa são mínimos e consideráveis apenas os riscos normais a um teste de força máxima, como lesões musculares, dor muscular tardia e dores articulares. Porém, devido ao seu nível de treinamento e aos cuidados tomados durante os testes, garanto que os riscos serão minimizados.

Ao final da pesquisa, você e seu instrutor receberão os resultados de todos os testes realizados, assim como, orientações de possíveis mudanças visando melhorar sua *performance* e saúde em geral. Você ainda poderá tirar dúvidas quando quiser e obter esclarecimento sobre os resultados dos testes e interpretação dos mesmos.

Você poderá obter quaisquer informações relacionadas à sua participação nesta pesquisa, a qualquer momento que desejar, por meio dos pesquisadores do estudo. Sua participação é voluntária, e em decorrência dela você não receberá qualquer valor em dinheiro. Você não terá nenhum gasto por participar nesse estudo, pois todos os testes inclusos na pesquisa serão realizados gratuitamente.

Você poderá não participar do estudo, ou se retirar a qualquer momento, sem que haja qualquer constrangimento junto aos pesquisadores, bastando você dizer ao pesquisador que lhe entregou este documento. Você não será identificado neste estudo, pois a sua identidade será identificada por número, sendo garantido o seu sigilo e privacidade.

Em caso de dúvida em relação a esse documento, favor entrar em contato com o Comitê de Ética em Pesquisa da Universidade Federal do Triângulo Mineiro, pelo telefone (34) 3700-6803, ou no endereço Rua Conde Prados, 191, Bairro Nossa Senhora da Abadia – Uberaba – MG – de segunda a sexta-feira, das 08:00 às 11:30 e das 13:00 às 17:30. Os Comitês de Ética em Pesquisa são colegiados criados para defender os interesses dos participantes de pesquisas, quanto a sua integridade e dignidade, e contribuir no desenvolvimento das .

CONSENTIMENTO LIVRE, APÓS ESCLARECIMENTO

TÍTULO DA PESQUISA: Efeitos do pré-condicionamento isquêmico sobre a força máxima no exercício supino reto.

Eu,____, li e/ou ouvi o esclarecimento acima e compreendi para que serve o estudo e a quais procedimentos serei submetido. A explicação que recebi esclarece os riscos e benefícios do estudo.

Eu entendi que sou livre para interromper minha participação a qualquer momento, sem justificar minha decisão e que isso talvez afete nas avaliações finais que poderei receber. Sei que meu nome não será divulgado, que não terei despesas e não receberei dinheiro para participar do estudo. Concordo em participar do estudo**,** “Efeitos do pré-condicionamento isquêmico sobre a força máxima no exercício supino reto”, e receberei uma via assinada deste documento.

Uberaba, .../ ..../..............

____

Assinatura do participante

____________________________________ ____________________________________

Assinatura do pesquisador responsável Assinatura do pesquisador assistente

Telefones de contato dos pesquisadores responsáveis:

Prof. Dr. Gustavo R. da Mota (34) 9102-1577 ou (34) 3318-5964/3318-5973

Prof. Anderson Luiz Rodrigues (16) 98182-5899 ou (16) 3324-2943

APPENDIX III – ANAMNESIS ARTICLE 2

MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DO TRIÂNGULO MINEIRO

Efeito do pré-condicionamento isquêmico sobre a força máxima no supino reto.

Nome:

Data de Nasc.:

Tempo de treinamento (anos):

Frequência semanal de treino (últimos 6 meses):

Peso:

Altura:

%G:

Hábitos de Consumo

TABACO? ( )NÃO – ( )SIM   Bebidas Alcoólicas? ( )NÃO – ( )SIM: _______VEZES POR SEMANA

Suplementos alimentares: ( )NÃO – ( )SIM:____

Drogas com efeitos ergogênicos: ( ) NÃO – ( ) SIM:____

História Patológica Alguma dor? ( )NÃO - ( )SIM:____

Possui alguma dessas enfermidades?

Hipertensão arterial ( )   Doenças cardiorrespiratórias ( ) Trombose venosa profunda ( ) Doenças metabólicas ( )   Insuficiência Vascular Periférica ( ) Problemas de coagulação do sangue ( ) Outra ( ) Qual?____

Histórico familiar com essas enfermidades?

Doenças cardiorrespiratórias ( ) Trombose ( ) Insuficiência Vascular Periférica( ) Outras doenças vasculares? _____________________

Medicações contínuas: ( ) NÃO – ( )SIM: ____

Compreendi e respondi este questionário. Todas as dúvidas que eu tinha foram respondidas de uma maneira plenamente satisfatória. Todas as respostas são verdadeiras.

Uberaba, _____ de _____________ de _____

____

Assinatura do participante

APPENDIX IV – ANAMNESIS ARTICLE 1

MINISTÉRIO DA EDUCAÇÃO
UNIVERSIDADE FEDERAL DO TRIÂNGULO MINEIRO

Traditional and active isquemic pré-conditioning effects on high-intensity intermittent exercise

Nome:

Data de Nasc.:

Tempo de treinamento (anos):

Peso:

Altura:

%G:

Hábitos de Consumo

TABACO? ( )NÃO – ( )SIM   Bebidas Alcoólicas? ( )NÃO – ( )SIM: _______VEZES POR SEMANA

Suplementos alimentares: ( )NÃO – ( )SIM:____

Drogas com efeitos ergogênicos: ( ) NÃO – ( ) SIM:____

História Patológica Alguma dor? ( )NÃO - ( )SIM:____

Possui alguma dessas enfermidades?

Hipertensão arterial ( ) Doenças cardiorrespiratórias ( ) Trombose venosa profunda ( ) Doenças metabólicas ( ) Insuficiência Vascular Periférica ( ) Problemas de coagulação do sangue ( ) Outra ( ) Qual?____

Histórico familiar com essas enfermidades?

Doenças cardiorrespiratórias ( ) Trombose ( ) Insuficiência Vascular Periférica( ) Outras doenças vasculares? _____________________

Medicações contínuas: ( ) NÃO – ( )SIM: ____

Compreendi e respondi este questionário. Todas as dúvidas que eu tinha foram respondidas de uma maneira plenamente satisfatória. Todas as respostas são verdadeiras.

Uberaba, _____ de _____________ de _____

____

Assinatura do participante

APPENDIX V – PARECER CONSUBSTACIADO DO CEP

UNIVERSIDADE FEDERAL DO TRIÂNGULO MINEIRO - MG

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: ESTRATÉGIAS DE POTENCIALIZAÇÃO E RECUPERAÇÃO DO DESEMPENHO EM DIFERENTES POPULAÇÕES

Pesquisador: GUSTAVO RIBEIRO DA MOTA

Área Temática:

Versão: 3

CAAE: 33413214.1.0000.5154

Instituição Proponente: Universidade Federal do Triângulo Mineiro - MG

Patrocinador Principal: Universidade Federal do Triangulo Mineiro

DADOS DO PARECER

Número do Parecer: 993.636

Data da Relatoria: 13/03/2015

Conclusões ou Pendências e Lista de Inadequações:

De acordo com as atribuições definidas na Resolução CNS 466/12, o CEP-UFTM manifesta-se pela aprovação do protocolo de pesquisa proposto.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

ATTACHMENTS

ATTACHMENT I – PERCEPTUAL SCALES

VISUAL ANALOGUE SCALE OF PAIN

Perceived Recovery Status Scale

TAXA	Descrição
0	Nenhuma recuperação
1	Muito pouca recuperação
2	Pouca recuperação
3	Recuperação Moderada
4	Boa Recuperação
5	Muito boa recuperação
6	
7	Muito, muito boa recuperação
8	
9	
10	Totalmente recuperado

Rate of perceived exertion scale

ESCALA DE BORG ADAPTADA PERCEPÇÃO DE ESFORÇO	
0	REPOUSO
1	DEMASIADO LEVE
2	MUITO LEVE
3	MUITO LEVE-LEVE
4	LEVE
5	LEVE-MODERADO
6	MODERADO
7	MODERADO-INTENSO
8	INTENSO
9	MUITO INTENSO
10	EXAUSTIVO

ATTACHMENT II – JOURNALS

European journal of sport Science

Preparing Your Paper -Original Investigation

- Should be written with the following elements in the following order: title page; abstract; keywords; main text introduction, materials and methods, results, discussion; acknowledgments; declaration of interest statement; references; appendices (as appropriate); table(s) with caption(s) (on individual pages); figures; figure captions (as a list)
- Should be no more than 4000 words.
- Should contain an unstructured abstract of 250 words.
- Should contain between 3 and 6 **keywords**. Read making your article more discoverable, including information on choosing a title and search engine optimization.
- There should be no more than 40 references, and no more than 4 tables and figures.

Format-Free Submission

Authors may submit their paper in any scholarly format or layout. Manuscripts may be supplied as single or multiple files. These can be Word, rich text format (rtf), open document format (odt), or PDF files. Figures and tables can be placed within the text or submitted as separate documents. Figures should be of sufficient resolution to enable refereeing.

- There are no strict formatting requirements, but all manuscripts must contain the essential elements needed to evaluate a manuscript: abstract, author affiliation, figures, tables, funder information, and references. Further details may be requested upon acceptance.
- References can be in any style or format, so long as a consistent scholarly citation format is applied. Author name(s), journal or book title, article or chapter title, year of publication, volume and issue (where appropriate) and page numbers are essential. All bibliographic entries must contain a corresponding in-text citation. The addition of DOI (Digital Object Identifier) numbers is recommended but not essential.
- The journal reference style will be applied to the paper post-acceptance by Taylor & Francis.
- Spelling can be US or UK English so long as usage is consistent.

Note that, regardless of the file format of the original submission, an editable version of the article must be supplied at the revision stage.

Journal of strenth and conditioning research (Impact factor = 2.340)

Due to the large amount of information for the submission of the article, I took the liberty of offering the link for the consultation: http://edmgr.ovid.com/jscr/accounts/ifauth.htm - access 24/06/2020 at 9:56 p.m.

ATTACHMENT III – Abstract´s oral presentation on international congress.

Efeito de exercício prévio específico sobre o desempenho intermitente máximo e indicadores fisiológicos em jovens basquetebolistas

O objetivo deste estudo foi verificar o efeito de exercício prévio específico sobre o desempenho intermitente máximo e indicadores fisiológicos em jovens basquetebolistas. Nove jogadores de basquetebol (homens, massa corporal 67,5 ± 4 kg, altura 176,4 ± 4 cm, idade 16,2 ± 1,4 anos), realizaram de maneira randomizada e cruzada (1 semana entre as sessões) o YO-YO Intermittent Recovery Test 1 (YO-YO IR1) com (YOYO A) e sem (YOYO P) um protocolo específico de aquecimento antes do teste. Na sessão com aquecimento (YOYO A), os jogadores realizavam um protocolo de aquecimento utilizando os primeiros três níveis do YO-YOIR1, repetidos três vezes, com intensidade de 70% FC máxima e na sessão YOYO P iniciavam o teste sem aquecimento. Foram registrados a distância máxima percorrida (DMP), a frequência cardíaca máxima (FCMx) e a frequência cardíaca média (FCM), a percepção subjetiva de recuperação (PSR) e o lactato sanguíneo (LAC). Somente DMP (982±211,77 contra 1008,89±220,71; p=0,499) e PSREC (9,11±1,45 contra 9,00±1,12; p=0,728), não foram diferentes entre os grupos YOYOA e YOYOP respectivamente. Em todas as outras variáveis, FCMx (199,11±9,49 contra 191,44±7,18; p= 0,007), FCM (183,67±10,01 contra 177,84±7,18; p=0,006) e LAC (11,97±4,32 contra 9,19±1,77; p=0,035), a sessão YOYOA apresentou valores maiores que YOYOP (p <0,05). Estes resultados mostram que a realização deste protocolo de aquecimento pode ser prejudicial à performance no YO-YO IR1.

CONFIRA A AUTENTICIDADE DESTE CERTIFICADO
www.portalrealize.com.br

CERTIFICADO

Certificamos que o trabalho intitulado: "EFEITO DE EXERCÍCIO PRÉVIO ESPECÍFICO SOBRE O DESEMPENHO INTERMITENTE EM BASQUETEBOLISTAS." do(s) autor(es): ANDERSON LUIZ RODRIGUES, foi apresentado na modalidade Tema Livre (TL) no XI Congresso Internacional de Educação Física e Motricidade Humana e XVII Simpósio Paulista de Educação Física, evento realizado no Instituto de Biociências - Universidade Estadual Paulista - Campus de Rio Claro na cidade de Rio Claro - São Paulo, no período de 19 a 22 de Junho de 2019.

Identificador: 0d909894929297da5a721cbad79207cc

Rio Claro - São Paulo, 22 de Junho de 2019.

Prof. Dr. José Angelo Barela - UNESP
Presidente do XI CIEFMH e XVII SPEF
Instituto de Biociências - UNESP - Rio Claro

Prof. Dr. Carlos Alberto Anaruma - UNESP
Chefe do Depto de Educação Física
Instituto de Biociências - UNESP - Rio Claro

PROGRAMA

EIXO TEMÁTICO - AT 02: Biodinâmica do rendimento e treinamento esportivo:

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