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Artigo

COMPARISON OF THE EFFECTIVENESS OF INTERMITTENT PNEUMATIC COMPRESSION, COLD WATER IMMERSION, AND A PASSIVE PROTOCOL IN THE RECOVERY OF MUSCLE DAMAGE INDUCED BY PLYOMETRIC EXERCISE

COMPARATIVO DO EFEITO DA COMPRESSÃO PNEUMÁTICA INTERMITENTE, CRIOIMERSÃO CORPORAL E RECUPERAÇÃO PASSIVA NA RECUPERAÇÃO DO DANO MUSCULAR INDUZIDO POR EXERCÍCIO PLIOMÉTRICO

COMPARATIVO DEL EFECTO DE LA COMPRESIÓN NEUMÁTICA INTERMITENTE, CRIOINMERSIÓN CORPORAL Y RECUPERACIÓN PASIVA SOBRE LA RECUPERACIÓN DEL DAÑO MUSCULAR INDUCIDO POR EL EJERCICIO PLIOMÉTRICO

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ABSTRACT: Introduction: Muscle fatigue is recognized as one of the causes of injury in sports. Recovery methods are frequently used by sports teams. However, research into the effectiveness of such methods remains limited. Methods: Eleven recreational athletes participated. The study lasted four weeks; the first was dedicated to familiarization, and the last three weeks were to follow-up. Volunteers performed bout of 100 drop jumps, followed by intermittent pneumatic compression (IPC), cold water immersion (CWI), or passive recovery; each method performed in a different week. Variables included were triple horizontal jump (THJ), serum creatine kinase (CK), and muscle soreness; and were registered before, 24, 48, and 72 hours after exercise. Results: Although muscle soreness normalized after 48 hours with the IPC ($p = 0.18$), it remained altered after 72 hours with the CWI and passive recovery ($p = 0.01$ and $p = 0.01$, respectively). With regards to the CK, normalization was observed within 48 hours of CWI ($p = 0.31$), while the IPC and passive resulted in normalization after 72 hours ($p = 0.14$ and $p = 0.22$, respectively). In relation to the THJ, normalization was observed within 48 hours of CWI ($p = 0.25$), 72 hours after the passive method ($p = 0.21$), and showed late reduction with IPC, after 72 hours ($p = 0.01$). Conclusion: objective variables demonstrated better results with the use of CWI.

KEYWORDS: recovery of function, post-exercise recovery techniques, cryotherapy, athletic injuries, sports.



RESUMO: Introdução: A fadiga muscular é apontada como uma das principais causas de lesão no esporte. Métodos de recuperação pós exercício são adotados por diferentes profissionais. Entretanto, o conhecimento sobre o efeito desses métodos é limitado. Métodos: 11 atletas recreacionais foram estudados por 4 semanas. Na primeira semana ocorreu a familiarização; e nas últimas três a coleta dos dados. Os voluntários realizaram uma série de 100 drop jumps, seguido de um dos métodos: compressão pneumática intermitente (CPI), crioterapia ou protocolo passivo, cada método em uma semana. As variáveis foram: salto triplo horizontal (STH), creatina quinase plasmática (CK) e dor muscular, avaliadas em 24, 48 e 72 horas após o exercício. Resultados: a dor muscular normalizou após 48 horas com CPI ($p = 0.18$) e permaneceu alterada após 72 horas com crioterapia ou passivo ($p = 0.01$ e $p = 0.01$). Sobre a CK, normalização foi observada em 48 horas com crioterapia ($p = 0.31$), e CPI e passivo normalizaram após 72 horas ($p = 0.14$ e $p = 0.22$). No STH a normalização foi observada em 48 horas com crioterapia ($p = 0.25$), 72 horas com passivo ($p = 0.21$), e permaneceu alterado em 72 horas com CPI ($p = 0.01$). Conclusão: As variáveis objetivas avaliadas demonstraram melhor efeito de recuperação após a crioterapia.

PALAVRAS-CHAVE: recuperação da função fisiológica, técnicas de recuperação após exercício, crioterapia, traumatismos em atletas, esportes.

RESUMEN: Introducción: La fatiga muscular es reconocida como una de las causas de lesión en el deporte. Los equipos deportivos utilizan con frecuencia métodos de recuperación. Sin embargo, la investigación sobre la eficacia de estos métodos sigue siendo limitada. Métodos: Participaron once deportistas recreativos. El estudio duró cuatro semanas; la primera estuvo dedicada a la familiarización y las últimas tres semanas fueron de seguimiento. Los voluntarios realizaron una serie de 100 saltos, seguidos de compresión neumática intermitente (IPC), inmersión en agua fría (CWI) o recuperación pasiva; cada método realizado en una semana diferente. Las variables incluidas fueron triple salto horizontal (THJ), creatina quinasa sérica (CK) y dolor muscular; y se registraron antes, 24, 48 y 72 horas después del ejercicio. Resultados: Aunque el dolor muscular se normalizó después de 48 horas con el IPC ($p = 0,18$), permaneció alterado después de 72 horas con el CWI y la recuperación pasiva ($p = 0,01$ y $p = 0,01$, respectivamente). Con respecto a la CK, la normalización se observó dentro de las 48 horas posteriores a la CWI ($p = 0,31$), mientras que la IPC y la pasiva resultaron en normalización después de 72 horas ($p = 0,14$ y $p = 0,22$, respectivamente). En relación al THJ, la normalización se observó dentro de las 48 horas posteriores al CWI ($p = 0,25$), 72 horas después del método pasivo ($p = 0,21$), y mostró reducción tardía con IPC, después de las 72 horas ($p = 0,01$).



Conclusión: las variables objetivas demostraron mejores resultados con el uso de CWI.

PALABRAS CLAVE: recuperación de función, técnicas de recuperación post-ejercicio, crioterapia, lesiones atléticas, deportes.



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1. Introduction

The benefits of regular physical activity are well recognized by many varied research studies (Fox,1999). However, in professional sports, when physical demands increase to heighten performance, the risk of musculoskeletal injury (MI) increases proportionally. Considering football as an example, Silva *et al.* (2008) observed that 100% of athletes presented with at least one MI per season and that three out of four athletes presented with at least two injuries. Furthermore, striking founds from a recent epidemiologic study reported that, in a single season, 1293 MI injuries in 427 Spanish first division football athletes (approximately three MI per athlete) were registered (Salces *et al.*, 2014). Moreover, the available literature provides epidemiologic information regarding base football categories: 78% of athletes investigated by Ribeiro *et al.*, (2007) presented with a MI during a single season, with a mean of 2.36 MI per athlete, while more than half of these injuries resulted in withdrawal from participation.

It is postulated that muscle strains are the most prevalent form of MI in football players (approximately 40% of all MI), and that the most frequent mechanism of injury occurs without contact (Cohen *et al*, 1997). Furthermore, the risk of injury is increased in the second half of the match, this is proportional to the reduction in eccentric muscle capacity due to acute fatigue resulting from the intense exercise required in football (Greig and



Siegler, 2009). Such injuries are also more frequent in the middle of the season, considering that the interval between matches is frequently reduced during this period (Silva *et al*, 2008, and SALCES *et al*, 2014).

A study that included the opinions of doctors from national football teams participating in the FIFA world cup 2014, indicated that accumulated fatigue is the second most common cause of MI (Mccall *et al*, 2015).

Fatigue is defined as a tired sensation, and acute reduced muscle function; these symptoms are related to progressive increases in physical load, when the objective is adaptation to stress and improvement in physical performance (Versey and Halson, 2013). The accumulation of fatigue during a season can last for days or weeks, while continued physical stress, as a result of fatigue, increases the risk of muscle injury and consequent absence from training and competition (Versey and Halson, 2013). The risk of structural injury to muscle increases with continued exercise; this is concomitant to a high proportion of microtrauma to muscle tissue which occurs due to physical exercises with eccentric characteristics and consequent local inflammation and oxidative stress (Cruzat *et al*, 2007).

The proportion of muscle-microtrauma caused by eccentric contraction is well recognized, indeed, this type of muscle action has been utilized in experimental studies to induce muscle-microtrauma and verify the effectiveness of subsequent recovery methods (Cochrane *et al*, 2013). Plyometric exercises have also been used with the same objective (Loturco *et al*, 2016). In these studies, biochemical variables, such as serum kinase creatine concentration (CK) (Cochrane *et al*, 2013), physical performance (Hauswirth *et al*, 2011), and muscle pain (Bailey *et al*, 2007), have been investigated in order to measure the proportion of micro-damage to muscle tissue following physical exercise.

When considering fatigue as a relevant cause of MI in sport, medical and physical training staff have adopted several methods to enable rapid muscle recovery and, consequently, minimize the risk of MI related to



accumulated fatigue [8]. Physiologically, the objective of such recovery methods is to minimize the acute loss of muscle capacity to produce force after mechanical damage to muscle cells, to minimize secondary damage caused by hypoxia, and to minimize the inflammatory process and the accumulation of metabolites (Glasgow *et al*, 2014).

The following recovery methods are among the most commonly used in sport: whole body exposure to very cold air and far infrared radiation (Hauswirth *et al*, 2011), intermittent pneumatic compression (IPC) (Cochrane and Booker, 2014), cold water immersion (CWI) (Bailey *et al*, 2007), massage (Best *et al*, 2008), and self-use of a foam roller (Pearcey *et al*, 2015).

Despite the wide range of recovery methods reported in the literature and used in clinical practice, there is a lack of studies comparing the effectiveness of different methods in the recovery of muscle fatigue induced by intense physical exercise. Studies with the purpose of evaluating the effectiveness of recovery methods usually compare results from an intervention protocol to results from a passive protocol (Bailey *et al*, 2007, Howatson *et al*, 2009). Studies may also compare the results from different protocols using the same resource but changing one variable, in the case of CWI, time application or water temperature (Glasgow *et al*, 2014). To the best of our knowledge, no study has compared the effectiveness of CWI and IPC in the recovery of exercise-induced fatigue.

Thus, the objective of this study was to determine whether a CWI protocol and IPC protocol promote similar patterns of recovery compared to a passive recovery protocol. To this end, several variables were analysed following the induction of muscle damage by lower limb plyometric bout, these included: physical performance, serum CK concentration, and muscle soreness. We also aimed to determine whether there was a superior protocol (CWI or IPC) in terms of the muscle recovery.



2 Material and Methods

2.1 Participants

Eleven male recreational football players were invited, and accepted, to participate in the study. Participants were aged between 18 and 29 years old, mean 22.7 ± 3.4 years, with a mean body mass of 76.2 ± 11.5 kg and a mean height of 174 ± 0.4 cm. Inclusion criteria were as follows: healthy, no MI, able to perform the physical exercise protocol proposed by the current study, and no intake of drugs or supplements within the last six months. The study sample size was based on previous studies with similar intervention models (Cochrane *et al*, 2013, Ingram *et al*, 2009).

Data were collected between September and October 2017, in the school physiotherapy outpatient clinic at Centro Universitário de Jaguariúna, located in Jaguariúna, São Paulo, Brazil.

2.2 Study Design

The study period lasted four weeks. The first week was dedicated to familiarization and in the following three weeks, volunteers were asked to perform a physical exercise protocol which was followed by passive recovery, CWI, or IPC. Each recovery method was adopted in a different week by all the study participants and the recovery method to be used in a given week was defined by random. Volunteers were not blinded to the intervention and they were asked to maintain their usual eating routine and not perform any additional physical exercises during the study period.



2.3 Questionnaire

Prior to the physical exercise protocol all participants answered a questionnaire composed by demographic and physical activity experience data. Moreover, data regarding previous health status (diseases and MI) and the intake of anti-inflammatory drugs and nutritional supplements were also registered in order to avoid any bias in the results.

2.4 Familiarization

During the first week, all volunteers were informed about the study procedures and performed the bout of plyometric exercises for familiarization. The protocol phases were as follows:

Warm-up: The warm-up was performed for 5 minutes on a cycle ergometer. Volunteers were asked to cycle at a moderate speed, sufficient to feel warmed up but not tired.

Triple horizontal jump (THJ): This performance test was chosen to reflect the similarity in plyometric muscle action and mechanism to the exercise protocol; such a test has been previously adopted by Cochrane and Booker (2014). The participants were asked to position their feet in a parallel position, in front of a start line on the ground. They were then asked to perform three consecutive horizontal jumps (countermovement was permitted) with their feet touching the ground simultaneously. The participants were asked to aim to jump as far as possible whilst making minimal contact with the ground during the intermediate landing. The total distance reached was measured with a metric tape positioned on the ground and the best performance of three attempts was registered. For registration, we considered the distance between the start line and the closer heel at the end of the foot position.



2.5 Physical Exercise Protocol to Induce Muscle Damage

After warming up and performing the THJ test, volunteers performed a bout of plyometric exercises composed of 100 consecutive drop jumps. A platform of 45 cm was used for the exercises, as outlined in a previous study (Loturco *et al.*, 2016). Participants were asked to jump as high as possible after landing on the ground and a six second interval was permitted between each drop jump.

2.6 Data Collection Model

Muscle soreness was registered at the beginning of each exercise protocol using a 10 cm visual analogue scale (VAS). The serum CK concentration was measured by a portable biochemical analyser (Reflotron Plus®, Roche); The CK concentration is described by “units per litre”. Measurement involved inserting a blood drop collected from the participants’ fingertips using a disposable lancet. Participants then performed the THJ test followed by a bout of 100 drop jumps, as described in the familiarization section.

2.7 Intervention and Passive Protocol

Passive recovery: In the first week of data collection, participants were asked to remain seated for 20 minutes (at room temperature) following the bout of plyometric exercises.

CWI: In the second week of data collection, participants performed the bout of plyometric exercises followed by CWI. A cold-water bath was used for the protocol with an amount of water which was sufficient to cover the participants’ iliac crest. The CWI protocol lasted ten minutes and the temperature was monitored and maintained at 10°C by adding ice when

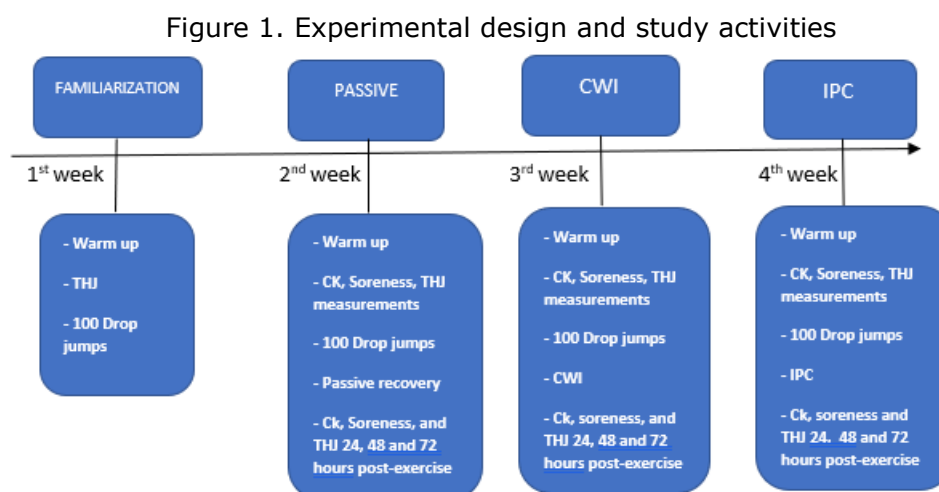


necessary. This CWI protocol was based on a previous study (Bailey *et al.*, 2007) and demonstrated good results.

IPC: In the third week of data collection, participants performed the same plyometric bout of exercises followed by use of an IPC device (Normatec®). The participants lower limbs were enclosed in the inflatable device that covered from distal toes to the proximal inguinal region. The IPC device was used for 30 minutes, according to the manufacturers recommendation. This protocol has been previously used in several experimental studies, including that by Cochrane *et al.* (2013). During the IPC protocol participants remained in a supine position with a pillow under their lower limbs for elevation.

2.8 Post-recovery Measurements

The participants' muscle soreness, serum CK concentration, and THJ performance were measured 24, 48, and 72 hours after each recovery protocol. The study design is outlined in Figure 1.



Source: created by authors



3. Statistics

Data were analysed using SPSS (version 22.0). Descriptive analysis is demonstrated by the mean and standard deviation. Data normality was evaluated by the Shapiro-Wilk test. For each intervention, Wilcoxon matched pair signed rank test was used to verify the results of each variable (24, 48, and 72 hours post-test) compared to pre-test levels. The significance level was set at $p \leq 0.05$.

3.1 Ethics

The experiments reported were performed in accordance with the ethical standards of the Helsinki declaration and participants signed and informed consent form. The protocol of the study was submitted and approved by the University research ethics committee (n^o 73375317.1.0000.5409).

4. Results

All participants completed the full four weeks of the study with no loss of data. There were no differences in terms of the pre-exercise variables in the three weeks of follow-up (CK $p=0.88$; muscle soreness $p=0.23$, and THJ $p=0.34$). Comparison of CK, muscle soreness, and THJ performance data (pre versus 24, 48, and 72 hours post-exercise) for each intervention are shown in Table 1. Variables are expressed by mean.



Table 1. Variable changes following each intervention at each timepoint tested

		Passive	P	CWI	P	IPC	P
CK (U/L) (n = 11)	Pre	46,90		50,80		50,80	
	24_h	373,30	0,02	386,50	0,01	187,60	0,01
	48_h	401,10	0,02	88,80	0,31*	185,20	0,01
	72_h	83,00	0,22*	106,70	0,44*	120,20	0,14*
Soreness (n = 11)	Pre	0,18		0,36		0,00	
	24_h	5,36	0,01	2,90	0,01	1,27	0,02
	48_h	6,27	0,01	4,09	0,01	0,54	0,18*
	72_h	2,72	0,01	1,81	0,01	0,36	0,32*
THJ (n = 11)	Pre	6,66		6,75		6,83	
	24_h	6,35	0,13*	6,39	0,01	6,77	0,11*
	48_h	6,09	0,03	6,66	0,25*	6,86	0,72*
	72_h	6,35	0,21*	6,73	0,89*	6,54	0,01

Abbreviation: CK: creatine kinase, THJ: triple horizontal jump; CWI: cold water immersion, IPC: intermittent pneumatic compression; U/L: units per litre; *p ≥ 0,05.

Source: created by authors

CK: The serum concentration presented significant positive change at 24 and 48 hours post-exercise for IPC (24h p=0.01 and 48h p=0.01) and returned to pre-exercise level within 72 hours (p=0.14). Similar results were observed for the passive recovery method (24h p=0.02, 48h p=0.02), and normalization after 72 hours (p=0.22). On the other hand, the CWI method promoted the return of serum CK to the pre-exercise level 48 hours post-exercise (24h p=0.01, 48h p=0.31, and 72h p=0.44).

THJ: With regards to the CWI intervention, the THJ performance was significantly reduced 24 hours after plyometric exercise (p=0.01) and normalized 48 and 72 hours post-exercise (p=0.25 and p=0.89 respectively). For the passive protocol, the THJ performance was not significantly changed 24 hours after exercise (p=0.13); however, it was decreased 48hours (p=0.03) post-exercise and normalized 72 hours post-exercise (p=0.21). Considering the use of IPC, no significant changes were observed in the THJ performance after 24 (p=0.11) and 48 hours (p=0.72); however, when using that device, a late reduction in performance was noted 72 hours post-exercise (p=0.01).



Muscle soreness: Whereas IPC seemed to be more effective for muscle soreness normalization, promoting recovery after 48 hour (24h $p=0.02$, 48h $p=0.18$, and 72h $p=0.32$), the soreness level (at any of the three time points) was not recovered using either CWI or the passive protocol (CWI 24h $p=0.01$, 48h $p=0.01$, and 72h $p=0.01$; passive protocol 24h $p=0.01$, 48h $p=0.01$, and 72h $p=0.01$).

5. Discussion

This study sought to compare the effectiveness of CWI, IPC, and passive recovery protocols by evaluating the objective variables, CK serum concentration and THJ performance, and the subjective variable, muscle soreness level, following a bout of plyometric exercise. We found that CWI was more effective with regards to the CK serum concentration (normalization 48hours post-exercise) than both the passive and IPC protocols (normalization 72h post-exercise).

Similarly, CWI induced normalization in THJ performance 48 hours post-exercise, while this variable was normalized after 72 hours with the passive protocol, and a late performance reduction was observed after 72 hours (no normalization) with IPC. However, IPC was more effective with regards to muscle soreness (the only subjective variable assessed); a substantial increase was observed after 24 hours with normalization after 48 and 72 hours. On the other hand, CWI and the passive protocol did not lead to recuperation from muscle soreness, even after 72 hours.

The efficacy of CWI as a post-exercise recovery method has been well studied and is supported by literature outlining the research of various subjective and objective variables. Although a previous study reported that CWI was ineffective in terms of reducing muscle soreness, CK serum concentration, and maximal voluntary contraction, following a similar bout of 100 drop jumps in recreational athletes (Howatson *et al*, 2009), it can be



hypothesized that some variables, such as water temperature, may have influenced the results. Indeed, the previous study protocol involved 12 minutes of immersion in water, with a water temperature of 15°C. In contrast, Bailey *et al.* (2007) demonstrated that, compared to the passive protocol, CWI (at 10°C) after prolonged intermittent running, promoted recovery of muscle soreness after 48 hours, biochemical normalization after one hour (myoglobin blood concentration), and performance recovery of maximal isometric voluntary contraction of the hamstrings after 48 hours. However, that study did not promote performance recovery of maximal voluntary contraction of quadriceps compared to the passive protocol (Bailey *et al.*, 2007).

The current study protocol involved 10 minutes of cold water immersion with a water temperature of 10°C. Glasgow *et al.* (2014) observed that the use of CWI for 10 continuous minutes at 6°C was more effective in the recovery of muscle soreness induced by eccentric exercise than contrast water immersion therapy (cold and hot between 10°C and 38°C), and also than intermittent CWI (1 minute in 10°C followed by no immersion for 1 minute, repeated 3 times). This suggests that an increased sensation of temperature reduction felt in the 6°C protocol may have contributed to the positive effect observed in the subjective variable (Glasgow *et al.*, 2014). In line with this finding, Ingram *et al.* (2009) observed favourable results for the continuous use of CWI at 10°C compared to the contrast immersion protocol (alternating between immersion at 10°C and 40°C) after intermittent running exercise (Ingram *et al.*, 2009). These results were more favourable after CWI with regards to muscle soreness and objective variables, such as the muscle strength of knee extensors and flexors, and the performance in run sprints. The findings of the current study agree with these previous studies regarding the probable benefits of CWI with a water temperature of 10°C.



Moreover, a systematic review with meta-analysis (Machado *et al*, 2016), concluded that CWI protocols between 10°C and 15°C and for 10 to 15 minutes lead to better results in terms of acute and late muscle soreness induced by exercises compared to other protocols; this review, alongside the results of other previous studies, justified the choice of protocol in the current investigation.

Finally, the results from another systematic review demonstrated that the majority of studies which investigated the effectiveness of CWI (20°C or less), utilized a temperature of between 10°C and 15°C. Furthermore, the mentioned review demonstrated several benefits with respect to early performance recovery after extenuating exercises in different sports as cycling, running, climbing, or even in specific performance tests such as the vertical jump or lower limb strength tests (Versey and Halson, 2013).

The use of IPC has been recommended for a wide variety of post-operative treatments and is a method that is proven to be effective in the prevention of deep vein thrombosis (Hills *et al*, 1972, Silbersack *et al* 2004). However, its effectiveness as a recovery method in sports is still poorly researched and its physical recovery benefits to athletes remain ambiguous. Among the few studies detailing the effectiveness of IPC, two have proposed to verify its effectiveness: the first, sought to verify the effectiveness of IPC compared to a passive protocol by measuring isokinetic and single leg vertical jump performance and serum CK concentration before and 24, 48 and 72 hours after a bout of eccentric isokinetic quadriceps exercise. In this study, and in agreement with our findings, the use of IPC did not improve the objective variable results compared to the passive protocol (Cochrane *et al*, 2013). Interestingly, in the aforementioned study, the single leg vertical jump performance was unchanged at all timepoints measured, for both protocols (IPC and passive) after isokinetic exercise. This result indicates that other muscle groups, which are not involved in the isokinetic quadriceps exercise protocol (such as the gluteus, hamstrings, and calf muscles), can



guarantee a normal performance in the vertical jump test, even in the first evaluation after exercise. Differently, our study evaluated the THJ performance after a bout of drop jumps, with the same muscle groups involved in both the exercise and evaluation protocols.

Considering metabolic fatigue another important limiting factor for the continuity of intense exercises, Hanson *et al.* (2013) sought to verify the effectiveness of IPC (for 20 minutes) for the reduction of lactate blood concentration following the Wingate test, compared to 20 minutes of passive recovery and 20 minutes of active recovery on a cycle ergometer. Following the Wingate test, the IPC optimized blood lactate concentration comparable to that observed for the passive recovery protocol; however, this was not more efficient than the active cycle-ergometer recovery protocol (HANSON *et al.*, 2013). Consequently, the first mentioned study showed that IPC did not improve the recovery of structural muscle damage in terms of the analysis of objective parameters of performance and CK serum concentration, while there was some evidence in the second study of its efficacy in the reduction of blood lactate concentration compared to the passive recovery method whereas superior efficacy compared to active recovery could not be established. On the other hand, the current study observed that following the exercise, muscle soreness was normalized within 48 hours by using IPC. It is important to mention that, to the best of our knowledge, no study has evaluated the effectiveness of IPC with regards to muscle soreness. It is interesting to find that the only parameter to show IPC effectiveness was the subjective one (muscle soreness). This may be due to a number of reasons: first, from the three protocols studied, this is the only technological resource applied which may have generated a false effect relating to the perception of soreness, while CWI is an accessible and routinely adopted resource. Moreover, considering our study design and sample, we cannot rule out that the repetition of the exercise protocol for three consecutive weeks may have generated a perception of stress exercise



adaptation which was more pronounced in the third week (when IPC as used).

This can be based in the clear and progressive knowledge regarding the exercise protocol, mainly because of the fact that participants performed the same protocol in the first, second and also in third week. Thus, we cannot ignore the hypothesis of a quite subjective perception of less efforts performed in the third week have influenced in the result related to muscle soreness. Despite this, no significant differences were observed before the plyometric protocol for the three included variables in the three weeks of follow-up.

There is an additional limitation of the current study: although the sample size was based on previous studies (Cochrane *et al*, 2013, INGRAM *et al*, 2009), the small number of volunteers did not permit us to use a randomized design with no repetition of the plyometric protocol by participants. Moreover, it is not possible to know whether the same results regarding muscle soreness would be observed if the CWI or passive recovery protocols had been adopted during the third week of data collection. These further highlights the requirement of a randomized model with a larger sample number in future studies.

Despite these limitations, the current study is one of the few to compare two different recovery methods (CWI and IPC) to the passive protocol. Previous studies have, for the most part, compared the effectiveness of CWI to the passive recovery protocol (Bailey *et al*, 2007), and such information was ratified by a literature review (Versey and Halson, 2013). Another example is the study by Glasgow *et al*. (2014), despite investigating the efficacy of CWI protocols (using different temperatures) in the management of delayed muscle soreness, CWI was the only therapeutic protocol tested (GLASGOW *et al*, 2014). Still in this sense, IPC efficacy has been also compared to passive recovery method (Cochrane *et al*., 2013).



Our findings, as well as those of previous studies, clearly indicate that the selection of post-exercise recovery method must be carefully considered; this is mainly due to the fact that individual perception does not reflect concomitant physical performance and biochemical recovery. The apparent benefits of IPC still require to be further studied in order to scientifically justify the investment in the acquisition of such devices, and their use by athletes who intend to promote post-exercise recovery.

6. Conclusion

CWI is an accessible method which has repeatedly showed positive results in terms of the recovery of objective and subjective parameters following intense exercise. Although we have demonstrated that the recovery of exercise-induced muscle soreness is improved with IPC, randomized studies with a greater number of participants are still required in order to include a sham group and exclude any potential bias resulting from progressive adaptation of the participants to the exercise. In summary, and compared to CWI, the results of the IPC protocol remain inconsistent in relation to objective variables.



References

1. BAILEY DM, Erith SJ, Griffin PJ, Dowson A, Brewer DS, Gant N, Williams C. Influence of cold water immersion on indices of muscle damage following prolonged intermittent shuttle running. *J Sci Med Sport*. 2007;25(11):1163-1170.
2. BEST TM, Hunter R, Wilcox A, Haq F. Effectiveness of sports massage for recovery of skeletal muscle from strenuous exercise. *Clin J Sports Med*. 2008;18(5):446-460.
3. COCHRANE D J, Booker H. Does acute vibration exercise enhance horizontal jump performance? *J Sports Sci Med*. 2014;1;13(2):315-20.
4. COCHRANE DJ, Booker HR, Mundel T, Barnes MJ. Does intermittent pneumatic leg compression enhance muscle recovery after strenuous eccentric exercise?. *Int J Sports Med*. 2013;34(11):969-974.
5. COHEN M, Abdalla RJ, Ejnisman B, Admaro JT. Orthopedic lesions in soccer. *Rev Bras Ortop*. 1997;32(12):940-944.
6. CRUZAT VF, Rogero MM, Borges MC, Tirapegui J. Current aspects about oxidative stress, physical exercise and supplementation. *Rev Bras Med Esporte*. 2007;13(5):336-342.
7. FOX KR, The influence of physical activity on mental well-being. *Public Health Nutr*. 1999;2(3A):411-418.
8. GLASGOW PD, Ferris R, Bleakley CM. Cold water immersion in the management of delayed-onset muscle soreness: is dose important? A randomized controlled trial. *Phys Ther Sport*. 2014;15(4):228-33.
9. GREIG M, Siegler JC. Soccer-specific fatigue and eccentric hamstrings muscle strength. *J Athl Train*. 2009;44(2):180-184.
10. HANSON E, Stetter K, Li R, Thomas A. An intermittent pneumatic compression device reduces blood lactate concentrations more effectively than passive recovery after Wingate testing. *J Athl Enhanc*. 2013;2(3):1-4.
11. HAUSSWIRTH C, Louis J, Bieuzen F, Pournot H, Fournier J, Filliard R, Brisswalter, J. Effects of whole-body cryotherapy vs. far-infrared vs. passive modalities on recovery from exercise-induced muscle damage in highly-trained runners. *Plos One*. 2011;6(12):e27749.



12. HILLS NH, Pflug JJ, Jeyasingh K, Boardman L, Calnan JS. Prevention of deep vein Thrombosis by intermittent pneumatic compression of calf. *Br Med J.* 1972;1(5793):131-135.
13. HOWATSON G, Goodall S, Van Someren KA. The influence of cold water immersions on adaptation following a single bout of damaging exercise. *Eur J Appl Physiol.* 2009;105(4):615-621.
14. INGRAM J, Dawson B, Goodman C, Wallman K, Beilby J. Effect of water immersion methods on post exercise recovery from simulated team sport exercise. *J Sci Med Sport.* 2009;12(3):417-421.
15. LOTURCO I, Abad CCC, Nakamura FY, Ramos SP, Kobal R, Gil S, Pereira, LA, Burini F, Rochel H, Ugrinowitsch C, Tricoli, V. Effects of a far infrared rays emitting clothing on recovery after an intense plyometric exercise bout applied to elite soccer: a randomized double-blinded placebo-controlled trial. *Biol Sport.* 2016;33(3):277-283.
16. MACHADO AF, Ferreira PH, Micheletti JK, Almeida AC, Lemes IR, Vanderlei FM, Netto JJ, Pastre, CM. Can water temperature and immersion time influence the effect of cold water immersion on muscle soreness? A systematic review and meta-analysis. *Sports Med.* 2016;46(4):503-514.
17. MCCALL A, Davison M, Andersen TE, Beasley I, Bizzini M, Dupont G, Carling C, Dvorak, J. Injuries prevention strategies at the FIFA 2014 World Cup: perceptions and practices of the physicians from 32 participating national teams. *Br J Sports Med.* 2015;49(9):603-608.
18. PEARCEY GEP, Bradbury-squires DJ, Kawamoto JE, Drinkwater EJ, Behm DG, Button DC. Foam rolling for delayed-onset muscle soreness and recovery of dynamic performances measures. *J Athl Train.* 2015;50(1):5-13.
19. RIBEIRO RN, Vilaça F, Oliveira HU, Vieira LS, Silva AA. Prevalence of football injuries in youth players: comparative study in different categories. *Rev Bras Educ Fís Esporte.* 2007; 21(3): 190-194.
20. SALCES JN, Gómez-Carmona PM, Gracia-Marco L, Moliner-Urdiales D, Sillero-Quintana M. Epidemiology of injuries in first division Spanish football. *J Sports Sci.* 2014;32(13):1263-1270.



21. SILBERSACK Y, Taute BM, Hein W, Podhaisky H. Prevention of deep-vein thrombosis after total hip and knee replacement. *J Bone Joint Surg Br.* 2004;86(6);809-812.
22. SILVA DAS, Souto MD, Oliveira ACC. Lesões em atletas profissionais de futebol e fatores associados. *E F Desportes.* 2008;13(21):1-1.
23. VERSEY NG, Halson SL. Water immersion recovery for athletes: effects on exercise performance and practical recommendations. *Sports Med.* 2013;43(11):1101-1130.