Exercise Physiology

Effects caused by the use of an intermittent pneumatic compression boot on muscle recovery indicators after downhill running

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Abstract - Objective: The purpose of this work was to evaluate the effects of using an intermittent pneumatic compression boot (IPCB) on muscle recovery parameters after a downhill running (DRP) protocol. **Study design:** The study included 17 physically active men (23.3 ± 2.4 years, 82 ± 14.8 kg, and 173 ± 0.06 cm). The DRP consisted of 6 sets of 5 min, interspersed with 2 min of rest, with a slope of -3° and intensity corresponding to 70% (10.3 ± 1.1 km/h) of peak aerobic speed. One limb was treated with IPCB and the contralateral limb was treated with placebo. IPCB application occurred immediately after, and 24 h and 48 h after DRP and lasted 30 min, with pressure of 100 mmHg applied intermittently. The muscle recovery indicators evaluated were perception of delayed muscle soreness (DOMS), muscle quality in the rectus femoris (RF) and vastus lateralis (VL), in addition to concentric and eccentric peak torque (PT) in knee flexors and extensors. **Results:** Significant interactions between time and treatment were observed only for VL DOMS ($F = 5.160$; $P < 0.0001$; $\eta^2p = 0.02$), indicating a lower perception of DOMS in this region when compared to placebo from 48 h after DRP. For the other variables, only time effects were identified. We can conclude that the use of IPCB after a DRP was only effective in reducing DOMS in the VL region from 48 h after DRP. Registered with REBEC (ID RBR-48hdw55). **Conclusion:** The use of IPCB was only effective in reducing DMT in the VL 48 h after DRP.

Keywords: recovery, eco-intensity, DOMS, torque.

Introduction

In sports practices, it is common to use therapeutic strategies with the aim of optimizing muscle recovery after training and, consequently, reducing the inflammatory action caused by training routine[1]. Among these, stretching, electrostimulation, active recovery, cryotherapy, hydrotherapy, massages and compression techniques stand out[2].

More recently, the use of intermittent pneumatic compression boots (IPCB) has grown, but this growth has not been accompanied by scientific evidence of the same magnitude[3,4]. The IPCB has its action like massage[3,5], where air chambers are inflated with pressures between 80 and 200 mmHg and deflated in sequence, always from the distal to the proximal region. The repetition of these maneuvers facilitates venous return, thus promoting the drainage of metabolites produced and accumulated in the lower limb during exercise and promoting acceleration in the muscle recovery process[6]. However, there is still little evidence in the literature on studies that have addressed this topic. In this sense, we believe that more studies involving the use of IPCB are necessary, with the purpose of accelerating the recovery process, to confirm or not its effectiveness as a strategy[5,6].

The objective of the study was to understand the real effects of the use of IPCB on muscle recovery indicators. The hypothesis would be that the use of IPCB would contribute to the muscle recovery process after downhill running activity. Another aspect to be highlighted is the stimulation and application of technical and scientific concepts in the work of the physical therapist, leaving empiricism aside, seeking a basis that results in better treatment for the athlete patient, as well as professional improvement.

Material and methods

Experimental design

The study was classified as a randomized, crossover, blinded, placebo-controlled clinical trial, that was registered with REBEC (ID RBR-48hdw55) and approved by the Ethics and Research Committee with Human Beings of the University where the study was developed (CAAE:

65240622.9.0000.5020). The research protocol involved 6 steps: 1) Assessment of delayed onset muscle soreness (DOMS) using algometry; 2) Assessment of muscle quality (echo-intensity) using ultrasound; 3) Assessment of concentric and eccentric torque of knee extensors and flexors using isokinetic dynamometry; 4) A maximum progressive test on a treadmill; 5) A DRP protocol on the treadmill; 6) Application of IPCB/Placebo. All moments at which each step was carried out are described in Figure 1.

Randomization

Considering the difficulties of comparing different groups, it was decided to use the contralateral limb as the control limb. For this purpose, a draw was carried out determine which limb would receive treatment with IPCB. The contralateral limb automatically received placebo treatment (therapeutic ultrasound turned off). It was ensured that 50% of the limbs treated with the IPCB were on the right side. Volunteers were informed that the study was investigating which of the two recovery strategies (IPCB and Therapeutic Ultrasound) would be the most efficient in promoting muscle recovery.

Participants

The sample calculation (G*Power Software version 3.1.9.2 University of Kiel, Kiel, Germany) indicated the need for 22 participants (effect size = 0.5; statistical power = 0.80; number of groups = 2 (IPCB and Placebo) and number of measurements = 6 (-72 h, Pre, Post, 24 h, 48 h, and 72 h)) with a significance level of $p < 0.05$. However, 17 men (23.3 ± 2.4 years, 82.0 ±14.8 kg and 173 ± 0.06 cm) completed all stages of the research. The inclusion criteria were: (a) being between 18 and 30 years of age, (b) being physically active according to the IPAQ, and (c) not having practiced strength training in the three months preceding the study. The exclusion criteria were: (a) being a smoker, (b) suffering from visible or known diseases or infectious or inflammatory processes, c) a history of injury to the lower limbs in the previous 6 months, and d) user of anti-inflammatory medications, herbal medicines, substances ergogenic aids, such as creatine, arginine, and caffeine, or micronutrient supplements.

Determination of peak aerobic speed

The determination of peak aerobic velocity (PAV) was adapted from the study by Rossato et al.[7]. Participants performed a progressive maximal running test on an ergometric treadmill (Movement 350RT, Manaus, Brazil). The initial speed was 6 km/h, with an increase of 1 km/h every minute, until maximum voluntary exhaustion, characterized by the inability to maintain the intensity. PAV was considered the last speed completed before exhaustion.

Downhill running protocol

The downhill running protocol (DRP) was adapted from Baumann et al.[8], using an intensity corresponding to 70 % of PAV. The slope applied was -3°, with 6 sets of

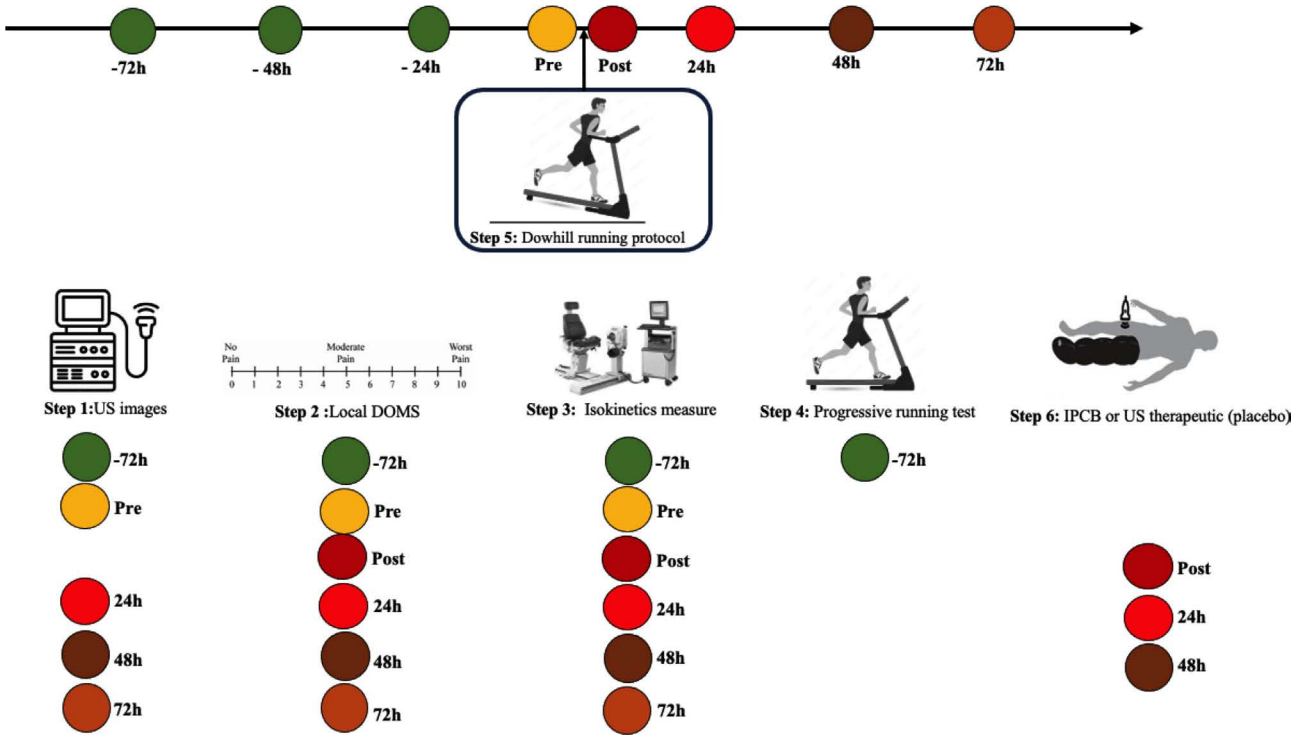

Figure 1 - Timeline of the experimental study, showing the sequence adopted to carry out the activities.

5 min being performed, with 2-min breaks between sets. The total duration of the DRP was 40 min.

Assessment protocol determination of specific DOMS

DOMS was always quantified by the same evaluator. The model followed was adapted from the study by Chesterton et al.[9]. Participants were asked about their perception of DOMS (scale from 0 to 10 points) in the regions of the Rectus Femoris (RF) and Vastus Lateralis (VL) muscles and after the evaluator applied pressure of 50 N with a manual dynamometer (Instrutherm DD-200 - contact area 1 × 1 cm) on the region. The pressure application site was the middle distance between the anterior superior iliac spine and the superior border of the patella and head of the fibula. All DOMS assessments were performed on both the IPCB-treated limb and the placebo-treated limb.

Assessment of muscle quality

All assessments involving echo intensity (EI) were carried out by a single experienced researcher. To assess muscle quality (echo-intensity), the B-mode ultrasound system (Mindray, China) was used, with a linear-array probe operating at 32 Hz (60 mm, 7.5 MHz, 3.0 cm depth, without image filter). Muscle quality was assessed in the Rectus Femoris (RF) and Vastus Lateralis (VL) muscles, with three US images obtained in sequence for each muscle with the subject at rest. The US probe was covered with water-soluble transmission gel and positioned longitudinally to the muscle fibers and perpendicular to the skin at 50% (RF and VL)[10,11].

The images were analyzed using Image J software (straight line, line color: yellow, version 1.48v, National Institutes of Health, Bethesda, MA, United States). The average EI was determined using a standard grayscale histogram function and expressed as a value between 0 = black and 255 = white[12]. Ultrasound images were performed on both lower limbs.

Assessment of peak torque of knee extensors and flexors

The concentric and eccentric peak torque values of knee extensors and flexors were evaluated on an isokinetic dynamometer (Biodex System 4 Pro, Biodex Medical Systems, United States). A protocol adapted from Rossato et al.[7] was used, where participants remained seated, with an 85° trunk flexion, and the assessed lower limb was fixed to the dynamometer. All calibrations were performed in accordance with the manufacturers' recommendations. The range of motion was 70°, with 90° being full knee extension. The protocol consisted of: 1) 20 warm-up repetitions (90°/s); 2) three sets of five repetitions at 60°/s in concentric mode for both knee extensors and flexors; 3) three sets of five repetitions at 60°/s in eccentric mode for both knee extensors and flexors. The peak torque (PT) was recorded for each movement analyzed.

Application of IPCB and placebo therapeutic ultrasound

To use the IPCB, *Rebolt Go Premium Boost System®* equipment was used. The intervention session lasted 30 min, with a standard pressure of 100 mmHg. The gradual inflation of the chambers occurred starting from the feet towards the thighs. Each of the 5 air chambers compressed the limb for 30 s and was then deflated and reinflated. The alternation cycle remained until the end of the stipulated time. Only the selected limb received IPCB treatment.

The application of the placebo therapeutic ultrasound (off) occurred in the thigh region, with emphasis on the areas of the rectus femoris and vastus medialis muscles of the limb opposite to the IPCB application, with a duration of 15 min in each area, totaling 30 min. Contact gel and traditional movements were used, with slow and rhythmic sliding throughout the established time. The application of IPCB and placebo occurred simultaneously and at three moments after the DRP (immediately after, and 24 h and 48 h after).

Statistical analysis

Data are presented using descriptive statistics (mean and standard deviations). The sphericity analysis was performed using Mauchly's test and the normality by the Shapiro Wilk test. Two-way analysis of variance for repeated measures (two-way ANOVA) and the additional Tukey test were used to detect any effect of time (-72, Pre, Post, 24, 48, and 72 h) and treatment (IPCB or placebo) as well as time × treatment interactions. Tukey adjustments for the significance level in multiple comparisons were considered. Additionally, the ANOVA analysis identified the partial eta squared (η^2p). All analyses were performed using SPSS version 20.0 for Windows and an assumed significance level of 0.05.

Results

The average values for PAV were 14.7 ± 1.5 km/h, and the average speed used in the DRP (70 % of PAV) was 10.3 ± 1.1 km/h. The RF DOMS values are shown in Figure 2a. No significant time-treatment interaction ($F = 5.160$; $p = 0.2537$; $\eta^2p = -0.02$) or treatment effects were observed ($F = 1.32$; $p = 0.2234$; $\eta^2p = 0.01$). Significant effects were only observed for time ($F = 5.160$; $p < 0.0001$; $\eta^2p = 3.04$), where the values of Post ($p < 0.0001$), 24 h ($p = 0.0001$), 48 h ($p < 0.0001$), and 72 h ($p = < 0.0001$) were statistically higher than those observed -72 h. Furthermore, the values of Post ($p < 0.0001$), 24 h ($p < 0.0001$), 48 h ($p < 0.0001$), and 72 h ($p < 0.0001$) were statistically higher than the Pre moment. Finally, the DOMS for 48 h ($p < 0.0001$) presented statistically higher values than those observed at the Post moment.

The DOMS values presented in the VL at different times and in both groups are shown in Figure 2b. We

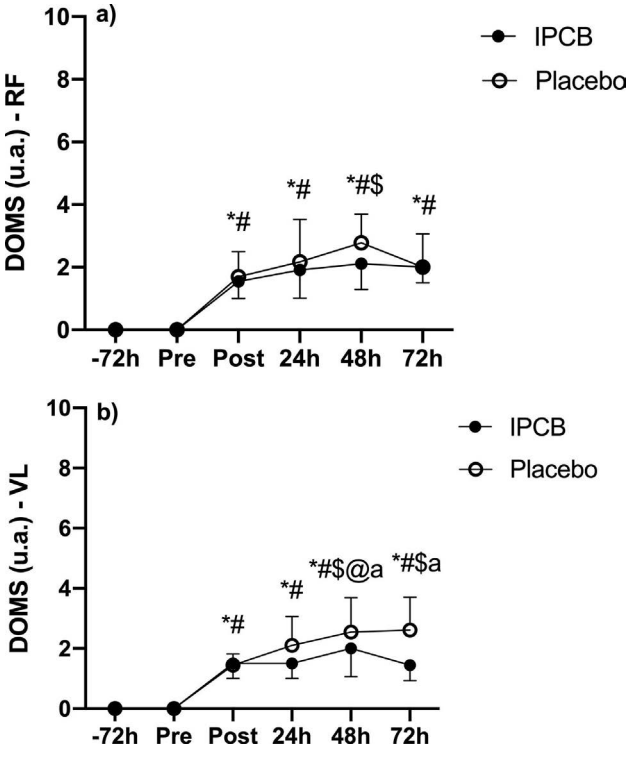

Figure 2 - DOMS behavior in the RF and VL at different times for the limb with IPCB and the limb treated with Placebo. *Significant difference ($p < 0.05$) in relation to -72 h, #Significant difference ($p < 0.05$) in relation to Pre, $Significant difference ($p < 0.05$) in relation to Post, @Significant difference ($p < 0.05$) in relation to 24 h, aTime-treatment interaction.

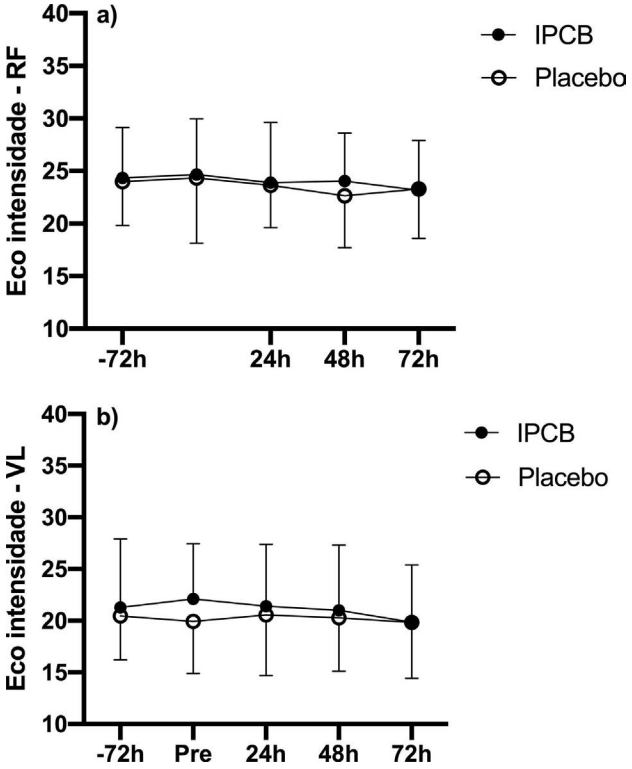

Figure 3 - EI behavior in RF and VL at different times, for the limb treated with IPCB and the limb treated with Placebo.

observed a significant time-treatment interaction ($F = 5.160$; $p < 0.0001$; $\eta^2p = 0.02$), indicating that the use of IPCB was efficient in promoting lower DOMS values, when compared to placebo, from 48 h after DRP. Effects of treatment ($F = 1.32$; $p = 0.0064$; $\eta^2p = 0.01$) and time ($F = 5.16$; $p < 0.0001$; $\eta^2p = 3.04$) were also observed, where the values of Post ($p < 0.0001$), 24 h ($p = 0.0001$), 48 h ($p < 0.0001$), and 72 h ($p = < 0.0001$) were statistically superior to those observed at -72 h. Furthermore, the values of Post ($p < 0.0001$), 24 h ($p < 0.0001$), 48 h ($p < 0.0001$), and 72 h ($p < 0.0001$) were statistically higher than the Pre moment. The values at 48 h ($p < 0.0001$) and 72 h ($p = 0.0022$) were statistically higher than those observed at the Post moment. Finally, the values identified at 48 h ($p = 0.0180$) were statistically higher than those presented at 24 h after DRP.

In relation to the EI values of the RF muscle (Figure 3a), no time-treatment interaction ($F = 4.128$; $p = 0.6106$; $\eta^2p = 0.02$), treatment ($F = 1.32$; $p = 0.7852$; $\eta^2p = 0.02$) and time effects were observed ($F = 5.16$; $p = 0.0586$; $\eta^2p = 0.08$). Similar results were also observed in relation to VL EI (Figure 3b), where no significant differences were observed for time-treatment interaction ($F = 4.128$; $p = 0.6161$; $\eta^2p = 0.02$), and treatment ($F = 1.32$; $p = 0.5940$; $\eta^2p = 0.04$) and time effects ($F = 4.128$; $p = 0.3802$; $\eta^2p = 0.04$).

The values of the torque parameters evaluated at different moments in both groups are shown in Figure 4. Figure 4a presents the values of concentric PT of knee extensors (PTCon-Ext). No time-treatment interaction ($F = 5.160$; $p = 0.94$; $\eta^2p = 0.01$) or effect of treatment ($F = 1.32$; $p = 0.769$; $\eta^2p = 0.01$) were observed, only an effect of time ($F = 5.16$; $p < 0.0001$; $\eta^2p = 0.29$), where the post ($p < 0.0001$), 24 h ($p < 0.0001$), and 48 h ($p = 0.0166$) values were statistically lower than the values obtained for -72 h. Statistically lower values were also observed in the Post ($p = 0.0003$) and 24 h ($p = 0.005$) moments when compared to the Pre moment.

The concentric PT values of knee flexors (PTCon-Flex) are shown in Figure 4b. We did not observe a time-treatment interaction ($F = 5.160$; $p = 0.70$; $\eta^2p = 0.04$), or treatment effect ($F = 1.32$; $p = 0.64$; $\eta^2p = 0.08$), only an effect of time ($F = 5.16$; $p < 0.0001$; $\eta^2p = 0.53$), where the Post ($p < 0.0001$) and 24 h ($p = 0.0279$) values were statistically lower than those observed at -72 h. Furthermore, the Post values were statistically lower ($p < 0.0001$) than the Pre moment. Finally, the values of 24 h ($p < 0.0001$), 48 h ($p < 0.0001$), and 72 h ($p < 0.0001$) presented values that were statistically higher than those observed in the Post moment. Regarding the eccentric PT of knee extensors (PTEcc-Ext), the values are shown in Figure 4c. Like the others, we did not observe a time-treatment interaction ($F = 5.160$; $p = 0.88$; $\eta^2p = 0.02$), no treatment effect ($F = 1.32$; $p = 0.82$; $\eta^2p = 0.01$), only an

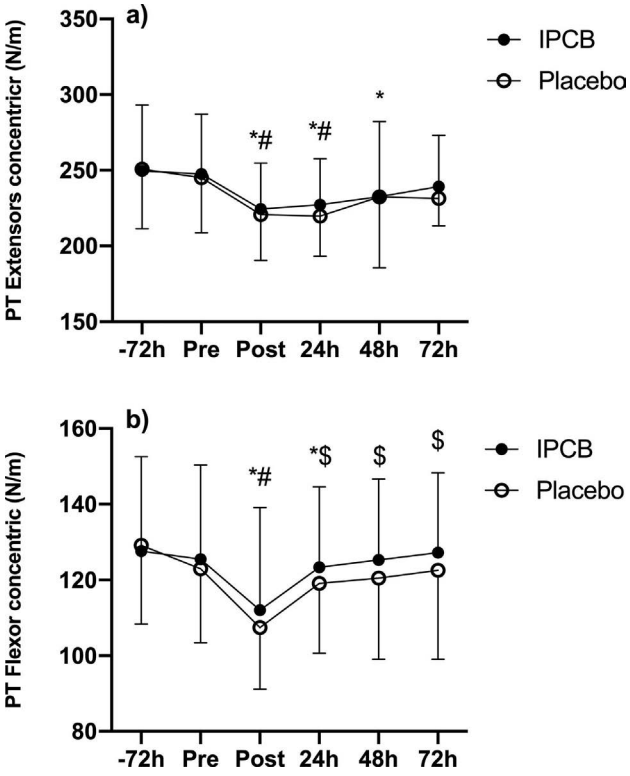

Figure 4 - Behavior of torque parameters at different times for the limb treated with IPCB and the limb treated with Placebo. *Significant difference ($p < 0.05$) in relation to -72 h, #Significant difference ($p < 0.05$) in relation to Pre, $Significant difference ($p < 0.05$) in relation to Post.

effect of time ($F = 5.16$; $p < 0.0001$; $\eta^2p = 0.28$), where the values of Post ($p < 0.0001$), 24 h ($p = 0.0017$), and 48 h ($p = 0.0160$), showed significant reductions in relation to -72 h. Similar results were also observed when comparing the values of Post ($p < 0.0001$), 24 h ($p = 0.0023$), and 48 h ($p = 0.0204$), with the values obtained at the Pre moment. Finally, the knee flexor eccentric PT (PTEcc-Flex) values are shown in Figure 4d. There was no time-treatment interaction ($F = 5.160$; $p = 0.51$; $\eta^2p = 0.05$), or effect of treatment ($F = 1.32$; $p = 0.876$; $\eta^2p = 0.01$), only an effect of time ($F = 5.16$; $p < 0.0001$; $\eta^2p = 0.53$), where the values of Post ($p < 0.0001$), 24 h ($p < 0.0001$), 48 h ($p = 0.0004$), and 72 h ($p = 0.0057$) presented values that were statistically lower than those observed at the -72 h moment. Statistically lower values were also observed when compared to Pre in the moments Post ($p < 0.0001$), 24 h ($p < 0.0001$), and 48 h ($p = 0.0064$). Finally, the values observed at 48 h ($p = 0.0330$) and 72 h ($p = 0.0028$) were statistically higher than those observed at the Post moment.

Discussion

The objective of the current study was to investigate the effects of using IPCB on indirect markers of muscle damage/recovery, such as DOMS, EI, and concentric and eccentric torque parameters of knee extensors and flexors, after a DRP. For this, we used the contralateral limb as a control, the main findings indicated that the DRP used was effective in increasing DOMS and promoting reductions in torque parameters for up to 48 h after DRP. Furthermore, the use of IPCB was only efficient in reducing DOMS after 48 h in VL when compared to placebo, with no change for the other indicators evaluated. Our initial hypothesis was that IPCB, due to its compressive drainage, could stimulate the functional recovery of all markers evaluated, but we did not observe these responses.

Our data corroborate the literature, indicating that running downhill generates elevations in DOMS, reaching peaks after 24 or 48 h[13]. Downhill running employs a greater share of eccentric muscular actions when compared to flat or uphill running[3]. Eccentric actions, in turn, cause microdamage to muscular structures, triggering an inflammatory process[2,14]. The inflammatory process is characterized by the release of inflammatory mediators, including pro-inflammatory cytokines (such as interleukin-1β and interleukin-6) and prostaglandins[15]. These mediators act on pain receptors (nociceptors) present in sensory nerve fibers, increasing sensitivity to pain[16].

Furthermore, factors such as edema and interstitial pressure cause an increase in the permeability of blood vessels, increasing interstitial pressure, compressing nerve endings, and contributing to an increase in the sensation of pain[17]. In this mechanism, the action is credited to the IPCB. Our results indicated that the use of IPCB caused lower DOMS values in the VL after 48 h. Martin et al.[18] suggest that the intermittent pressure exerted by the IPCB can promote increases in blood and lymphatic circulation, thus facilitating venous return and reducing edema in the region, which would be responsible for the reduction in DOMS.

Studies that used post-exercise IPCB and evaluated DOMS present conflicting results. Hoffman et al.[19] and Winke & Williamson[17] reported reductions in DOMS following an IPCB intervention, while Wiecha et al.[20] and Draper et al.[6] did not identify changes in the perception of DOMS. We believe that the inconsistency of these findings is due to the methodological variety of the studies, where different pressures, exercise modalities, application times, evaluation moments, and the absence of a control group/limb may be responsible for the large variation in results. Furthermore, DOMS has an important psychological component. These aspects can be credited to the strategy used in our study, where the adoption of the contralateral limb as a control, associated with a placebo treatment (therapeutic ultrasound turned off) helped to reduce possible variations in DOMS.

Traditionally, EI, despite some inconsistencies that lead to conclusions contrary to the expected physiological effects, has been used to measure muscle quality, acute swelling, intramuscular glycogen, and muscle damage[21].

Regarding muscle damage, several authors have observed that increases in EI (clearer images) indicate damage to connective and muscle tissues, in addition to inflammation[22,23].

To the best of our knowledge, only Sun et al.[24] evaluated the effects of 2 downhill running protocols (-9°; 30 min; low intensity = 50% HRmax and high intensity = 70% HRmax) on the EI of quadriceps muscles. The authors concluded that compared to the intensity of 50% of HRmax, the highest running intensity (70% HRmax) caused significant worsening in the EI of the quadriceps muscles (except Vastus Medialis), lasting for up to 48 h after running downhill. Although we used a similar intensity (70%PAV) and total duration (6 sets of 5 min) to the study by Sun et al.[24], the slope used by the authors was higher than that adopted in our study (-3°). Therefore, we believe that greater slopes are necessary for significant changes to be detected in the EI of lower limb muscles.

Regarding the effects of using IPCB on EI, to the best of our knowledge, our study is the first to evaluate EI after using IPCB. Considering that the use of IPCB could have effects on reducing edema[19,25], our hypothesis was that the images related to the limb treated with IPCB would present lower EI values when compared to the placebo. However, our results were not confirmed. This may have been due to the fact that we used an inclination (-3°) that was insufficient to promote more significant alterations.

Regarding the torque parameters analyzed, we observed significant reductions for all parameters immediately after the DRP (Figure 4) when compared to baseline values (-72 h and Pre). With the exception of PTCon-Flex, all other parameters remained significantly below baseline values for 24 h. Another observation was the fact that the eccentric torque parameters showed the greatest reductions (PTEcc_Ext = -15.3% and PTEcc_Flex = -16.8%) when compared to the concentric torque parameters (PTCon_Ext = -10.2% and PTCon_Flex = -12.2%). Our findings corroborate Eston et al.[26], who state that during downhill running, the knee extensor muscles, anterior and posterior tibial muscles, as well as the hip extensors tend to be overloaded as they act as antigravity muscles during running.

Furthermore, Close et al.[27] compared torque parameters after flat and downhill running (30 min, 65% $VO_{2max,}$ and -15%) and reported significant reductions in concentric and eccentric peak torque values of knee extensors immediately after downhill running. In addition, peak concentric torque values of knee extensors remained below baseline values for up to 48 h. However, the authors did not report knee flexor torque parameters. Our results also corroborate those obtained by Garnier et al.[28]. The authors evaluated the concentric and eccentric peak torque of knee extensors after 45 min of downhill running (-15%) at 75% of the HR reserve. The results indicated that the greater reductions occurred in eccentric (-12.2%) than in concentric (-10.2%) peak torque. However, the analyses were only carried out with measurements taken immediately after running downhill. Therefore, our study was pioneering in evaluating concentric and eccentric torque parameters of knee extensors and flexors both before (-72 h and pre) and after DRP (post, 24 h, 48 h, and 72 h).

Regarding the effects of using IPCB on the recovery of torque parameters, we did not observe significant differences in relation to the limb treated with placebo. Our results corroborate previous studies that also reported no differences in relation to the control group[20,25]. These findings indicate that IPCB does not seem to be able to promote faster recovery of torque parameters when compared to other recovery strategies or even recovery without the use of strategies.

Our study has limitations and strengths. The assessment of blood markers, such as creatine kinase and lactate dehydrogenase could have been useful to assess the magnitude of muscle damage caused by DRP. Furthermore, measures to monitor edema could have been added to the methodology. However, the use of the contra-lateral limb as a control, the application of a placebo, and the diversity of indirect markers of muscle recovery used can be considered strengths of our study.

Conclusions

The DRP used was effective in increasing DOMS and reducing the torque parameters evaluated, but did not promote changes in the EI. Furthermore, the use of IPCB was only effective in reducing DOMS in the VL 48 h after DRP. However, it did not show significant differences regarding muscle quality or torque production in any phase of the protocol. The limitations presented in the study, such as the absence of the evaluation of blood markers such as creatine kinase and lactate dehydrogenase, could have been useful in evaluating the magnitude of muscle damage caused by DRP. In addition, measures that could be used to monitor edema could have been selected for the methodology used, as it influences the indicators of pain perception. We suggest that blood markers and limb circumference be implemented in future studies, in addition to the method used in the present study, to confirm or refute our findings.

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