Compressive cryotherapy as a non-pharmacological muscle recovery strategy and with no adverse effects on basketball

Diego Fernández-Lázaro¹, Juan Mielgo-Ayuso², Alberto Caballero-García³, Alfredo Córdova Martínez², Jesús Seco-Calvo⁴, César I. Fernández-Lázaro¹.⁵


Summary

Introduction: Both cold water immersion and compression garments have been routinely used to speed recovery after exercise, however, there is a lack of knowledge of applying both techniques simultaneously: Pressurice Compressport, which is a simple tool, non-pharmacological and free of side effects that allows the application of compressive cryotherapy (CC).

Objective: To investigate the chronic effect of Pressurice Compressport, after each match and training session, on the markers of muscle damage, muscle strength and fatigue.

Methods: A prospective cohort design. In 24 male basketball players divided into two groups, recovery (RP) (n=12) and control (GC) (n=12). Serum markers of muscle metabolism, quadriceps strength (FC) and perceived effort values (RPE) by Borg CR10 scale were measured at 3 times in the study: a) day 1, (T1); b) day 28 (T2) and c) day 56 (T3). The CC was applied immediately after each match and training.

Results: A progressive decrease in all markers of muscle damage was observed at the end of the pre-season in the RP group. On the contrary, in the GC they increased significantly for creatine kinase (CK) (T1 vs. T3 p<0.05). The time course of myoglobin (Mb) in the RP group (p>0.05) followed a pattern different from that of GC (p<0.05). In RP, the RPE significantly decreased (p<0.05) in all points of the study. The HR was higher in the RPE than in the GC, in addition gains were obtained throughout the pre-season in RPE and a decrease in GC.

Conclusion: CC is potentially capable of promoting recovery from muscle damage associated with competition and training, with reductions in markers of muscle damage, improvements in muscle strength and significant decrease in RPE.


Crioterapia compresiva como estrategia de recuperación muscular no farmacológica y sin efectos adversos en baloncesto

Resumen

Introducción: Tanto la inmersión en agua fría como las prendas de compresión han sido usadas rutinariamente para acelerar la recuperación después del ejercicio, sin embargo, hay una falta de conocimiento del uso de ambas técnicas de forma simultánea. Pressurice Compressport, es una herramienta simple, no farmacológica y carente de efectos secundarios que permite aplicar la crioterapia compresiva (CC).

Objetivo: Investigar el efecto crónico del Pressurice Compressport, tras cada partido, y sesión de entrenamiento, sobre los marcadores de daño muscular, la fuerza muscular y la fatiga.

Métodos: Un diseño de cohorte prospectivo. En 24 jugadores de baloncesto masculinos divididos en dos grupos, recuperación (RP) (n=12) y control (GC) (n=12). Los marcadores séricos del metabolismo muscular; la fuerza de cuádriceps (FC) y los valores de esfuerzo percibido (RPE) por escala de Borg CR10, se midieron en 3 momentos del estudio: a) día 1, (T1); b) día 28 (T2) y c) día 56 (T3). La CC se aplicó inmediatamente después de cada partido y entrenamiento.

Resultados: Se observó una disminución progresiva de todos los marcadores de daño muscular al final de la pre-temporada en el grupo RP. Por el contrario, en el GC aumentaron y fueron significativas para la creatína quinasa (CK) (T1 vs. T3 p<0.05). El curso temporal de la mioglobina (Mb) en el grupo RP (p>0.05) siguió un patrón diferente al GC (p<0.05). En RP, los RPE disminuyeron significativamente (p<0.05) en todos los puntos del estudio. La FC fue mayor en el RP que en el GC, además se obtuvieron ganancias a lo largo de la pre-temporada en RP y una disminución en GC.

Conclusión: La CC es potencialmente capaz de promover la recuperación del daño muscular asociada con la competición y el entrenamiento, con reducciones en los marcadores del daño muscular, mejoras de la fuerza muscular y disminución significativa RPE.


Award for the best submission in the 8th National Sports Medicine Meetings in Reus, 2019

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Introduction

Basketball players are constantly exposed to high physical demands due to repeated accelerations/decelerations and explosive jumps. This generates muscle pain, caused mainly by eccentric loads and due to trauma through contact. In addition to these factors, short recovery times between training sessions and competitions lead to an excessive level of fatigue accumulated throughout the weekly cycle, all driving towards low performance in competition.

The capacity to recover after intense training sessions and matches, constitutes one of the most determining factors in the performance improvement process of the athletes. When correct physical and therapeutic recovery is applied after training sessions or competition, athletes can return more quickly to their sporting routines compared to when they do not receive any.

To reduce the magnitude of fatigue and to speed up recovery time, sports teams have a wide range of regenerative strategies: active recovery (continuous low-intensity running and stretches), ergo-nutritional methods (replacing substrates and electrolytes), passive recovery (sleep and rest), and physiotherapy methods. Various recovery methods are used in physiotherapy after exercise, with the aim of relieving secondary muscle-skeletal alterations caused by training and competition. Among these interventions are "contrast therapy," which alternates between hot and cold treatment; full-body "cryotherapy," "cold water immersion" (CWI); and hydro-massage. These physiotherapy modalities can alleviate fatigue and increase performance during training and competition.

Today, compression garments are commonly used by athletes during and/or after a training session or competition. The most used compression garments are compression stockings, which have numerous applications in the sporting world (Table 1). The physiological grounding is based on decreasing pressure that is generated in the leg, with the maximum pressure on the ankles (15-30 mmHg), reducing gradually to the top of the leg (10 mmHg). Compressions are used frequently in high performance sport as a recovery practice following physical exercise, with the aim of reducing delayed onset muscle soreness (DOMS), diminishing associated symptoms and the perception of pain. They can also reduce inflammation and the volume of the lower limbs, as well as the diameter of gastrocnemius veins. Using them may also generate ergogenic benefits, such as a reduction in lactate levels associated with an acceleration of venous return by reducing venous distension, restoring valvular insufficiency and the reduction of venous blood. Therefore, as a recovery strategy, compression stockings are cheap, easily accessible and non-invasive, as well as easy to implement during exercise and 15-24 hours after training and competition.

A recent study has indicated the use of CWI as a technique to improve muscle damage recovery and to prevent over-training symptoms in basketball players. The effects of CWI are reflected in reduced pain, inflammation, blood flow, cell metabolism and muscle pain. The efficiency of CWI appears to depend on the application length, the treatment area, the time it is applied, level of physical activity and the modality used. Whatever the protocol used, the main beneficial effect of cold during recovery is vasoconstriction, which limits the permeability of the vessels and therefore inflammatory processes, reducing muscle pain.

In view of the above, the study of the effects of recovery practices for performance has become a priority issue for players, coaches and sports researchers alike, as improved recovery has the potential to increase sporting performance. Both CWI and compression stockings have been used routinely to speed up recovery after exercise on an individual level. Therefore, applying compressive cryotherapy (CC) allows two recovery practices to be applied together, which could potentially yield better results in the athletes’ recovery and performance.

There is currently a specific instrument for applying CC - Pressurice Compressport - which is a simple, non-pharmaceutical resource with no side effects.

Therefore, the aim of this study was to research the chronic effect of Pressurice Compressport, after each match and after each training session, on muscle pain indicators, by assessing the serum levels of enzymes and/or proteins. This work is a new study, as some basketball studies have researched the effect of diverse recovery procedures on recovery and fatigue indicators, yet these studies do not usually include the analysis of muscle metabolism markers.

<p>| Table 1. Applications of support stockings in sport. |
|-----------------|-----------------|</p>
<table>
<thead>
<tr>
<th>Applications</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>They enhance venous return</td>
<td>They improve the circulation, stimulating the distribution of blood flow, achieving better tissue oxygenation.</td>
</tr>
<tr>
<td>They improve metabolic efficiency</td>
<td>They demonstrate the effectiveness of low intensity running, but not that of intensities over 14-16 km/hr.</td>
</tr>
<tr>
<td>They cool, driving out heat</td>
<td>These garments comprise two layers, one used to cool / wick away sweat, and another to absorb part of the heat produced.</td>
</tr>
<tr>
<td>They avoid heat loss</td>
<td>If it is cold, the stockings have a heat-preserving function.</td>
</tr>
<tr>
<td>They avoid vibrations</td>
<td>The compression holds the muscles in the zone and prevents the lateral movement of the calf muscles.</td>
</tr>
<tr>
<td>They encourage recovery</td>
<td>They increase venous return and toxin drainage. They reduce inflammation and muscle pains.</td>
</tr>
</tbody>
</table>

Material and methods

A prospective cohort study was carried out. Twenty-four voluntary male basketball players participated in this study, which adhered to the...
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Helsinki Declaration recommendations and that was approved by the local university ethics committee.

Physical examination

All the subjects signed an informed consent form and underwent a medical examination. None of the participants smoked, drank alcohol or took medication or illegal substances. No injuries were obtained before or during the study.

Subjects

Participants were recruited using a non-random consecutive sample method of the two groups. The intervention group, with recovery practices (RP), 12 professional male basketball players (EBA League) (23.3 ± 5.4 years; 194 ± 9.8 cm; 95.8 ± 12.7 kg; 56.5 ± 7.7 mL·kg⁻¹·min⁻¹). The control group (CG) 12 university league students (22.1 ± 3.8 years; 178 ± 8.6 cm; 78.3 ± 8.6 kg; 47.2 ± 6.3 mL·kg⁻¹·min⁻¹).

Training

All the professional players followed the same training plan (2 daily sessions, held 5 days in a row with 1 day of rest, staggered with 6 friendly matches. After each session, the RP group received the corresponding recovery practices via CC.

All the university players followed the same training plan, 1 daily session, with 4 days in a row of training and 2 days of rest, staggered with 3 friendly matches. After each session, the CG did not receive the CC because this group did not have the Pressurice Compressport.

Dietary assessment

A professional dietician registered the strict daily intake of food and liquids of the athletes throughout the study (Table 2) using the EasyDiet package. All participants also received multivitamin complexes that included folic acid (5 mg/day), vitamin C (1 g/day), vitamin B12 (1.000 µg/day), ramified amino acids and glutamine.

Protocol

All the participants had to attend the laboratory at three specific times during the pre-season (8 weeks). We performed the analytical control at 3 points during the study: a) on day 1, just before starting the study (T1); b) in week 4, halfway through this period (T2); and in week 8, corresponding with the end of this period (T3).

Determining perceived effort

Before extracting blood, the participants were asked to grade their perceived muscle discomfort at each point in time (T1, T2, T3), using the Borg CR-10 scale validated to rate perceived effort (RPE) and 18,19.

Determining quadriceps strength

For the strength test, we measured the quadriceps strength (QS) at each point in time (T1, T2, T3) with a dynamometer (Leg Jamar, USA). Two attempts were made with the predominant leg and the best score was noted.

Blood extraction and analysis

Regulations from the World Anti-Doping Agency (WADA) were followed for the collection and transport of samples (www.wada-ama.org). Antecubital venous blood samples were taken from the basketball players. All the samples were collected under basal conditions and in fasting, with at least 12 hours fasting prior to the intervention, either

### Table 2. Average daily energy and micro-nutrient intake in each group of basketball players from the recovery group (RP) and the control group (CG) during the 8-week long study.

<table>
<thead>
<tr>
<th>Group</th>
<th>Control (CG)</th>
<th>Recovery (RP)</th>
<th>p</th>
<th>RDA*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal/kg)</td>
<td>42.3±5.8</td>
<td>42.7±5.2</td>
<td>0.293</td>
<td></td>
</tr>
<tr>
<td>Ca (mg)</td>
<td>1,196±222</td>
<td>1,251±123</td>
<td>0.361</td>
<td>1,000</td>
</tr>
<tr>
<td>Mg (mg)</td>
<td>572±109</td>
<td>581±85</td>
<td>0.863</td>
<td>320</td>
</tr>
<tr>
<td>P (mg)</td>
<td>2,184±84</td>
<td>2,276±94</td>
<td>0.583</td>
<td>700</td>
</tr>
<tr>
<td>Fe (mg)</td>
<td>24.0±5.6</td>
<td>24.5±4.7</td>
<td>0.880</td>
<td>10</td>
</tr>
<tr>
<td>Zn (mg)</td>
<td>14.7±0.8</td>
<td>14.7±0.8</td>
<td>0.763</td>
<td>8</td>
</tr>
<tr>
<td>Vitamin A (µg)</td>
<td>1,951±1,270</td>
<td>2,002±875</td>
<td>0.679</td>
<td>700</td>
</tr>
<tr>
<td>Vitamin E (mg)</td>
<td>18.0±3.5</td>
<td>17.5±2.6</td>
<td>0.466</td>
<td>15</td>
</tr>
<tr>
<td>Thiamine (mg)</td>
<td>2.70±0.20</td>
<td>2.68±0.32</td>
<td>0.537</td>
<td>1.1</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>2.87±0.22</td>
<td>2.95±0.28</td>
<td>0.693</td>
<td>1.1</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>39.0±6.8</td>
<td>38.2±4.8</td>
<td>0.850</td>
<td>14</td>
</tr>
<tr>
<td>Vitamin B6 (mg)</td>
<td>3.99±0.62</td>
<td>4.01±0.86</td>
<td>0.831</td>
<td>1.3</td>
</tr>
<tr>
<td>Folic Acid (mg)</td>
<td>654±176</td>
<td>656±169</td>
<td>0.985</td>
<td>400</td>
</tr>
<tr>
<td>Vitamin B12 (µg)</td>
<td>9.79±3.89</td>
<td>9.55±3.55</td>
<td>0.768</td>
<td>2.4</td>
</tr>
<tr>
<td>Vitamin C (µg)</td>
<td>361±148</td>
<td>401±179</td>
<td>0.683</td>
<td>700</td>
</tr>
</tbody>
</table>

*RDA: Recommended Dietary Allowances
Data is expressed as Average ± Standard Deviation. p: Differences between groups determined by independent t tests (CG vs. RP).
sitting or lying. The Vacutainer system was used (10 ml for tubes of serum, 5 ml and 3 ml tubes with EDTA). Immediately after extraction, the tubes were inverted 10 times and stored in a sealed box to be later kept at 4ºC. During the 30-minute journey to the laboratory, temperature was controlled using a specific label (Libero Ti1, ELPRO-BUCHS, Switzerland). The EDTA samples (anti-coagulant) were homogenised for 15 minutes before being analysed. The tubes that contained blood plus EDTA were centrifuged at 2,000 rpm for 15 minutes. The plasma was extracted using a Pasteur pipette and was transferred to a sterile storage tube where it was kept at -20ºC until it was analysed.

Leukocytes (LEU), monocytes (MON), lymphocytes (LIN), red blood cells (RBC), haemoglobin (Hb) and haematocrit (Hct) were determined using a haematological counter System Coulter MAX-M model. The serum levels of creatine kinase (CK), lactate dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT) and total proteins (TP) were measured at each point of the study (T1, T2 and T3) using coupled enzymatic reactions in an automatic self-analyser (Hitachi 917, Japan). The myoglobin (Mb) was measured using a “sandwich” immunochemiluminescent trial technique of two points.

Percentage changes in the plasmatic volume (% ΔPV), were calculated using the Van Beaumont equation, and all the values of the parameters analysed were adjusted.

### Use of compressive cryotherapy: Pressurice Compressport

After each training session (48 sessions) and after each match played (6 matches), the RP group received CC. The Pressurice Compressport (Compressport® Veno-Muscular Compression Technology, Switzerland) was fitted to the lower extremity, from the ankle to the iliac crest. The special gel formulation in the silicon compartment enabled it to remain flexible after cooling, allowing it to mould optimally to the shape of the leg. The gel was cooled at a controlled temperature of 8ºC. It comprised 2 applications of 15 minutes each, separated by 5 minutes, in which the athletes rested at room temperature. The compression wrapping was applied along with the cold gel and later the cold gel was removed (after the two 15-minute positions), and the compression garment was left on for a total of 90 minutes at complete rest in a sitting position. The garment was personal and provided a constant pressure of between 20 and 25 mmHg.

### Statistical analysis

This was performed using the IBM Statistical Package (SPSS Version 22) and Graphpad Prism (Graphpad Software Version 6.01 San Diego, CA). The data was expressed as average ± standard deviation (SD). The differences in the parameters were assessed using a Scheffé test to identify significant differences between T1, T2 and T3 independently. Next, the normality of the data was confirmed using the Wilks lambda test to decide to use the parametric analysis. Significant differences are p<0.05.

### Results

#### Dietary intake

Table 2 displays the energy and micro-nutrient intake of the basketball players. There were no significant differences between the study groups (CG and RP) in total calorie intake, vitamins and minerals (p> 0.05).

#### Haematology

Analysing the different haematological markers (Table 3), significant differences were only observed in the behaviour of the Hb in the CG throughout the study (p<0.05). Furthermore, in the CG Hb, significant differences were established (p<0.05) between T1 (15.33 ± 0.72) vs. T2 (16.15 ± 0.85) and significant differences (p<0.05) were also found between T2 (16.15 ± 0.85) vs. T3 (14.97 ± 0.92).

#### Biochemistry

##### Muscle markers

Table 4 displays the behaviour of the hormonal biochemical serum indicators and total proteins during the pre-season (T1, T2 and T3) in the CG and RP. Compared to the CG, the RP group had a better pattern of change over the pre-season period, demonstrating a descending trend between T1 and T3 in all muscle markers. CK, AST, ALT, LDH and Mb.

Individually, the most relevant results demonstrated: CK activity increased significantly (p < 0.05) in the CG in T3 (304.56±123.16) compared to T1 (201.43±88.73); in terms of the transaminases for the AST there was a significant decrease (p < 0.05) in the RP in T3 (18.09±2.18) compared to T1 (22.09±4.18) and for the ALT there was a significant increase (p < 0.05) in the CG in T2 (33.08±2.99) compared to T1 (30.25±1.32). Furthermore, significant changes (p < 0.05) can be seen (Figure 1, Table 4) in the behaviour of Mb in both groups (CG and RP) throughout the study. Also, for the Mb we observed a significant increase in the CG (p < 0.05) between the start (T1) (19.77±0.74) and the end of the study (T3) (25.68±3.68), however, in the RP there was a significant reduction (p < 0.05) between the study points T2 (27.88±3.67) and T1 (24.60±1.98).

#### Total proteins

The total proteins (Table 4) did not reveal significant changes in behaviour throughout the study, nor between the points analysed (T1, T2, T3).

#### Determining perceived effort

Table 5 displays the RPE in the CG, the Borg CR10 scale indicates a significant increase (p<0.05) of the perceived fatigue in T2 (8.64±1.26) and T3 (8.96±1.16) compared to T1 (7.03±1.79); conversely, for the RP there was a significant reduction in perceived fatigue (p<0.05) in T2.
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Determining quadriceps strength with dynamometer

Table 6 displays the determination of QS. Compared to the CG, the RP group displayed a better pattern of change over the pre-season period, demonstrating an ascending trend (non-significant) in strength gain from the start of the study (T1 77.42±8.34) and the two points assessed (T2 78.41±6.82; T3 80.10±7.31). However, the in CG the opposite was observed, i.e. a non-significant reduction. None of the groups (CG and RP) revealed significant changes in QS behaviour throughout the study.

Discussion

As far as we are aware, this study may be the first to examine the application of CC with the Pressurice Compressport tool as a muscle recovery strategy in basketball players, using biochemical responses as indicators. The main finding in this research was that the use of CC with the usage protocol described in our study, could be associated with reductions in muscle pain markers and inflammation that entail improvements in muscle recovery in line with descriptions in other studies that use cryotherapy or the use of compression garments.

Moreover, the significant improvement in perceived exertion (RPE) and an increasing trend in quadriceps strength (QS) observed at the end of the pre-season in the RP, could point towards the effective intervention of the CC programme as an applicable recovery model.

It is already recognised that repeated high-intensity training sessions or matches induce fatigue, muscle pain and a poorer performance, with reduced competitive capacity. Faced with this situation, different recovery mechanisms have been proposed using cold therapies and compressive mechanisms.

Sustained intense exercise increases levels of circulating muscle pain markers, of LDH, CK and Mb and ALT/AST. All these parameters are indicators of increased muscle pain and oxidative stress, which negatively affect athletes as not only can it reduce their performance, but it can also put their health at risk.

Figure 1. Representation of the myoglobin values (Mb) in the control group (CG) and recovery group (RP) throughout the study period.
Depending on the intensity of the exercise performed, physiological recovery times vary, from hours right up to a week, meaning the different recovery systems develop a different muscle-skeletal evolution. As a result of muscle pain and muscle fatigue in athletes, muscle strength drops, as well as work capacity and sporting performance. Deterioration occurs in the muscle’s capacity to store glycogen, the ultra-structural alteration of the sarcomere associated with the increase of decomposition of contractile muscle proteins, and exacerbated inflammatory responses.

Until this study was performed, the effects of CC as a muscle recovery therapy had not been researched in real, long-term situations (8 weeks), during a pre-season of high physical requirement training sessions. In turn, some studies indicate that a single episode of cold therapy or compression stockings after exercise do not significant

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**Table 4. Muscle metabolism markers and total proteins in the basketball players from the recovery group (RP) and the control group (CG).**

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Time</th>
<th>Sign.</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creatine Kinase (CK) (U/l)</td>
<td>RP</td>
<td>T1</td>
<td>236.72±98.13</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>201.43±88.73</td>
<td>NS</td>
</tr>
<tr>
<td>Aspartate transaminase (AST) (U/l) (80-40 U/L)</td>
<td>RP</td>
<td>T2</td>
<td>201.43±88.73</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T2</td>
<td>23.64±2.11</td>
<td>NS</td>
</tr>
<tr>
<td>Alanine transaminase (ALT) (U/l) (10-50 U/L)</td>
<td>RP</td>
<td>T3</td>
<td>31.53±8.79</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T3</td>
<td>30.25±1.32</td>
<td>NS</td>
</tr>
<tr>
<td>Lactate dehydrogenase (LDH) (105-333 U/l)</td>
<td>RP</td>
<td>T1</td>
<td>409.77±73.90</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>322.43±110.15</td>
<td>NS</td>
</tr>
<tr>
<td>Myoglobin (Mb) (ng/mL) (25-72 ng/mL)</td>
<td>RP</td>
<td>T1</td>
<td>24.60±1.98</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>19.77±0.74</td>
<td>NS</td>
</tr>
<tr>
<td>Total proteins (TP) (g/dL) (6.6-8.7 g/dL)</td>
<td>RP</td>
<td>T1</td>
<td>7.7±0.44</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>7.73±0.32</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with p<0.05.

Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, p < 0.05.
b: Significant difference vs. T2, p < 0.05.

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**Table 5. BORG CR-10 Determining perceived effort in the basketball players from the recovery group (RP) and the control group (CG).**

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Time</th>
<th>Sign.</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>BORG CR-10</td>
<td>RP</td>
<td>T1</td>
<td>7.6±2.13</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>7.03±1.79</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with p<0.05.

Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, p < 0.05.

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**Table 6. Determining quadriceps strength by dynamometer in the basketball players from the recovery group (RP) and the control group (CG).**

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Time</th>
<th>Sign.</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadriceps dynamometer</td>
<td>RP</td>
<td>T1</td>
<td>77.42±8.34</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>GC</td>
<td>T1</td>
<td>71.06±7.91</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with p<0.05.

Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, p < 0.05.
modify muscle recovery. Therefore, the optimum duration and the combination of recovery interventions, of cold and compression, are not well defined collectively in athletes.

In our study, recovery intervention with CC was performed daily after each training session and matches. In both study groups (RP and CG), CK and LDH activity displayed levels above the physiological range at the start of the study (T1), revealing a progressive decrease in the muscle pain markers at the end of the pre-season in the RP group (T3). However, the CG increased the markers of the muscle metabolism levels LDH and CK (T1 vs. T3 p<0.05). In terms of the Mb of the RP group, it followed a different pattern during the season to that of the CG, with no significant changes observed in the duration of the season (p>0.05), but with increases in the CG (p<0.05). More specifically, after a significant increase between T1 and T2 (p<0.05), the Mb then dropped considerably between the following sample points (T2 vs. T3 p>0.05), despite the RP group following a greater training and match load, suggesting the high efficiency of the CC programme over long application periods (8 weeks). Conversely, in the CG, in which players did not follow the CC recovery programme, there were increases in Mb, especially in T3, where it increased significantly (p<0.05) compared to the start T1, suggesting worse muscle recovery to that observed in the test group.

In this respect, the diverse forms of cryotherapy, including CWI, are effective treatments in reducing the metabolism, inflammation, blood flow, pain, and cutaneous, muscular and intravascular temperatures\(^6\). Some studies have used immersions of ≤10 °C with different treatment durations (3-10 minutes), contracting capillaries, reducing capillary permeability and blood flow, thus reducing swelling and the inflammatory response, which could reduce the negative effects associated with exercise\(^{2,3,13,34}\). Furthermore, theories have been made regarding the application of CWI on local inflamed areas, allowing for a reduction in the permeability of the membranes, thus reducing the intracellular-intravascular flow of CK and Mb\(^{13,33}\), which could explain the results observed in the RP group. In this respect, Seco et al\(^6\), report that in the intervention group of basketball players that were treated with CWI, the Mb was significantly lower than in the control group, between the start and finish of the study, and that between both groups the Mb displayed a significantly different behavioural pattern, yielding extremely similar results to those described in this study. Also, in the CG throughout the pre-season, evident with the significant increase of ALT (T1 vs. T2 p<0.05) and AST, indicative of muscle fatigue\(^{27}\), in contrast to the levels of the RP group (significant reduction of ALT and AST; T1 vs. T3 p<0.05).

After analysing our results, it is relevant that the strength studied in the QS test was greater in the RP than in the control group after recovery at the end of the pre-season. Gains were observed throughout the pre-season in the RP and there was a decrease in the CG. We believe that both the biochemical and strength responses suggest the high effectiveness of the CC muscle recovery strategy used with the test group. These results were supported by reductions in RPE (p<0.05), at the mid-point (T2) and at the end of the season (T3), according to the Borg CR-10 rating measurements.

In turn, the use of compression garments applied to local-regional zones, have proven to be effective at reducing some muscle metabolism markers, observing a significant positive effect of compression in CK\(^4\) as well as the Mb\(^6\) and a moderate effect on the attenuation of AST\(^10\). Nevertheless, previously the positive (yet non-significant) influence was described of compression garments on reducing muscle pain markers, with the significant increase of CK, LDH, AST and ALT on the CG associated to the non-significant increase in the group using compression garments (with no differences between groups)\(^37\). These results are similar to those we have reported, in which there is a progressive reduction of the muscle pain markers at the end of the pre-season in the RP, which suggests that the compressive therapy we applied stimulates faster recovery.

Our data suggests a positive impact of CC in the long term, and we believe that applying CC via Pressurice Compressport could also potentially be used for short-term muscle recovery due to its synergistic effect based on the collective actions of both recovery tools. A reduction in cutaneous blood flow occurs, as well as changes in the intracellular-intravascular fluid, a reduction of muscle inflammation and an increase in the cardiac output, which could increase blood flow and the possible transportation of nutrients and waste through the body\(^6,25\). However, previous specific studies are needed to compare and guide the selection of the sample interval.

For the data provided in this study, this work supports the theory that sports medicine techniques such as CC contribute to a better and faster recovery from fatigue, thus improving performance over an extended period of high physical demand. The study also suggested that future research is required to exploit the benefits of therapeutic methods even further, to promote recovery from muscle fatigue, including cheaper methods that require less infrastructure.

We acknowledge that this study faced various limitations. Firstly, the consecutive sample method and the prospective design of the cohort should be considered for future studies with the aim of designing random controlled clinical trials. Moreover, as CC is a recovery practice that encompasses two techniques (CWI and the use of compression garments), the inclusion of the two groups receiving a single therapy would provide a foundation for examining if there is greater muscle recovery, variations in strength and in perceived exertion in CC than in CWI or in the use of compression garments.

To conclude, we believe that applying CC during the pre-season is a potential method of promoting the recovery of muscle damage associated with competition and training. In particular, it has been demonstrated that CC improved muscle recovery in basketball players during an 8-week long pre-season, associated with reductions in muscle pain markers. Furthermore, improvements in muscle strength and the significant reduction of perceived fatigue at the end of the study, suggest a reduction of muscle fatigue in the group of athletes that received CC.
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Conflict of interests

The authors claim to have no conflict of interest whatsoever.

Bibliography

Compressive cryotherapy as a non-pharmacological muscle recovery strategy and with no adverse effects on basketball.

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