Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 11), Art 368, pp. 2913-2919, November 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Can ischemic preconditioning improve CMJ performance in young elite basketball players? A pilot study.

RICART LUNA B[1], CERRILLO J[2], RODRIGO-MALLORCA D[3]*, ALONSO-AUBIN DA[4], CHULVI-MEDRANO I[5].
[1,2,]Alquería Lab. Valencia. SPAIN
[3,5]Sport Performance and Physical Fitness Research Group (UIRFIDE). University of Valencia, Valencia, SPAIN.
[4]Strength Training and Neuromuscular Performance Research Group (STreNgthP). Camilo Jose Cela University, Madrid, SPAIN.
[4]Wingsport. Madrid.

Published online: November 30, 2022
(Accepted for publication November 15, 2022)
DOI:10.7752/jpes.2022.11368

Abstract:
Ischaemic preconditioning (IP) is a non-invasive method based on brief periods of ischaemia followed by periods of blood reperfusion by means of a tourniquet placed on the proximal part of the limb to be trained. In recent years, its effects on post-activation performance enhancement (PAPE) have been investigated as a pre-workout potentiation strategy with high demands on strength and neuromuscular power. The objective of the present study was to record the acute effects induced by an ischemic preconditioning (IPC) protocol on jumping ability in elite basketball players. 22 basketball players (17.31 (1.35) years old; 195 (0.05) cm; 86.36 (6.71) kilograms; 22.60 (1.73) kg/m^2) from a professional club were recruited. After a familiarization phase with IPC subjects were involved in the experimental phase (48 h after). Following 5 minutes cycling warm-up a pressurized cuff (250 mmHg) was applied in the inguinal region using a protocol of 4 sets of 5 minutes with IPC interspersed 5 minutes of reperfusion (0 mmHg). 5 countermovement jumps on platform force were performed before and after (10minutes after) IPC protocol. IPC intervention showed a significant ($p<0.05$) increased acute jump performance in the mean PRE 31,02 (4.13) cm / 1026.90 (101.28) watts vs POST 32.97 (3.60) cm / 1058,55 (92.72) watts and in the best record PRE 32.55 (4.05) cm /1052.57 (100.83) watts VS POST 34.66 (4.10) cm / 1080.42 (103.11) watts on CMJ jump. The results showed a small size effect. IPC as warm-up in young elite basketball players may induce post-activation performance enhancement in power increasing CMJ outcome.
Key words: jump, occlusion pressure, blood flow restriction, PAPE .

Introduction

The cardioprotective effects of cycles of occlusion followed by reperfusion or ischemic preconditioning (IPC) were initially described in a canine sample (Murry et al., 1986). Subsequently, similar benefits were verified in a human sample (Cho & Kim, 2019). In humans, IPC application has even been extended to the sports field since it seems that it could improve posterior performance (Caru et al., 2019; O'Brien & Jacobs, 2021; Salvador et al., 2016). Although the molecular mechanisms underlying this effect have not been discovered (O'Brien & Jacobs, 2021), its application is expanding.

IPC consists of exposure to short periods of blood flow restriction (BFR) in a rested position (e.g. seated or lying down position), followed by periods of reperfusion (Loukogeorgakis et al., 2005; Murry et al., 1986; Shimizu et al., 2009). IPC was shown to improve cycling performance and Wingate performance, among other capabilities (Crisafulli et al., 2011; de Groot et al., 2010). The mechanisms that could induce these effects could be an enhanced adenosine triphosphate (ATP) production by glycolytic and phosphogenic pathways (Addison et al., 2003; Pang et al., 1995). Also, IPC was shown to improve skeletal muscle blood flow by inducing conduit artery vasodilatation (Enko et al., 2011), inducing functional sympatholysis (Horiuchi et al., 2015). Thus, it is presumed that IPC could be an interesting intervention for improving exercise capacity and sports performance.

The most common way in which IPC is used is through a protocol involving three or four 5-minute cycles of circulatory occlusion (using a variety of occlusion levels from 100 mmHg to 300 mmHg) followed by reperfusion (Carvalho & Barroso, 2019; Incognito et al., 2016; O'Brien & Jacobs, 2021). Moreover, as an easy to administer, non-invasive, and potentially inexpensive intervention, it could be a good option for improving

Corresponding Author: RODRIGO-MALLORCA D, E-mail: dariorodrigom@gmail.com

performance in subsequent competition as PAPE effect. On neuromuscular performance it has been proven that there are benefits on isometric strength, aerobic and anaerobic capacity (Amani-Shalamzari et al., 2019).

Explosive strength and power levels in basketball players have been shown to be related to their performance (de los Reyes et al., 2020). One of the ways in which power is represented during the game is through jumping ability (Santos & Janeira, 2008). Actions both defensive (blocks, rebounds and steals) and offensive (passes, rebounds and shots to the basket), are conditioned by the height and / or timing of the jump (Ziv & Lidor, 2010). Throughout a basketball game, each player performs more than 50 jumps (McInnes et al., 2008), for which a small improvement in jumping ability could lead to an advantage over the opponent. In high-performance sport, the countermovement jump (CMJ) is used to register changes in neuromuscular outcome, and to quantify adaptations to training programs (Heishman et al., 2020).

In certain way IPC induces an increase in subsequent performance that may be very similar to the PAPE phenomenon. In this way a recent study has examined the post-activation potentiation effects of body-weight lunge exercises with blood-flow restriction on jump performance in eighteen anaerobically trained men (Doma et al., 2020). Therefore, it is conceivable that IPC could improve explosive strength and power on a sport such basketball in which explosive actions and jumps are decisive in performance.

However, to the best authors knowledge, few studies have been carried out investigating the possible effects of IPC it could have on a sport such as basketball, in which explosive actions and jumps predominate and these actions being decisive. These previous studies have contradictory data, Beaven et al. (2012) reported an improvement in CMJ performance after IPC, while Lindner et al. (2021) reported no improvement in CMJ performance after IPC. Consequently, the purpose of this study was to evaluate the effects of IPC on CMJ. We hypothesized that IPC would increase acute CMJ performance.

Methods

Participants

Twenty-two young elite basketball players (17.31 (1.35) years old; 195 (0.05) cm; 86.36 (6.71) kg; 22.60 (1.73) kg/m2) volunteered to participate in this study. All of them were members of professional basketball club. Exclusion criteria were musculoskeletal injury, cardiovascular disease, and the general exercise contraindications. Experimental procedures of the study were approved by the ethics committee of the University of Valencia (Number: 1523453) and investigations involving humans were in accordance with the ethical standards laid down in the 2013 updated Declaration of Helsinki.

Procedure

Informed consent document was obtained from all subjects and his parent/guardian. All tests were performed in the same facilities. As shown in Figure 1, the intervention was divided into three sessions, Familiarization (FAM), Pre-Test (PRE) and Post-Test (POST). To avoid any confounding circadian effect all the protocol was performed at same hours. All test was conducted by the same researcher, that is Conditioning and Strength Specialist and educated in blood flow restriction technique and CMJ test.

Familiarization (FAM)

In the first session anthropometric measurements were taken (Seca 769, CE 0123, Ltd., Hamburg, Germany) and body mass (Tanita BC-601, Tokyo, Japan), the participants were given a familiarization session in which they were lying down total reclined on the stretcher without any movement and the cuffs were placed on the proximal part of both legs performing 2 sets of 5 minutes at 100 mmHg of pressure. The familiarization protocol was achieved using a high-precision compression meter (Riester Komprimeter; Riester Germany). The cuff dimensions were 57 cm long x 9 cm wide.

Pre-Test (PRE) and Post-Test (POST)

About 48 hours after familiarization session the baseline measures were performed. To reduce any expectation or placebo effect, no information about the study was explained. Participants performed five maximal CMJs with ~30 s between each jump. Each trial began with subjects standing on the force plates with knees fully extended and hands on hips to eliminate the influence of arm swing. Participants were then instructed to descend to a self-selected countermovement depth and to jump as high and as fast as possible. A Chronojump Boscosystem® (Barcelona, Spain) was used to measure the vertical jump. It was performed following the recommendations of Bosco jump test battery for CMJ performance (Bosco et al., 1983). The jump height and difference were determined in two conditions: pre-intervention and post-intervention immediately after applying IPC. Countermovement jumps were performed and the best of three attempts at each time point, determined by maximal force (N), was recorded.

Ischemic Preconditioning (IPC)

IPC was performed by applying the cuffs pressurized to 250 mmHg (Kim et al., 2012) in the inguinal region of both legs. Four sets of 5 minutes were performed (inducing ischemic intervals), interspersing the sets with 5 minutes of rest for reperfusion. The total duration of the procedure was 40 minutes.

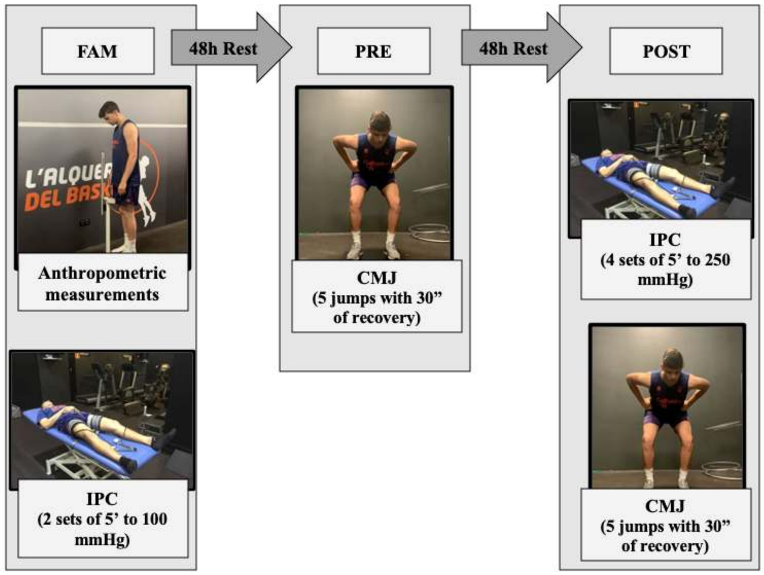

Figure 1. Protocol intervention

Statistical Analysis

The acute changes on the performance jump with CMJ were assessed at (1) baseline (pre) and (2) immediately upon finishing the intervention (post). An intrasubject of repeated measures study design was used where each subject performed the test CMJ pre and post intervention with IPC and served as a control himself. All measurements on the sample were performed pre and immediate post-intervention (acute response). To describe the data standard deviation and mean were used. Data distribution was analyzed with Shapiro-Wilk normality test. For normally distributed variables Student's T-test for related sample were applied to examine the effect of intervention on jump high (pre vs post) Data were prepared with Microsoft Excel 2016 and were analyzed using SPSS software version 21.0 (IBM Corp, Armond, NY, USA). Alpha was set at $p < 0.05$ considered statistically significant for all comparisons. To normalize the differences between small samples, groups differences between groups the effect size study was applied using Cohen's delta ([mean post-test - mean pre-test]/standard deviation pre-test). To determine the effect size of the intervention, the values for trained subjects published by Rhea (2004) were: trivial effect $d<0.25$; small effect d= 0.25-0.50; moderate effect d= 0.50-1.0; large effect $d > 1.0$.

Results

Descriptive characteristics of participants are summarized in Table 1.

Table 1. Characteristics of participants (n = 22)

Characteristics	N	Range	Minimum	Maximum	Mean	SD
Age (y)	22	4.00	16.00	20.00	17.32	1.36
Height (m)	22	0.19	1.85	2.04	1.96	0.06
Body mass (kg)	22	29.30	67.30	96.60	86.36	6.71
BMI (kg/m²)	22	6.34	19.66	26.00	22.61	1.73

Abbreviations: BMI, body mass index.

IPC intervention showed a significant ($p<0.05$) increased acute jump performance in the pre/post mean +1.95 cm and in the best record +2.11 on CMJ jump (Table 2) this reflects a percentage increase of 6.29 % and 6.49% respectively. For power the data was similar, showed significantly greater values post IPC.

Table 2. Comparison pre-post in CMJ variables.

Variables	Mean	SD	Mean Dif.	SD of Dif.	Δ%	p	d
CMJpre_mean_cm	31,02	4,13	1,95	1,37	6,29	<0,01	0,50
CMJpost_mean_cm	32,97	3,61					
CMJpre_best_cm	32,55	4,05	2,11	1,74	6,49	<0,01	0,52
CMJpost_best_cm	34,67	4,11					
CMJ_pre_mean_w	1026,91	101,29	31,65	26,50	3,08	<0,01	0,32
CMJpost_mean_w	1058,56	92,73					
CMJ_pre_best_w	1052,57	100,83	31,85	28,43	3,03	<0,01	0,31
CMJ_best_w	1084,42	103,11					

Abbreviations: CMJ, countermovement jump; cm, centimeters; w, watts; SD, standard deviation; Dif, difference, d, effect size

The effect size analysis in the IP intervention showed a moderate effect in the pre/post mean conditions for jump height (cm) (d = 0.50) but a small effect size in the pre/post mean conditions for developed power (watts) (d = 0.32). The same is true for the best records showing a moderate effect in the pre/post best record conditions for jump height (cm) (d = 0.52) but a small effect size in the pre/post best record conditions for developed power (watts) (d = 0.31). Figure 2 shows the jump values of all individually performed CMJs. It may be seen that there is no clear heterogeneity in the incremental response after CPI, it should be underlined that out of the 22 subjects 14 subjects showed their best jump in 4 (n=8) and in 5 (n=6).

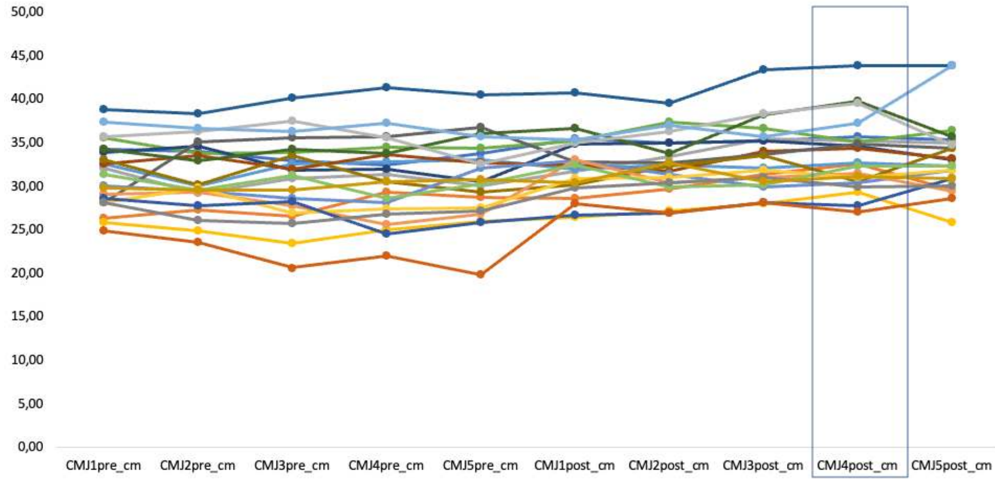

Figure 2. Individual CMJ values during all jumps

Discussion

The use of ischemic preconditioning as an ergogenic strategy has shown a positive trend in both aerobic and anaerobic activities (Salvador et al., 2016), but there is little evidence on the effects it can generate on jumping capacity. Our aim was to test whether the application of IPC would increase performance on jumping capacity. The main finding found from our results is an increase in jumping ability, both in the best and mean of the 5 jumps performed. As we hypothesized, we can conclude that an increase in CMJ was induced by IPC. To the best of our knowledge, only 2 studies have examined the probable ergogenic effects of IPC on jumping ability (Beaven et al., 2012; Lindner et al., 2021).

Our data are consistent with previous research. Beaven et al. (2012) reported an acute increase on jump height CMJ with 6 kg bar in a 10 health young subjects after an IPC intervention consisting of 2 x 3 min with a pressure of 220 mmHg applied unilaterally. In a similar way, since it was a small sample, they calculated the effect size (ES = 0.61) and it was very similar to ours (ES= 0.52). These findings contrast with a previous study which reported no ergogenic effect. Lindner et al 2021 has been showed no effect on jump ability (Lindner et al., 2021) in 14 NCAA athletes. In this case IPC was induced applying 100 percent occlusion, which is a lower value than that applied in our investigation (250 mmHg). This fact could suggest a correlation between the degrees of external occlusion and the effects of IPC, although it should be noted that in the same line of the BFR there could be a hermetic relationship as previously suggested (Loenneke et al., 2014).

Several mechanisms have been proposed as responsible for generating the ergogenic effects of IPC that could suggest the possibility of optimizing the conditions of muscle strength capabilities. Valenzuela et al. (2021) found that the performance of IPC 40 minutes before did not cause benefits on the load-force-velocity ratio or the number of repetitions to muscle failure in the bench press exercise (Carvalho & Barroso, 2019). The results are similar when performed on lower limbs (e.g. knee extension) (O'Brien & Jacobs, 2021). Similar conclusion has been reported when the neuromuscular variables analyzed were isometric. This no effect in the neuromuscular capabilities is transferred to a no ergogenic effect in the field situation for instance in sprint capability (Gibson et al., 2013; Thompson et al., 2018). However, it does seem to have an ergogenic effect when applied in sprint swimmers (Ferreira et al., 2016). In our case, there does not seem to be a trend about the best moment when there is a greater effect in CMJ (Figure 2). The inconsistency of the data may be due to the great heterogeneity of the methodological application of the IPC and in the lack of knowledge of the exact physiological mechanisms (O'Brien & Jacobs, 2021). In this sense both the level of occlusion and the time from application to subsequent exertion may be defining.

Firstly, our study applied 250 mmHg versus 220 mmHg which is generally applied. The decision was because recently it has been described the need to increase the level of occlusion to improve explosive strength by applying BFR in squat (Gepfert et al., 2020). Likewise, these values have been previously used in clinical population without reporting adverse effects (Chung et al., 2021) and in previous studies on sports performance this level of occlusion has been applied to induce IPC (ter Beek et al., 2020). However, the application of 250 mmHg does not seem to have a positive effect, for example, Ter Beek et al (2020) reported no ergogenic effect but data suggest that IPC in a maximal power output cycling test may attenuate the perception of effort at higher. Similar results have been reported on peak isometric torque and rate of force development. Therefore, the authors conclude that CPI will have no impact on explosive actions such as sprinting or jumping (Carvalho & Barroso, 2019).

On the other hand, the time for the IPC to take effect is unknown; if it is assumed that it has an immediate acute effect due to the anaerobic metabolic demand, the ergogenic effect should occur immediately after the intervention (Incognito et al., 2016), as in our case. However, if the mechanisms of potentiation are like those proposed by PAPE these ergogenic effects the time course of their force enhancements delayed effect (after minutes) in PAPE (Blazevich & Babault, 2019). Recently, a rest interval duration of 5:57 ± 2:44 min:sec has been suggested. was an effective and practical strategy to obtain the PAP at CMJ height in strength-trained individuals (do Carmo et al., 2021).

This study has several limitations that should be highlighted for the interpretation of the data of the present research. First, the sample is small and has a high training status. Secondly, neither a control group nor a SHAM group was included in which the CPI was applied with lower external occlusion (e.g. 20 mmHg). Due to our limitations and the scarcity of similar research, results should be taken with caution and further research is needed.

Conclusions

Passively applied IPC in the pre-training or competition phases, as a part of the warm-up, may induce an improvement in jumping performance due to its post-activation potentiation effect and, although it requires further research, as a practical recommendation it can be included as a warm-up in young elite basketball players and induce a post-activation performance improvement in the CMJ result that increases power, since it is a safe tool for athletes.

Conflicts of interest: The authors declare that they have no conflicts of interest.

References

Addison, P., Neligan, P., Ashrafpour, H., Khan, A., Zhong, A., Moses, M., Forrest, C., & Pang, C. (2003). Noninvasive remote ischemic preconditioning for global protection of skeletal muscle against infarction. *American Journal of Physiology. Heart and Circulatory Physiology*, *285*(4). https://doi.org/10.1152/AJPHEART.00106.2003

Amani-Shalamzari, S., Rajabi, S., Rajabi, H., Gahreman, D. E., Paton, C., Bayati, M., Rosemann, T., Nikolaidis, P. T., & Knechtle, B. (2019). Effects of Blood Flow Restriction and Exercise Intensity on Aerobic, Anaerobic, and Muscle Strength Adaptations in Physically Active Collegiate Women. *Frontiers in Physiology*, *10*, 810. https://doi.org/10.3389/FPHYS.2019.00810

Beaven, C., Cook, C., Kilduff, L., Drawler, S., & Gill, N. (2012). Intermittent lower-limb occlusion enhances recovery after strenuous exercise. *Applied Physiology, Nutrition, and Metabolism*, *37*(6), 1132–1139. https://doi.org/10.1139/H2012-101

Blazevich, A. J., & Babault, N. (2019). Post-activation Potentiation Versus Post-activation Performance Enhancement in Humans: Historical Perspective, Underlying Mechanisms, and Current Issues. *Frontiers in Physiology*, *10*, 1359. https://doi.org/10.3389/FPHYS.2019.01359

Bosco, C., Luhtanen, P., & Komi, P. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology*, *50*(2), 273–282. https://doi.org/10.1007/BF00422166

Caru, M., Levesque, A., Lalonde, F., & Curnier, D. (2019). An overview of ischemic preconditioning in exercise performance: A systematic review. *Journal of Sport and Health Science*, *8*(4), 355–369. https://doi.org/10.1016/J.JSHS.2019.01.008

Carvalho, L., & Barroso, R. (2019). Ischemic Preconditioning Improves Strength Endurance Performance. *Journal of Strength and Conditioning Research*, *33*(12), 3332–3337. https://doi.org/10.1519/JSC.0000000000002846

Cho, Y., & Kim, W. (2019). Perioperative Cardioprotection by Remote Ischemic Conditioning. *International Journal of Molecular Sciences*, *20*(19). https://doi.org/10.3390/IJMS20194839

Chung, J., Hur, M., Cho, H., Bae, J., Yoon, H. K., Lee, H. J., Jeong, Y. H., Cho, Y. J., Ku, J. H., & Kim, W. H. (2021). The effect of remote ischemic preconditioning on serum creatinine in patients undergoing partial nephrectomy: A randomized controlled trial. *Journal of Clinical Medicine*, *10*(8), 1636. https://doi.org/10.3390/JCM10081636

Crisafulli, A., Tangianu, F., Tocco, F., Concu, A., Mameli, O., Mulliri, G., & Caria, M. (2011). Ischemic preconditioning of the muscle improves maximal exercise performance but not maximal oxygen uptake in humans. *Journal of Applied Physiology*, *111*(2), 530–536. https://doi.org/10.1152/JAPPLPHYSIOL.00266.2011 de Groot, P., Thijssen, D., Sánchez, M., Ellenkamp, R., & Hopman, M. (2010). Ischemic preconditioning improves maximal performance in humans. *European Journal of Applied Physiology*, *108*(1), 141–146. https://doi.org/10.1007/S00421-009-1195-2

de los Reyes, Y., Pardo, A., & Romero, D. (2020). Anthropometric comparison, explosive strength and agility in young basketball players from Bogotá-Colombia [in spanish]. *Retos*, *38*, 406–410.

do Carmo, E., de Souza, E., Roschel, H., Kobal, R., Ramos, H., Gil, S., & Tricoli, V. (2021). Self-selected Rest Interval Improves Vertical Jump Postactivation Potentiation. *Journal of Strength and Conditioning Research*, *35*(1), 91–96. https://doi.org/10.1519/JSC.0000000000002519

Doma, K., Leicht, A., Boullosa, D., & Woods, C. (2020). Lunge exercises with blood-flow restriction induces post-activation potentiation and improves vertical jump performance. *European Journal of Applied Physiology*, *120*(3). https://doi.org/10.1007/S00421-020-04308-6

Enko, K., Nakamura, K., Yunoki, K., Miyoshi, T., Akagi, S., Yoshida, M., Toh, N., Sangawa, M., Nishii, N., Nagase, S., Kohno, K., Morita, H., Kusano, K. F., & Ito, H. (2011). Intermittent arm ischemia induces vasodilatation of the contralateral upper limb. *Journal of Physiological Sciences*, *61*(6), 507–513. https://doi.org/10.1007/S12576-011-0172-9

Ferreira, T., Sabino-Carvalho, J., Lopes, T., Ribeiro, I., Succi, J., da Silva, A., & Silva, B. (2016). Ischemic Preconditioning and Repeated Sprint Swimming: A Placebo and Nocebo Study. *Medicine and Science in Sports and Exercise*, *48*(10), 1967–1975. https://doi.org/10.1249/MSS.0000000000000977

Gepfert, M., Krzysztofik, M., Kostrzewa, M., Jarosz, J., Trybulski, R., Zajac, A., & Wilk, M. (2020). The Acute Impact of External Compression on Back Squat Performance in Competitive Athletes. *International Journal of Environmental Research and Public Health*, *17*(13), 1–11. https://doi.org/10.3390/IJERPH17134674

Gibson, N., White, J., Neish, M., & Murray, A. (2013). Effect of ischemic preconditioning on land-based sprinting in team-sport athletes. *International Journal of Sports Physiology and Performance*, *8*(6), 671–676. https://doi.org/10.1123/IJSPP.8.6.671

Heishman, A., Daub, B., Miller, R., Freitas, E., Frantz, B., & Bemben, M. (2020). Countermovement Jump Reliability Performed With and Without an Arm Swing in NCAA Division 1 Intercollegiate Basketball Players. *Journal of Strength and Conditioning Research*, *34*(2), 546–558. https://doi.org/10.1519/JSC.0000000000002812

Horiuchi, M., Endo, J., & Thijssen, D. H. J. (2015). Impact of ischemic preconditioning on functional sympatholysis during handgrip exercise in humans. *Physiological Reports*, *3*(2). https://doi.org/10.14814/PHY2.12304

Incognito, A., Burr, J., & Millar, P. (2016). The Effects of Ischemic Preconditioning on Human Exercise Performance. *Sports Medicine*, *46*(4), 531–544. https://doi.org/10.1007/S40279-015-0433-5

Kim, J. C., Shim, J. K., Lee, S., Yoo, Y. C., Yang, S. Y., & Kwak, Y. L. (2012). Effect of combined remote ischemic preconditioning and postconditioning on pulmonary function in valvular heart surgery. *Chest*, *142*(2), 467–475. https://doi.org/10.1378/CHEST.11-2246

Lindner, T., Scholten, S., Halverson, J., Baumgarten, K., Birger, C., & Nowotny, B. (2021). The Acute Effects of Ischemic Preconditioning on Power and Sprint Performance. *South Dakota Medicine : The Journal of the South Dakota State Medical Association*, *74*(5), 210–219.

Loenneke, J., Thiebaud, R., Abe, T., & Bemben, M. (2014). Blood flow restriction pressure recommendations: the hormesis hypothesis. *Medical Hypotheses*, *82*(5), 623–626. https://doi.org/10.1016/J.MEHY.2014.02.023

Loukogeorgakis, S., Panagiotidou, A., Broadhead, M., Donald, A., Deanfield, J., & MacAllister, R. (2005). Remote ischemic preconditioning provides early and late protection against endothelial ischemia-reperfusion injury in humans: role of the autonomic nervous system. *Journal of the American College of Cardiology*, *46*(3), 450–456. https://doi.org/10.1016/J.JACC.2005.04.044

McInnes, S. E., Carlson, J. S., Jones, C. J., & McKenna, M. J. (2008). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences*, *13*(5), 387–397. https://doi.org/10.1080/02640419508732254

Murry, C., Jennings, R., & Reimer, K. (1986). Preconditioning with ischemia: a delay of lethal cell injury in ischemic myocardium. *Circulation*, *74*(5), 1124–1136. https://doi.org/10.1161/01.CIR.74.5.1124

O'Brien, L., & Jacobs, I. (2021). Methodological Variations Contributing to Heterogenous Ergogenic Responses to Ischemic Preconditioning. *Frontiers in Physiology*, *10*, 575. https://doi.org/10.3389/FPHYS.2021.656980

Pang, C., Yang, R., Zhong, A., Xu, N., Boyd, B., & Forrest, C. (1995). Acute ischaemic preconditioning protects against skeletal muscle infarction in the pig. *Cardiovascular Research*, *29*(6), 782–788.

Rhea, M. (2004). Determining the magnitude of treatment effects in strength training research through the use of the effect size. *Journal of Strength and Conditioning Research*, *18*(4), 918–920. https://doi.org/10.1519/14403.1

Salvador, A., de Aguiar, R., Lisbôa, F., Pereira, K., Cruz, R., & Caputo, F. (2016). Ischemic Preconditioning and Exercise Performance: A Systematic Review and Meta-Analysis. *International Journal of Sports Physiology and Performance*, *11*(1), 4–14. https://doi.org/10.1123/IJSPP.2015-0204

Santos, E. J., & Janeira, M. A. (2008). Effects of complex training on explosive strength in adolescent male basketball players. *Journal of Strength and Conditioning Research*, *22*(3), 903–909. https://doi.org/10.1519/JSC.0B013E31816A59F2

Shimizu, M., Tropak, M., Diaz, R. J., Suto, F., Surendra, H., Kuzmin, E., Li, J., Gross, G., Wilson, G. J., Callahan, J., & Redington, A. N. (2009). Transient limb ischaemia remotely preconditions through a humoral mechanism acting directly on the myocardium: Evidence suggesting cross-species protection. *Clinical Science*, *117*(5), 191–200. https://doi.org/10.1042/CS20080523

ter Beek, F., Jokumsen, P., Sloth, B., Stevenson, A., & Larsen, R. (2020). Ischemic Preconditioning Attenuates Rating of Perceived Exertion But Does Not Improve Maximal Oxygen Consumption or Maximal Power Output. *Journal of Strength and Conditioning Research*. https://doi.org/10.1519/JSC.0000000000003625

Thompson, K., Whinton, A., Ferth, S., Spriet, L., & Burr, J. (2018). Ischemic Preconditioning: No Influence on Maximal Sprint Acceleration Performance. *International Journal of Sports Physiology and Performance*, *13*(8), 986–990. https://doi.org/10.1123/IJSPP.2017-0540

Valenzuela, P., Martín-Candilejo, R., Sánchez-Martínez, G., Bouzas Marins, J., de la Villa, P., & Sillero-Quintana, M. (2021). Ischemic Preconditioning and Muscle Force Capabilities. *Journal of Strength and Conditioning Research*, *35*(8), 2187–2192. https://doi.org/10.1519/JSC.0000000000003104

Ziv, G., & Lidor, R. (2010). Vertical jump in female and male basketball players--a review of observational and experimental studies. *Journal of Science and Medicine in Sport*, *13*(3), 332–339. https://doi.org/10.1016/J.JSAMS.2009.02.009