BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

The Effect of Intermittent Pneumatic Compression in Reducing Pain and Restoring Muscle Function After Physical Training

Oky Dwi Silviyanti [1], Gadis Meinar Sari [2,*], Mohammad Fathul Qorib [3], Ahmad Assagaf Rahmat [1], Alam Hadi Kosasih [4] and Mochamad Azhar Ilmi [5]

1 Master Degree on Sport, Exercise and Health Science, Faculty of Medicine, Universitas Airlangga, Prof. Dr. Moestopo 47 Street, Surabaya 60131, East Java, Indonesia;
2 Departement of Physiology and Medical Biochemistry, Faculty of Medicine, Universitas Airalngga, Prof. Dr. Moestopo 47 Street, Surabaya 60131, East Java, Indonesia;
3 Departement of Anatomy, Histology and Pharmacology, Faculty of Medicine, Universitas Airlangga, Prof. Dr. Moestopo 47 Street, Surabaya 60131, East Java, Indonesia;
4 Departement of Physical Education, Faculty of Islamic Education and Teacher Training , Universitas Garut, Samarang Street No. 52A, Mekarwangi, Tarogong Kaler District, Garut Regency, West Java 44151, Indonesia;
5 Departement of Sport Science, Faculty of Sport and Health Science, Universitas Negeri Surabaya, Lidah Wetan, Lakarsantri, Surabaya 60213, East Java, Indonesia

* Correspondence: gadis-m-s@fk.unair.ac.id

Citation: Silviyanti O.D., Sari G.M., Qorib M.F., Rahmat A.A., Kosasih A.H., Ilmi M.A. - The Effect of Intermittent Pneumatic Compression in Reducing Pain and Restoring Muscle Function After Physical Training
Balneo and PRM Research Journal ***2026**, 17(1): 950*

Academic Editor(s):
Constantin Munteanu

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 17.12.2025
Published: 31.03.2026

Reviewers:
Cristina Popescu
Alexandra Ecaterina Ciota

Abstract: Delayed onset muscle soreness (DOMS) is a common problem that affects performance when left untreated. Intermittent pneumatic compression (IPC) was a recovery method used to reduce pain intensity. However, the effects of IPC on pain intensity and leg muscle strength had not been extensively studied, and the effectiveness remained unclear. Objec-tives: This study aimed to analyze the benefits of IPC as a recovery aid after physical activ-ity. Method: The experimental study comprised 16 young men who were randomly assigned to two groups, namely intervention (IN) and control (CN). Both groups carried out countermovement jumps (CMJ), completing 20 repetitions in each of 5 sets. The IN group then received IPC intervention for 20 minutes, while the CN group rested. Pain intensity in leg muscles, vertical jump performance, leg muscle strength, and creatine kinase (CK) levels were measured. A pre-test was conducted before the intervention, and a post-test was conducted 24 hours after the intervention. Result: There were significant results for quadriceps muscle pain intensity (p=0.000), hamstring muscle (0.005), vertical jump (p=0.000), leg muscle strength (0.003), and CK levels (p=0.044). Conclusion: IPC application was effective in reducing pain intensity due to delayed-onset muscle soreness. This method was also effective as a clearance to aid recovery by reducing CK levels after plyometric training.

Keywords: intermittent Pneumatic Compression, DOMS, Plyometric, Creatine Kinase

1. Introduction

Injury is the main problem encountered by people during physical training. Sports injuries can occur in muscles, bones, ligaments, and tendons, caused by several factors, including overtraining, overuse, being overweight, field conditions, or environmental factors. However, some complaints resulting from physical training do not constitute injuries, such as delayed onset muscle soreness (DOMS). This condition occurs 8 to 24 hours after exercise and can peak, then gradually subside within 48–72 hours [1,2,3,4].

DOMS is characterized by a sensation felt when muscles are moved or stretched, with increased pain and stiffness [5]. The onset of pain is due to physiological damage to the sarcomere, which causes a decrease in muscle strength, function, and rate of velocity development (RVD) [6,7,8,9]. However, muscle strength and RVD return to normal on the second and third days after exercise [9]. In addition to causing pain, microtrauma from DOMS leads to increased indicators of muscle damage in the blood. Creatine kinase (CK) is a serum biomarker widely used to assess exercise-induced muscle damage (EIMD) [10,11,12]. CK is an enzyme found in the cytosol and mitochondria with high energy requirements, especially in skeletal muscle. An increase in CK levels shows disruption and leakage of intracellular enzymes in the muscle cell membrane into the bloodstream [10,13]. CK levels increase sharply within 24 hours after exercise and then gradually decrease and return to baseline levels [14]. DOMS can be reduced with several other treatments, such as taking antioxidant supplements, intermittent pneumatic compression, massage, and roller massage [15,16,17].

Intermittent pneumatic compression (IPC) is a device that uses pressurized methods, such as peristaltic motion, to enhance blood circulation, leading to increased oxygen in the muscles and aiding in the removal of metabolic waste from the body [18]. The function of this device is similar to blood vessel compression to increase blood circulation, thereby enabling temporary pain reduction and benefiting people who are physically and psychologically active [17]. Physiologically, IPC improves blood circulation and metabolic recovery by mimicking the function of natural muscle pumps. This increases venous and lymphatic return, as well as metabolic cleansing, such as blood lactate [19,20,21]. IPC can also prevent the formation of deep vein thrombosis (DVT) by reducing venous stasis and activating fibrinolysis [22,23]. However, studies discussing the effects of IPC on exercise-induced muscle soreness are still limited. Skeletal muscles play a significant role in the human body during activity, exercise, recovery, and injury. Exercises that significantly use eccentric contractions often cause DOMS.

Eccentric contractions cause the series elastic component (SEC) and the parallel elastic component (PEC) to stretch, generating greater force and causing microtrauma. This condition leads to the release of hydroxyproline, which triggers a pain response [24]. Plyometrics produce eccentric contractions and generate 10-40% greater force compared to concentric contractions [24]. According to previous studies, Plyometric training, known as the stretch-shortening cycle (SSC), uses explosive movements that increase muscle strength and speed [25,26]. Therefore, this study aimed to analyze the effectiveness of IPC as a recovery modality after physical training.

2. Materials and Methods

Study Participant

Participants in this study included young and healthy men, aged 19-24 years, who met the inclusion criteria. These inclusion criteria comprise performing a minimum of 150 minutes per week of moderate intensity aerobic exercise [27], no history of musculoskeletal injury, and a normal body mass index (BMI) based on the Asia Pacific criteria of 18.5-22.9 kg/m^2 [28]. Meanwhile, participants who performed eccentric activities within three days before the study and consumed nonsteroidal anti-inflammatory drugs (NSAIDs), muscle relaxants, opioids, and corticosteroids were excluded [29,30].

Study Design

A true-experimental pre-test and post-test design was adopted, and participants were randomly divided into two groups, namely intervention (IN, n=8) and control (CN, n=8). Group assignment was carried out by lottery, with the subjects' names kept confidential. All participants from the IN and CN group carried out plyometric training in the form of countermovement jump (CMJ) for 20 repetitions for each of 5 sets with a 1-minute rest between sets [31,32].

After carrying out plyometrics, IN immediately received IPC (Normatec Recovery System, Watertown, MA, USA). Pressure was applied to the IPC intermittently with an intensity of 110 mmHg for 20 minutes to the limb [33,34]. During the treatment, the participant was in an upright sitting position with both legs extended. The IPC operated through several stages, commencing with pre-inflation, during which the device expanded and conformed to the shape of the limb. During pulsing, the device produced gentle pulsations resembling peristaltic movement. Backflow prevention stopped blood from flowing backward in the vessels. In the sequential pulse stage, pulsations moved sequentially from distal to proximal, alternating between limbs, with each pulsation lasting approximately 60 seconds. This protocol was consistent with the manufacturer's recommendations and previous studies [17,33,34]. Meanwhile, the CN group rested in the same position as the participants in the IN group for 20 minutes. All procedures carried out in this study have passed ethical review and were declared sound by the Health Research Ethics Committee, Faculty of Medicine, Universitas Airlangga, with the No.51/EC/KEPK/FKUA/2024. Before the activities, participants were provided with complete information about this study and asked for consent before participating.

Outcome Measurement

Measurements of pain intensity, vertical jump, and leg muscle strength were taken at two time points, namely pre test before plyometric and recovery treatment and post test 24 hours after plyometric and recovery treatment. Pain levels were measured using a visual analog scale (VAS), with participants circling a number between 0 and 10 to represent perceived discomfort [35]. The procedure for assessing pain intensity in the quadriceps muscle included carrying out eccentric movements with the quadriceps or squatting. For the hamstring muscle, the participant bent the leg and pushed the knee toward the chest. In the case of gastrocnemius, the participant sat on the floor with both legs straight and hands touching the fingertips while bending the body forward. Vertical jump and leg muscle strength measurements were taken before and 24 hours after the intervention using a dual force plate device (Forcedecks, FDLite V.2, VALDHUB, Australia). The movements carried out included CMJ to determine jump height and the squat with the hands holding the dual force plate to determine leg muscle strength [36,37,38]. CK levels were taken 24 hours after the plyometric exercise intervention at 10:00 AM. Blood samples were drawn from the median cubital vein using a phlebotomy technique, collecting 3 cc. The blood samples were then transported to a laboratory for analysis using the enzyme-linked immunosorbent assay (ELISA) method with the Integra 400 plus analyzer (serial number 422091) [39].

Statistical Analysis

The sample size was determined using the Higgins and Kleinbaum formula [40] based on VAS data from the study by Ilmi et al (2025) [41], with (Mean ± SD) intervention (1.40 ± 0.548) and control (3.83 ± 0.753) groups. Based on this calculation, the number of subjects was eight per group. All statistical analyses were carried out using SPSS software version 26 (Chicago, IL, USA) with a significance level of $p<0.05$. The mean and standard deviation of the data were presented. To determine normally distributed data, the Shapiro-Wilk normality test was used with a significance value of $p > 0.05$. Data on pain intensity, vertical jump, and leg muscle strength were calculated using one-way ANOVA. CK data were calculated using an independent samples t-test.

3. Results

Based on Table 1, there were average participant values for the IN and the CN groups. The homogeneity test for age, height, and weight showed that the data were normally distributed and there were no significant differences between the IN and CN groups ($p>0.05$). However, there was a significant difference in BMI between the two groups, as evidenced by $p<0.05$.

Table 1. Characteristics of subjects

Variable	Group (Mean ± SD)		P-value
	IN (n=8)	CN (n=8)	
Age	21.13 ± 1.553	21.00 ± 1.195	0.689
Height	167.00 ± 7.151	169.75 ± 5.849	0.599
Weight	63.75 ± 6.541	63.88 ± 4.291	0.323
BMI	22.38 ± 1.768	22.50 ± 1.069	0.045

Note: IN (Intervention group); CN (Control group); BMI (Body mass index); p-value (Levene test)

Table 2 shows the results of the one-way ANOVA test for pain intensity. The results were significant in the quadriceps muscle and hamstring muscle, with p-values of 0.000 and 0.005, respectively. However, there was no significant value for the gastrocnemius muscle. Vertical jump showed significant differences for both pre-exercise ($p = 0.013$) and post-exercise ($p = 0.000$), as well as leg muscle strength ($p = 0.003$).

Table 2. Pain intensity (quadriceps, hamstring, and gastrocnemius), vertical jump, and leg muscle strength between the treatment group and the control group

Variable	Group (Mean ± SD)		P-value	Effect Size (η^2)
	IN (n=8)	CN (n=8)		
VAS Quadriceps				
Pre-exercise	0.75 ± 0.463	0.75 ± 0.707	1.000	0.000
Post-exercise	1.88 ± 1.246	5.63 ± 1.685	0.000*	0.647
VAS Hamstring				
Pre-exercise	0.63 ± 0.518	0.88 ± 0.641	0.405	0.050
Post-exercise	1.63 ± 2.066	4.50 ± 1.309	0.005*	0.441
VAS Gastrocnemius				
Pre-exercise	1.25 ± 0.463	0.88 ± 0.641	0.201	0.114
Post-exercise	0.75 ± 0.886	2.00 ± 1.927	0.118	0.166
Vertical Jump (Cm)				
Pre-exercise	41.75 ± 4.950	35.63 ± 3.503	0.013*	0.368
Post-exercise	42.50 ± 4.243	31.50 ± 3.586	0.000*	0.691
Leg Muscle Strength (Kg)				
Pre-exercise	156.63 ± 29.534	162.75 ± 18.514	0.948	0.000
Post-exercise	158.88 ± 28.165	157.50 ± 16.57	0.003*	0.470

Note: Data are presented as Mean ± Standard Deviation; TR (treatment group); CN (control group); VAS (visual analogue scale); p-value: showing the results of the one-way ANOVA test calculation; * (significant); η^2 (effect size).

Table 3 shows the result of CK examined 24 hours after plyometric training and IPC intervention. Statistical analysis using the independent t-test showed that CK levels in the CN group were higher than in IN.

Table 3. Creatine kinase levels between the treatment group and the control group

Variable	IN (n=8)	CN (n=8)	P-value
	Mean ± SD	**Mean ± SD**	
Creatine Kinase (U/L)	304.63 ± 125.066	2266.13 ± 2507.773	0.044

Note: IN (intervention group); CN (control group); U/L (Unit per liter)

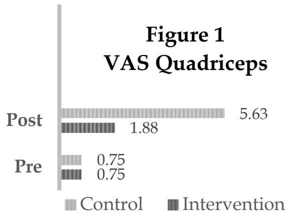

Figure 1
VAS Quadriceps

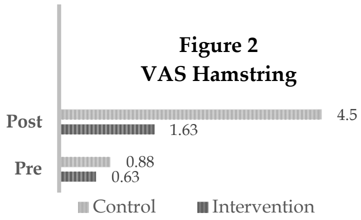

Figure 2
VAS Hamstring

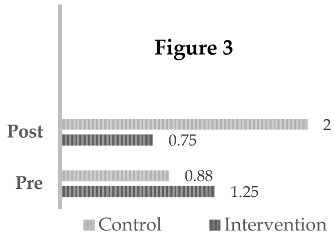

Figure 3

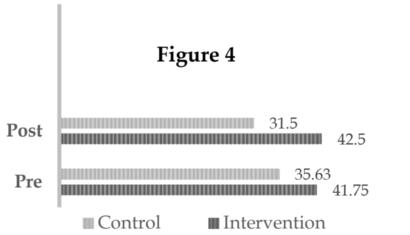

Figure 4

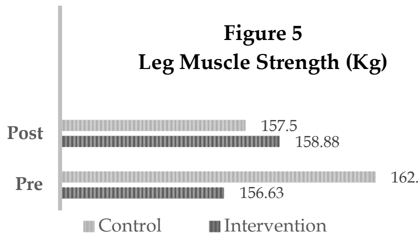

Figure 5
Leg Muscle Strength (Kg)

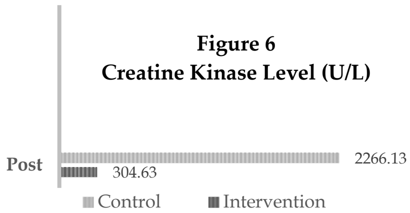

Figure 6
Creatine Kinase Level (U/L)

Figures 1 – 5 show the effect of intermittent pneumatic compression on pain intensity, vertical jump, limb muscle strength, and CK levels in the intervention and control groups.

4. Discussion

This study investigated the effect of IPC on pain intensity, vertical jump, leg muscle strength, and CK level after plyometric exercise. The result shows that administering IPC for 20 minutes after plyometric exercise reduces muscle pain in the quadriceps and hamstrings for the intervention group (IN) 24 hours after plyometric exercise, compared to the control group (CN). Furthermore, CK levels in IN were lower than in CN, and IPC showed significant results in both groups on vertical jump.

According to Gussoni et al (2023), plyometric exercise causes muscle damage that disrupts the protein structure within the muscle, leading to inflammation and pain [5]. This result is consistent with the report of Draper et al (2020) that IPC can reduce muscle pain resulting from plyometric exercise [17]. The mechanism of IPC in recovery includes pressurized methods, such as peristaltic movements, which improve blood circulation and promote venous return and lymphatic flow. These effects increase dopamine and serotonin levels, decrease cortisol levels, and gradually reduce muscle pain [17,18,42].

The most intense muscle pain after physical exercise was felt in the quadriceps, followed by hamstrings and gastrocnemius. The quadriceps muscles are dominated by fast-twitch fibers (type II glycolytic), which are prone to structural damage, leading to higher pain [43,44]. These fibers have limited oxidative capacity, leading to faster fatigue and lactate accumulation [45]. However, hamstrings and gastrocnemius have a higher proportion of slow-twitch fibers (Type I), ensuring resistance to exercise-induced damage. The hamstring muscles are prone to stretching because each crosses two joints, while the gastrocnemius provides stability through the Achilles tendon [46,47,48]. Plyometric movements, such as the CMJ, place a greater load on the quadriceps muscles due to eccentric contractions compared to the hamstrings and gastrocnemius. This condition leads to more dominant muscle damage in the quadriceps [49]. Eccentric exercise triggers microtrauma in fast-twitch fibers, leading to protein degradation and the release of hydroxyproline, which induces a stimulus as a pain response [50,49,24,51,52].

In this study, the vertical jump data showed significant results between the IN group and the CN group. The results for leg muscle strength also showed significant differences between the groups. A study conducted by Maia et al (2024) found that IPC has a significant effect on vertical jump [53]. The application of IPC after physical exercise prevents a decrease in muscle performance, which affects vertical jump height, reduces lactate levels, and decreases pain immediately after exercise and 48 hours later [54,42]. IPC affects muscle fibers and proprioceptive signaling, both of which contribute to neuromuscular recovery and muscle tone regulation [53]. The study conducted by Cochrane et al (2013) used vertical jump and dynamometry tests to measure jump height and limb muscle strength, with data collected before training and 24, 48, and 72 hours after. Northey et al (2016) also took measurements before and after training (24 hours). The results of both studies showed no significant difference in terms of time between the IPC and control groups. However, this study used different variables and data collection points [55,56].

In this study, CK levels in the IN group were lower compared to CN. This result supports the hypothesis regarding the effect of IPC on recovery after a series of exercises. CK levels increase significantly within 24 hours after exercise, especially after intense eccentric exercise [57]. This increase in CK can be stimulated by microtrauma to the muscles engaged during exercise [58]. CK levels gradually decrease after 48 hours, and this process is more effective when the muscles get enough rest [59]. IPC helps improve blood circulation, which increases oxygen supply to the muscles, thereby returning blood flow to the heart and helping to eliminate metabolic waste from the body [18]. This process reduces the accumulation of metabolic byproducts, including lactic acid, and accelerates clearance through increased perfusion of metabolically active tissues, such as the liver and skeletal muscles [21]. Smooth blood circulation adequately delivers oxygen to skeletal muscles, supporting the energy production process (ATP) needed for optimal muscle function. In general, this process increases the regeneration of damaged cells because the produced ATP provides sufficient energy to meet cellular needs.

5. Conclusions

In conclusion, IPC application is effective in reducing pain intensity due to delayed-onset muscle soreness. This method is also effective as a clearance to aid recovery by lowering CK levels after plyometric training.

Study Limitations

This study has several factors that require further investigation. Future studies are recommended to use a larger sample size to minimize bias and include female subjects for a more diverse study. Furthermore, this study should be conducted over a longer period of time with different exercise variations to achieve optimal results.

Author Contributions: "Conceptualization, O.D.S. and A.A.R.; methodology, O.D.S.; software, O.D.S.; validation, G.M.S. and M.F.Q.; formal analysis, G.M.S.; investigation, M.F.Q.; resources, M.A.I. and A.A.R.; data curation, O.D.S and A.A.R.; writing—original draft preparation, O.D.S.; writing—review and editing, O.D.S. and A.H.K.; visualization, M.A.I.; supervision, M.A.I.; project administration, A.H.K.; funding acquisition, O.D.S.

Responsibility Statement

The authors declare that this work is original and has not been published elsewhere. The authors are responsible for the content and authenticity of this article, and the corresponding author confirms that all authors have read and approved the manuscript.

Funding

This work was not supported by a funding source.

Institutional Review Board Statement:

All procedures carried out on the participants have passed ethical review and were declared ethically sound by the Health Research Ethics Committee, Faculty of Medicine, Universitas Airlangga, with the No.51/EC/KEPK/FKUA/2024.

Informed Consent Statement:

Informed consent was obtained from all subjects included in the study.

Data Availability Statement:

Not applicable.

Acknowledgments:

The authors are grateful to the Department of Physiology, Universitas Airlangga, for supporting this study to completion. The authors are also grateful to the Faculty of Sport and Health Science, Universitas Negeri Surabaya, for giving permission to include some of its students as participants in this study.

Conflicts of Interest:

The author declares no conflict of interest

References

1. Afonso J, Clemente FM, Nakamura FY, Morouço P, Sarmento H, Inman RA, et al. The Effectiveness of Post-exercise Stretching in Short-Term and Delayed Recovery of Strength, Range of Motion and Delayed Onset Muscle Soreness: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. Front Physiol. 2021;12(5). https://doi.org/10.3389/fphys.2021.677581.
2. Fleckenstein J, Neuberger EWI, Bormuth P, Comes F, Schneider A, Banzer W, et al. Investigation of the Sympathetic Regulation in Delayed Onset Muscle Soreness: Results of an RCT. Front Physiol. 2021;12(September):1–13.
3. Sonkodi B, Kopa Z, Nyirády P. Post orgasmic illness syndrome (POIS) and delayed onset muscle soreness (DOMS): Do they have anything in common? Cells. 2021;10(8). https://doi.org/10.3390/cells10081867.
4. Torre MF, Martinez-Ferran M, Vallecillo N, Jiménez SL, Romero-Morales C, Pareja-Galeano H. Supplementation with vitamins C and E and exercise-induced delayed-onset muscle soreness: A systematic review. Antioxidants. 2021;10(2):1–17. https://doi.org/10.3390/antiox10020279.
5. Gussoni M, Moretti S, Vezzoli A, Genitoni V, Giardini G, Balestra C, et al. Effects of Electrical Stimulation on Delayed Onset Muscle Soreness (DOMS): Evidence from Laboratory and In-Field Studies. J Funct Morphol Kinesiol. 2023;8(4). https://doi.org/10.3390/jfmk8040146.
6. Behm DG, Baker KM, Kelland R, Lomond J. The Effect of Muscle Damage on Strength and Fatigue Deficits. J Strength Cond Res. 2001;15(2):255–63. https://pubmed.ncbi.nlm.nih.gov/11710413/.
7. Byrne C, Eston RG, Edwards RT. Characteristics of isometric and dynamic strength loss following eccentric exercise-induced muscle damage. Scand J Med Sci Sport. 2001;11(3):134–40. https://pubmed.ncbi.nlm.nih.gov/11374426/.
8. Fridén J, Lieber RL. Eccentric exercise-induced injuries to contractile and cytoskeletal muscle fibre components. Acta Physiol Scand. 2001;171(3):321–6. https://doi.org/10.1046/j.1365-201x.2001.00834.

9. Nguyen D, Brown LE, Coburn JW, Judelson DA, Eurich AD, Khamoui A V, et al. Effect of delayed-onset muscle soreness on elbow flexion strength and rate of velocity development. J Strength Cond Res. 2009;23(4):1282–6. https://doi.org/10.1519/JSC.0b013e3181970017.
10. Magal M, Dumke CL, Urbiztondo ZG, Cavill MJ, Triplett NT, Quindry JC, et al. Relationship between serum creatine kinase activity following exercise-induced muscle damage and muscle fibre composition. J Sports Sci. 2010;28(3):257–66. https://doi.org/10.1080/02640410903440892.
11. Baird MF, Graham SM, Baker JS, Bickerstaff GF. Creatine-kinase- and exercise-related muscle damage implications for muscle performance and recovery. J Nutr Metab. 2012;2012. https://doi.org/10.1155/2012/960363.
12. Buffet-García J, Vicente-Campos D, López-Redondo M, Sánchez-Jorge S, Álvarez-González J, Plaza-Manzano G, et al. Association between Gray-Scale Ultrasound Imaging and Serological Creatine Kinase for Quantifying Exercise-Induced Muscle Damage: An Observational Study. Bioengineering. 2024;11(1). https://doi.org/10.3390/bioengineering11010040.
13. Watanabe LM, Fernandes de Lima L, Ferraz-Bannitz R, Takaara D, Coimbra Romano B, Braga Costa TM, et al. Association between creatine kinase activity, oxidative stress, and selenoproteins mRNA expression changes after Brazil nut consumption in patients using statins. Clin Nutr [Internet]. 2020;39(10):3175–81. Available from: https://doi.org/10.1016/j.clnu.2020.02.012
14. Brancaccio P, Maffulli N, Limongelli FM. Creatine kinase monitoring in sport medicine. Br Med Bull. 2007;81(1):209–30. https://doi.org/10.1093/bmb/ldm014.
15. Ranchordas MK, Rogerson D, Soltani H, Costello JT. Antioxidants for preventing and reducing muscle soreness after exercise: A Cochrane systematic review. Br J Sports Med. 2020;54(2):74–78. https://doi.org/10.1136/bjsports-2018-099599.
16. 16. Medeiros FVA, Bottaro M, Martins WR, Ribeiro DLF, Marinho EBA, Viana RB, et al. The effects of one session of roller massage on recovery from exercise-induced muscle damage: A randomized controlled trial. J Exerc Sci Fit. 2020;18(3):148–154. https://doi.org/10.1016/j.jesf.2020.05.002.
17. Draper SN, Kullman EL, Sparks KE, Little K, Thoman J. Effects of intermittent pneumatic compression on delayed onset muscle soreness (DOMS) in long-distance runners. Int J Exerc Sci. 2020;13(2):75–86. https://doi.org/10.70252/HSPN3402.
18. Won YH, Ko MH, Kim DH. Intermittent pneumatic compression for prolonged standing workers with leg edema and pain. Med (United States). 2021;100(28):E26639. https://doi.org/10.1097/MD.0000000000026639.
19. Artés A, Ferrer P, Javierre C, Viscor G, García I. Effects of intermittent pneumatic compression on the recovery of cardiovascular parameters after repeated sprint exercise. Eur J Appl Physiol [Internet]. 2024;124(4):1037–48. Available from: https://doi.org/10.1007/s00421-023-05333-x.
20. Rahmat AA, Sari GM, Qorib MF, Isna NM, Silviyanti OD, García-Jiménez JV, et al. High-pressure intermittent pneumatic compression applied immediately after physical exercise effectively reduces fatigue and enhances performance: a preliminary study. Retos. 2025 Apr. 1;66:950-6. https://doi.org/10.47197/retos.v66.113503.
21. Yanaoka T, Numata U, Nagano K, Kurosaka S, Kawashima H. Effects of different intermittent pneumatic compression stimuli on ankle dorsiflexion range of motion. Front Physiol. 2022;13(November):1–11. https://doi.org/10.3389/fphys.2022.1054806.
22. Kim NY, Ryu S, Kim YH. Effects of intermittent pneumatic compression device interventions to prevent deep vein thrombosis in surgical patients: A systematic review and meta-analysis of randomized controlled trials. PLoS One [Internet]. 2024;19(7 July):1–13. Available from: http://dx.doi.org/10.1371/journal.pone.0307602
23. Zhang X, Tu H, Yin Q, Li D, Wang L, Cao S, et al. Prevention of venous thrombosis through intraoperative intermittent pneumatic compression (IPC): a best practice implementation project. BMC Nurs. 2024;23(1).558. https://doi.org/10.1186/s12912-024-02221-3.
24. Davies G, Riemann BL, Manske R. Current Concepts of Plyometric Exercise. Int J Sports Phys Ther [Internet]. 2015;10(6):760–86. Available from: http://www.ncbi.nlm.nih.gov/pubmed/26618058%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4637913.
25. Febrianta Y, Yuwono PH, Irawan D, Putro DE, Probo A. The Effect of Plyometric Exercise on Leg Muscle Power, Kick Speed, and Agility of Pencak Silat Athletes. Balneo and PRM Research Journal 2025, 16(4): 920. https://bioclima.ro/Balneo920.pdf.
26. Bedoya AA, Miltenberger MR, Lopez RM. Plyometric Training Effects on Athletic Performance in Youth Soccer Athletes: A Systematic Review. J Strength Cond Res. 2015;29(8):2351–60. https://doi.org/10.1519/JSC.0000000000000877.
27. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451–62. https://doi.org/10.1136/bjsports-2020-102955.
28. Lim JU, Lee JH, Kim JS, Hwang Y Il, Kim TH, Lim SY, et al. Comparison of World Health Organization and Asia-Pacific body mass index classifications in COPD patients. Int J COPD [Internet]. 2017;12:2465–75. Available from: https://doi.org/10.2147/COPD.S141295.
29. Chicu M, Matran-dan MI, Esanu I, Mihailov L, Onofrei BA. Low back pain- Algorithm of diagnosis and management. Balneo and PRM Research Journal 2024, 15(1): 657. https://bioclima.ro/Balneo657.pdf.

30. Ciubean AD, Popa T, Ciortea VM, Dogaru GB, Ungur RA, Borda IM, et al. „ Digital therapeutics ” in musculoskeletal pain management : a narrative review of Gamification, Virtual Reality and Augmented Reality approaches. Balneo and PRM Research Journal 2024, 15(2): 691. https://bioclima.ro/Balneo691.pdf.
31. Asadi A. Effects of six weeks of depth jump and countermovement jump training on agility performance. Sport Sci. 2012;5(1):67–70. Available from: https://www.researchgate.net/publication/266318515_Effects_of_six_weeks_depth_jump_and_countermovement_jump_training_on_agility_performance.
32. van Roie E, Walker S, van Driessche S, Delabastita T, Vanwanseele B, Delecluse C. An age-adapted plyometric exercise program improves dynamic strength, jump performance, and functional capacity in older men either similarly or more than traditional resistance training. PLoS One [Internet]. 2020;15(8 August):1–22. Available from: http://dx.doi.org/10.1371/journal.pone.0237921.
33. Winke M, Williamson S. Comparison of a Pneumatic Compression Device to a Compression Garment During Recovery from DOMS. Int J Exerc Sci. 2018;11(3):375–383. https://doi.org/10.70252/YXDX1767.
34. Hoffman MD, Badowski N, Chin J, Stuempfle KJ. A randomized controlled trial of massage and pneumatic compression for ultramarathon recovery. J Orthop Sports Phys Ther. 2016;46(5):320–6. https://doi.org/10.2519/jospt.2016.6455.
35. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF. Arthritis Care Res. 2011;63(SUPPL. 11):240–252. https://doi.org/10.1002/acr.20543.
36. Collings TJ, Lima YL, Dutaillis B, Bourne MN. Concurrent validity and test–retest reliability of VALD ForceDecks' strength, balance, and movement assessment tests. J Sci Med Sport [Internet]. 2024;27(8):572–80. Available from: https://doi.org/10.1016/j.jsams.2024.04.014.
37. Heishman A, Brown B, Daub B, Miller R, Freitas E, Bemben M. The influence of countermovement jump protocol on reactive strength index modified and flight time: Contraction time in collegiate basketball players. Sports. 2019; 7(2):37. https://doi.org/10.3390/sports7020037.
38. Wiriawan O, Rusdiawan A, Ardy Kusuma D, Firmansyah A, Vicente García-Jiménez J, Ikhwan Zein M, et al. Unilateral Hamstring Muscle Strengthening Exercises Can Improve Hamstring Asymmetry and Increase Jumping Performance in Sub-Elite Badminton Athletes Los ejercicios unilaterales de fortalecimiento de los músculos isquiotibiales pueden mejorar la asimetría . Retos [Internet]. 2024;54:761–70. Available from: https://recyt.fecyt.es/index.php/retos/index
39. Kusnanik, N. W.; Ayubi, N.; Herawati, L.; Jatmiko, T.; Muin, A.; Bird, S. P. Curcumin reduces creatine kinase (CK) Levels Without Decreasing Malondialdehyde (MDA) Levels After 24 Hours of High-Intensity Physical Exercise. Retos 2023, 48, 878-882. https://doi.org/10.47197/retos.v48.96966.
40. Higgins JE, Kleinbaum AP. Design Methodology for Randomized ClinicalTrials, Part II of the Basis of Randomized Clinical Trials with an Emphasis on Contraceptive Research. NewYork Fam. 1985;
41. Ilmi MA, Setijono H, Roepajadi J, Turi M, Putri ST. Reduction in pain intensity, range of motion, and serum creatine kinase through manipulation of sport massage. Edelweiss Appl Sci Technol. 2025;9(5):1446–52. https://doi.org/10.55214/25768484.v9i5.7176.
42. Maia F, Nakamura FY, Pimenta R, Tito S, Sousa H, Ribeiro J. Intermittent Pneumatic Compression May Reduce Muscle Soreness but Does Not Improve Neuromuscular Function Following Exercise-Induced Muscle Damage: A Randomized Placebo-Controlled Trial. Int J Sports Physiol Perform. 2025;1(aop):1–7. https://doi.org/10.1123/ijspp.2024-0410.
43. Jacobs RA, Díaz V, Soldini L, Haider T, Thomassen M, Nordsborg NB, et al. Fast-twitch glycolytic skeletal muscle is predisposed to age-induced impairments in mitochondrial function. Journals Gerontol - Ser A Biol Sci Med Sci. 2013;68(9):1010–1022. https://doi.org/10.1093/gerona/gls335.
44. Qaisar R, Bhaskaran S, Van Remmen H. Muscle fiber type diversification during exercise and regeneration. Free Radic Biol Med [Internet]. 2016;98:56–67. Available from: http://dx.doi.org/10.1016/j.freeradbiomed.2016.03.025.
45. Zierath JR, Hawley JA. Skeletal muscle fiber type: Influence on contractile and metabolic properties. PLoS Biol. 2004;2(10):e348. https://doi.org/10.1371/journal.pbio.0020348.
46. Lievens E, Van Vossel K, Van de Casteele F, Wezenbeek E, Deprez D, Matthys S, et al. Muscle Fibre Typology as a Novel Risk Factor for Hamstring Strain Injuries in Professional Football (Soccer): A Prospective Cohort Study. Sport Med [Internet]. 2022;52(1):177–85. Available from: https://doi.org/10.1007/s40279-021-01538-2.
47. Edgerton VR, Smith JL, Simpson DR. Muscle fibre type populations of human leg muscles. Histochem J. 1975;7(3):259-266. https://doi.org/10.1007/BF01003594.
48. O'Brien M. The anatomy of the Achilles tendon. Ankle Clin. 2005;10(2):225-238. https://doi.org/10.1016/j.fcl.2005.01.011
49. Macaluso F, Isaacs AW, Myburgh KH. Preferential type II muscle fiber damage from plyometric exercise. J Athl Train. 2012;47(4):414-420. https://doi.org/10.4085/1062-6050-47.4.13.
50. Malisoux L, Francaux M, Nielens H, Theisen D. Stretch-shortening cycle exercises: An effective training paradigm to enhance power output of human single muscle fibers. J Appl Physiol. 2006;100(3):771–779. https://doi.org/10.1152/japplphysiol.01027.2005.

51. Fakhri S, Shakeryan S, Alizadeh A, Shahryari A. Effect of 6 Weeks of High Intensity Interval Training with Nano curcumin Supplement on Antioxidant Defense and Lipid Peroxidation in Overweight Girls- Clinical Trial. Iran J diabetes Obes. 2020;11(3):173–80. https://doi.org/10.18502/ijdo.v11i3.2606.
52. Anugrah SM, Kusnanik NW, Wahjuni ES, Zubaida I, Triprayogo R, Dhani DP, et al. Investigating the Impact of Varied Dosages of Royal Jelly Consumption on Creatine Kinase and Interleukin-6 Levels Post High-Intensity Resistance Training. Retos. 2024;55:428–35. https://doi.org/10.47197/RETOS.V55.103569.
53. Maia F, Nakamura FY, Sarmento H, Marcelino R, Ribeiro J. Effects of lower-limb intermittent pneumatic compression on sports recovery: A systematic review and meta-analysis. Biol Sport. 2024;41(4):263–275. https://doi.org/10.5114/biolsport.2024.133665.
54. Waller T, Caine M, Morris R. Intermittent pneumatic compression technology for sports recovery. Eng Sport 6. 2006;3:391–396. https://doi.org/10.1007/978-0-387-45951-6_70.
55. 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. https://doi.org/10.1055/s-0033-1337944.
56. Northey JM, Rattray B, Argus CK, Etxebarria N, Driller MW. Vascular Occlusion and Sequential Compression for Recovery after Resistance Exercise. J Strength Cond Res. 2016;30(2):533–9. https://doi.org/10.1519/JSC.0000000000001080.
57. Brancaccio P, Maffulli N, Buonauro R, Limongelli FM. Serum Enzyme Monitoring in Sports Medicine. Clin Sports Med. 2008;27(1):1–18. https://doi.org/10.1016/j.csm.2007.09.005
58. Koch AJ, Pereira R, Machado M. The creatine kinase response to resistance exercise. J Musculoskelet Neuronal Interact. 2014;14(1):68–77. https://pubmed.ncbi.nlm.nih.gov/24583542/.
59. Wiecha S, Jarocka M, Wiśniowski P, Cieśliński M, Price S, Makaruk B, et al. The efficacy of intermittent pneumatic compression and negative pressure therapy on muscle function, soreness, and serum indices of muscle damage: a randomized controlled trial. BMC Sports Sci Med Rehabil [Internet]. 2021;13(1):1–10. Available from: https://doi.org/10.1186/s13102-021-00373-2.