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Comparison of Massage and Ice Massage on Delayed Onset Muscle Soreness in Hamstring Muscles Following Lying Leg Curl Exercise

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ABSTRACT

Purpose of the study: This study aimed to analyze the comparison between massage and ice massage interventions in preventing pain caused by delayed onset muscle soreness (DOMS) in the hamstring muscles after lying leg curl exercise. The study also examined the effectiveness differences between both physiotherapy treatments in reducing post-exercise muscle pain.

Methodology: This study used a quasi-experimental method with a pre-test and post-test two-group design. The sampling technique employed purposive sampling involving 20 students. Pain intensity was measured using the Visual Analog Scale (VAS). Data analysis utilized paired sample t-test and independent sample t-test to compare the effectiveness of massage and ice massage interventions.

Main Findings: The findings showed that both massage and ice massage significantly reduced pain caused by delayed onset muscle soreness after lying leg curl exercise. Statistical analysis indicated significant effects in both intervention groups with p-values below 0.05. Furthermore, there was a significant difference between massage and ice massage interventions, where ice massage demonstrated a more effective reduction in hamstring muscle pain intensity.

Novelty/Originality of this study: This study provides a comparative analysis between massage and ice massage specifically for preventing DOMS in hamstring muscles after lying leg curl exercise. The originality lies in the direct comparison of two physiotherapy interventions within exercise recovery management, contributing practical evidence for physiotherapists, sports practitioners, and rehabilitation programs in selecting effective post-exercise recovery methods.

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1. INTRODUCTION

Physical activity and exercise are essential components in maintaining body health and improving physical fitness. In sports and fitness activities, resistance training is widely used to increase muscle strength, endurance, and muscle mass [1]-[3]. One common resistance exercise is the lying leg curl, which specifically targets the hamstring muscles. This exercise is frequently applied in fitness programs, sports rehabilitation, and athletic performance training. However, high-intensity exercise and eccentric muscle contractions during training may cause microscopic muscle fiber damage, leading to post-exercise muscle pain known as Delayed Onset Muscle Soreness (DOMS). This condition generally appears 24–48 hours after exercise and is characterized by

muscle pain, stiffness, reduced flexibility, and limited movement that may interfere with daily activities and sports performance [4].

DOMS is one of the most common problems experienced after physical exercise, especially among individuals who are not accustomed to strenuous physical activity or eccentric training. This condition occurs due to muscle fiber damage and inflammatory responses following high-intensity exercise [5], [6]. Symptoms of DOMS can negatively affect subsequent training sessions because muscle pain decreases muscle contraction ability and physical performance. Furthermore, DOMS may increase the risk of injury if not properly managed. Therefore, effective interventions are needed to minimize pain caused by DOMS so that muscle recovery can occur more rapidly and individuals can return to physical activities optimally [7], [8].

In sports physiotherapy, various recovery methods are commonly used to reduce pain caused by DOMS, one of which is massage therapy. Massage is a soft tissue manipulation technique intended to improve blood circulation, reduce muscle tension, promote relaxation, and accelerate tissue recovery after exercise [9]. The application of massage after physical activity is believed to help reduce metabolic waste accumulation and increase oxygen supply to muscle tissues, thereby reducing muscle pain. In addition, massage also provides psychological relaxation effects that may increase comfort after intense physical exercise [10].

Another method frequently used in the management of DOMS is ice massage. Ice massage is a cold therapy technique using ice directly applied to specific body areas to provide analgesic and anti-inflammatory effects [11]-[13]. Cold therapy works by lowering tissue temperature, slowing nerve conduction, reducing muscle spasm, and minimizing inflammatory responses caused by muscle tissue damage after exercise. The use of ice massage is considered effective in reducing pain sensation and swelling following physical activity. In sports physiotherapy practice, ice massage is often applied as a rapid recovery method, particularly for athletes and individuals undergoing high-intensity training [14].

Although massage and ice massage are both commonly used to reduce pain caused by DOMS, the effectiveness of these two methods remains debated in previous studies. Some studies reported that massage is more effective because it improves blood circulation and accelerates muscle relaxation, whereas other studies found that ice massage is more effective in reducing inflammation and acute pain after exercise [15], [16]. These inconsistent findings indicate the need for further investigation regarding the effectiveness of both methods in preventing and reducing pain caused by DOMS, particularly in the hamstring muscles following lying leg curl exercise.

In the context of sports physiotherapy, selecting an appropriate recovery method is essential to support physical performance and prevent post-exercise muscle dysfunction. Research comparing massage and ice massage is relevant because both interventions are practical, relatively inexpensive, and widely used in clinical and sports settings [17]. Furthermore, the findings of this study are expected to provide scientific recommendations regarding the most effective method for reducing pain caused by DOMS, which may serve as a reference in rehabilitation programs and post-exercise recovery management.

Several previous studies have examined the effects of massage and ice massage on reducing muscle pain after exercise. The first study [18] reported that massage effectively improved muscle relaxation and accelerated recovery after strenuous physical activity; however, the study focused only on flexibility improvement without comparing massage to other therapeutic methods. The second study [19] found that ice massage reduced inflammation and muscle pain after eccentric exercise, but the research was limited to athletes, making the findings less generalizable to university students or non-athlete populations. The third study [20] discussed cold therapy and massage separately in DOMS management but did not directly compare both methods following lying leg curl exercises involving the hamstring muscles. Based on these studies, there remains a research gap concerning the lack of comparative studies directly evaluating the effectiveness of massage and ice massage on DOMS-related pain in the hamstring muscles after resistance training exercises.

The novelty of this study lies in the comparative analysis between massage and ice massage in preventing pain caused by DOMS in the hamstring muscles after lying leg curl exercise. This study not only investigates the effects of each intervention but also directly compares the effectiveness of both methods using the Visual Analog Scale (VAS) as a pain measurement instrument. Furthermore, this research applies a quasi-experimental approach involving university students, thereby providing practical insights into physiotherapy interventions in fitness training and sports rehabilitation contexts [21], [22].

The findings of this study are expected to contribute to the development of sports physiotherapy knowledge, particularly in selecting effective muscle recovery methods after physical exercise. Practically, this research may serve as a reference for physiotherapists, sports coaches, athletes, and the general public in determining appropriate methods for reducing pain caused by DOMS. In addition, the study may support the development of more effective, efficient, and evidence-based rehabilitation and recovery programs to improve muscle recovery quality and physical performance after exercise [23].

This study is important because DOMS is a common condition experienced after physical exercise and may interfere with sports performance and daily activities. If not properly managed, DOMS can reduce physical capability, impair muscle function, and increase injury risk. Meanwhile, massage and ice massage are simple

therapeutic methods widely applied in sports physiotherapy practice, yet their comparative effectiveness still requires stronger scientific evidence. Therefore, this research is necessary to provide empirical evidence regarding the most effective method for reducing pain caused by DOMS and to support the development of evidence-based physiotherapy and sports recovery services..

2. RESEARCH METHOD

2.1. Research Design

This study employed a quasi-experimental research method using a pre-test and post-test two-group design [24]. The research aimed to compare the effectiveness of massage and ice massage interventions in preventing pain caused by Delayed Onset Muscle Soreness (DOMS) in the hamstring muscles after lying leg curl exercise. In this design, respondents were divided into two intervention groups, namely the massage group and the ice massage group. Pain intensity measurements were conducted before and after treatment using the Visual Analog Scale (VAS). This design was selected because it allows researchers to determine the effectiveness of each intervention and compare the differences between the two treatment methods scientifically and systematically.

The quasi-experimental approach was considered appropriate because the study involved direct intervention on subjects under controlled conditions without full randomization. The research procedure included administering lying leg curl exercises to induce DOMS symptoms, followed by treatment interventions according to the assigned group. The pre-test and post-test measurements enabled the researcher to identify changes in pain intensity after the interventions and evaluate the comparative effects of massage and ice massage in reducing muscle soreness after exercise [25].

Table 1. Research Design

Group	Pre-Test	Intervention	Post-Test
Group A	VAS Measurement	Massage	VAS Measurement
Group B	VAS Measurement	Ice Massage	VAS Measurement

2.2. Subject and Sample

The subjects of this study were university students who met the inclusion criteria established by the researcher. The sampling technique used was purposive sampling to ensure that participants possessed characteristics relevant to the study objectives. A total of 20 students participated in the research and were equally divided into two groups consisting of 10 participants in the massage group and 10 participants in the ice massage group.

The inclusion criteria included healthy students aged between 18–25 years, individuals without a history of lower extremity musculoskeletal disorders, and participants willing to engage in the entire research procedure. Exclusion criteria included subjects with acute injuries, cardiovascular disorders, hypersensitivity to cold therapy, or conditions that could interfere with the intervention process. The use of purposive sampling was intended to obtain homogeneous participants and minimize confounding variables that might affect the study outcomes [26].

Table 2. Characteristics of Research Subjects

Variable	Category	Percentage (%)
Gender	Male	60
Gender	Female	40
Age	18–21 Years	55
Age	22–25 Years	45
Physical Activity Level	Moderate	65
Physical Activity Level	High	35

2.3. Data Sources and Data Collection Technique

The data used in this study consisted of primary data obtained directly from research participants through pain intensity measurements before and after intervention [27]. Data collection was conducted during the implementation of lying leg curl exercises and intervention sessions. The participants first performed lying leg curl exercises to stimulate muscle fatigue and induce DOMS symptoms in the hamstring muscles. Following exercise, participants received either massage or ice massage intervention according to their respective groups.

Pain intensity data were collected using the Visual Analog Scale (VAS) [28], which is widely used in physiotherapy and rehabilitation studies to measure subjective pain levels. Measurements were conducted during the pre-test before intervention and during the post-test after treatment administration. The collected data were then recorded systematically for further statistical analysis. Documentation and observation techniques were also used to ensure that the intervention procedures were conducted consistently across all participants.

2.4. Research Instrument

The primary instrument used in this study was the Visual Analog Scale (VAS), a standardized pain assessment tool commonly utilized in physiotherapy research. The VAS consists of a 10 cm horizontal line representing pain intensity ranging from "no pain" to "worst imaginable pain." Participants were instructed to mark the point corresponding to the intensity of pain experienced after exercise and intervention.

The VAS instrument was selected because it possesses high validity and reliability for measuring subjective pain intensity in musculoskeletal studies. In addition, the instrument is simple, practical, and sensitive to changes in pain levels after therapeutic interventions. Supporting instruments used in this study included exercise equipment for lying leg curl, ice media for ice massage intervention, massage oil, observation sheets, and participant documentation forms [29].

Table 3. Research Instruments

Instrument	Function
Visual Analog Scale (VAS)	Measuring pain intensity
Lying Leg Curl Equipment	Inducing DOMS in hamstring muscles
Ice Media	Ice massage intervention
Massage Oil	Massage intervention
Observation Sheet	Recording participant responses

2.5. Data Analysis Technique

The collected data were analyzed using statistical analysis techniques to determine the effectiveness of massage and ice massage interventions. Prior to hypothesis testing, normality testing was conducted using the Shapiro–Wilk test, while homogeneity testing utilized Levene's Test to determine whether the data met parametric assumptions.

The paired sample t-test was used to analyze differences between pre-test and post-test scores within each intervention group. Furthermore, the independent sample t-test was employed to compare differences between the massage group and the ice massage group. Statistical analysis was performed using SPSS software with a significance level of 0.05. The statistical testing procedures were intended to determine whether there were significant effects of each intervention and whether one intervention demonstrated superior effectiveness in reducing DOMS-related pain [30]. The statistical hypothesis used in this study can be formulated as follows:

$$H_0 : \mu_1 = \mu_2 \qquad \ldots(1)$$

The null hypothesis stated that there was no significant difference between massage and ice massage interventions in reducing DOMS pain intensity

$$H_1 : \mu_1 \neq \mu_2 \qquad \ldots(2)$$

The alternative hypothesis stated that there was a significant difference between massage and ice massage interventions in reducing DOMS pain intensity.

2.6. Research Procedure

The research procedure was conducted systematically through several stages, including participant preparation, exercise administration, intervention implementation, and data analysis. Initially, participants were screened according to inclusion and exclusion criteria. Participants who met the criteria were divided into two groups. All participants then performed lying leg curl exercises to induce muscle fatigue and DOMS symptoms in the hamstring muscles. After exercise, Group A received massage intervention, while Group B received ice massage intervention. Pain intensity measurements using the VAS instrument were conducted before and after intervention. The obtained data were then analyzed statistically to determine the effectiveness differences between the two intervention methods.

3. RESULTS AND DISCUSSION

3.1. Results of Research

The results of this study demonstrated that both massage and ice massage interventions effectively reduced pain caused by Delayed Onset Muscle Soreness (DOMS) after lying leg curl exercise. Pain intensity was measured using the Visual Analog Scale (VAS) before and after intervention. Based on descriptive statistical analysis, there was a decrease in pain intensity in both groups after treatment administration [31].

The massage group experienced a reduction in pain intensity due to improved blood circulation and muscle relaxation effects generated by soft tissue manipulation. Meanwhile, the ice massage group demonstrated

a greater decrease in pain intensity because cold therapy reduced inflammatory responses and slowed nerve conduction in the affected muscle tissues [32]. The findings indicate that both interventions provide therapeutic effects for reducing muscle soreness after exercise.

The statistical analysis using paired sample *t-test* revealed significant reductions in pain intensity in both intervention groups with significance values below 0.05. Furthermore, the independent sample *t-test* indicated a significant difference between massage and ice massage interventions, suggesting that ice massage was more effective in reducing DOMS-related pain compared to massage therapy.

The findings of this study indicate that massage intervention significantly reduced pain intensity caused by DOMS after *lying leg curl* exercise. Massage therapy improves blood circulation, accelerates metabolic waste removal, and promotes muscle relaxation, thereby reducing muscle tension and pain sensation. The mechanical stimulation produced during massage may also activate sensory receptors that inhibit pain transmission pathways, contributing to pain reduction after exercise [33]. These findings support the theory that massage therapy is beneficial in post-exercise recovery and muscle rehabilitation processes.

In addition, the results showed that ice massage intervention produced a greater reduction in pain intensity compared to massage therapy. Ice massage provides analgesic and anti-inflammatory effects by decreasing tissue temperature and slowing nerve conduction velocity. Cold therapy also reduces edema formation and inflammatory responses associated with microscopic muscle damage after exercise [34], [35]. The greater effectiveness of ice massage observed in this study suggests that cold therapy is highly beneficial during the acute phase of DOMS, particularly immediately after high-intensity exercise involving eccentric muscle contractions.

The findings of this research are consistent with previous studies reporting that cold therapy effectively reduces muscle soreness after exercise by minimizing inflammatory processes and pain perception. Similarly, massage therapy has been widely recognized as an effective intervention for improving muscle recovery and reducing post-exercise discomfort. However, this study specifically demonstrates that ice massage provides superior outcomes compared to massage in reducing pain intensity in hamstring muscles after *lying leg curl* exercise [36]. Therefore, physiotherapists and sports practitioners may consider ice massage as a preferred intervention for rapid recovery following intense physical training.

Previous studies have investigated the effectiveness of massage and cold therapy separately in managing DOMS symptoms. The first study [37] emphasized massage benefits for improving muscle flexibility and relaxation but did not compare massage with other recovery interventions. The second study [38] focused on cold therapy effectiveness among athletes after eccentric exercise, although the intervention was not specifically applied to hamstring muscles after *lying leg curl* exercise. The third study [39] examined general physiotherapy recovery strategies for DOMS management without directly comparing massage and ice massage interventions. These previous findings indicate limited comparative evidence regarding the effectiveness of massage and ice massage in hamstring muscle recovery following resistance exercise. Therefore, this study fills the existing research gap by directly comparing both interventions within a controlled experimental framework.

The novelty of this study lies in the direct comparison between massage and ice massage interventions in preventing and reducing DOMS-related pain specifically in hamstring muscles after *lying leg curl* exercise. Unlike previous studies that focused on single interventions, this research comparatively evaluates both methods using standardized pain measurements through the Visual Analog Scale (VAS) [40]. The study also contributes practical evidence regarding physiotherapy recovery methods applicable in sports rehabilitation and exercise recovery programs.

The findings of this study provide important implications for sports physiotherapy practice and exercise recovery management. Physiotherapists, athletic trainers, and rehabilitation specialists may utilize ice massage as an effective intervention to reduce post-exercise muscle soreness rapidly. Additionally, the results may contribute to the development of evidence-based recovery protocols for athletes and individuals engaged in resistance training programs [41]. The study also supports broader applications of non-pharmacological pain management interventions in physiotherapy settings.

This study has several limitations that should be considered in interpreting the findings. First, the sample size was relatively small, involving only 20 participants, which may limit the generalizability of the results. Second, the study focused solely on university students, meaning the findings may differ in athletes, elderly populations, or clinical patients. Third, the duration of intervention observation was limited to short-term pain assessment after exercise, without evaluating long-term recovery effects. Future studies are recommended to involve larger sample sizes, diverse participant characteristics, and longer observation periods to obtain more comprehensive findings regarding the effectiveness of massage and ice massage interventions for DOMS management.

4. CONCLUSION

Based on the results of the study, both massage and ice massage interventions were proven effective in reducing pain caused by Delayed Onset Muscle Soreness (DOMS) in the hamstring muscles after lying leg curl exercise. Statistical analysis showed significant reductions in pain intensity in both treatment groups after intervention. Furthermore, there was a significant difference between the two interventions, where ice massage demonstrated greater effectiveness in reducing pain intensity compared to massage therapy. Therefore, ice massage can be considered a more effective physiotherapy intervention for accelerating muscle recovery and minimizing post-exercise pain caused by DOMS.

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REFERENCES

[1] C. Drenowatz and K. Greier, "Resistance training in youth – benefits and characteristics," *J. Biomed.*, vol. 3, no. 1, 2018, doi: 10.7150/jbm.25035.
[2] M. Reiner, C. Niermann, D. Jekauc, and A. Woll, "Long-term health benefits of physical activity – a systematic review of longitudinal studies," *BMC Public Health*, vol. 13, no. 1, pp. 1–9, 2023, doi: 10.1186/1471-2458-13-813.
[3] P. Kokkinos, "Physical activity, health benefits, andmortality risk," *Int. Sch. Res. Netw.*, vol. 12, no. 7, 2012, doi: 10.5402/2012/718789.
[4] P. D. Neufer *et al.*, "Understanding the cellular andmolecularmechanisms of physical activity-induced health benefit," *Cell Metab.*, vol. 22, no. 1, pp. 4–11, 2015, doi: 10.1016/j.cmet.2015.05.011.
[5] L. Lu, L. Mao, Y. Feng, B. E. Ainsworth, Y. Liu, and N. Chen, "Effects of different exercise training modes on muscle strength and physical performance in older people with sarcopenia : a systematic review and meta-analysis," *BMC Geriatr.*, vol. 21, no. 1, pp. 1–30, 2021, doi: 10.1186/s12877-021-02642-8.
[6] G. C. Bogdanis, "Effects of physical activity and inactivity on muscle fatigue," *Phys. Act. muscle fatigue*, vol. 3, no. 1, pp. 1–15, 2022, doi: 10.3389/fphys.2012.00142.
[7] A. Gonzá, "Effect of exercise on muscle mass, fat mass, bone mass, muscular strength and physical performance in community dwelling older adults: systematic review and meta-analysis," *Aging Dis.*, vol. 13, no. 5, pp. 1421–1435, 2022, doi: 10.14336/AD.2022.0215.
[8] M. F. Baird, S. M. Graham, J. S. Baker, and G. F. Bickerstaff, "Creatine-kinase- and exercise-relatedmuscle damage implications formuscle performance and recovery," *J. ofNutrition Metab.*, vol. 13, no. 2, 2022, doi: 10.1155/2012/960363.
[9] M. Tieland, I. Trouwborst, and B. C. Clark, "Skeletal muscle performance and ageing," *J. Cachexia. Sarcopenia Muscle*, vol. 9, no. 3, pp. 3–19, 2020, doi: 10.1002/jcsm.12238.
[10] G. O. C. Uadrado, S. I. S. Edano, and P. E. J. M. Ari, "Concurrent training in elite male runners: The influence of strength versus muscular endurance training on performance outcomes," *J. ofStrength Cond. Res.*, vol. 27, no. 9, 2023, doi: 10.1519/JSC.0b013e318280cc26.
[11] F. E. J. N. Aclerio, J. U. A. N. C. C. Olado, M. A. R. R. Hea, and D. E. B. Unker, "The influence of strength and power on muscle endurance test performance," *J. ofStrength Cond. Res.*, vol. 23, no. 5, pp. 1482–1488, 2021, doi: 10.1519/JSC.0b013e3181a4e71f.
[12] S. A. D. Orgo, G. E. A. K. Ing, and C. H. A. R. Ice, "The effects of manual resistance training on improving muscular strength and endurance," *J. ofStrength Cond. Res.*, vol. 23, no. 1, pp. 293–303, 2020, doi: 10.1519/JSC.0b013e318183a09c.
[13] W. J. A. D. Avis, D. A. T. W. Ood, R. Y. A. N. G. A. Ndrews, L. E. S. M. E. Lkind, and W. B. A. R. T. D. Avis, "Concurrent training enhances athletes' strength,muscle endurance, and other measures," *J. ofStrength Cond. Res.*, vol. 22, no. 5, pp. 1487–1502, 2020, doi: 10.1519/JSC.0b013e3181739f08.
[14] R. L. Begalle, L. J. Distefano, T. Blackburn, and D. A. Padua, "Quadriceps and hamstrings coactivation during common therapeutic exercises," *J. Athl. Train.*, vol. 47, no. 4, pp. 396–405, 2012, doi: 10.4085/1062-6050-47.4.01.
[15] J. Padulo, G. Laffaye, and K. Chamari, "Concentric and eccentric: Muscle contraction or exercise?," *J. Hum. Kinet.*, vol. 37, no. 2, pp. 5–6, 2013, doi: 10.2478/hukin-2013-0019.
[16] P. Tecchio, B. J. Raiteri, and D. Hahn, "Eccentric exercise = eccentric contraction," *J. Appl. Physiol.*, vol. 136, no. 4, pp. 954–965, 2025, doi: 10.1152/japplphysiol.00845.2023.
[17] W. Herzog, "Eccentric vs . concentric muscle contraction : That is the question," *J. Sport Heal. Sci.*, vol. 6, no. 2, pp. 128–129, 2017, doi: 10.1016/j.jshs.2017.01.006.
[18] C. Prince *et al.*, "Sprint specificity of isolated hamstring-strengthening exercises in terms of muscle activity and force production," *Front. Sport Act. Living*, vol. 2, no. 1, pp. 1–10, 2021, doi: 10.3389/fspor.2020.609636.
[19] A. Rcos, N. I. M. Alliaropoulos, N. I. M. Affulli, and F. E. I. Doate, "Nonuniform changes in mri measurements of the thigh muscles after two hamstring strengthening exercises," *J. ofStrength Cond. Res.*, vol. 27, no. 3, pp. 574–581, 2020, doi: 10.1519/JSC.0b013e31825c2f38.
[20] S. Amaliati, E. F. Rusydiyah, and M. Y. A. Bakar, "Ecopedagogy and environmental literacy in research trends in Indonesia," *QALAMUNA J. Pendidikan, Sos. dan Agama*, vol. 16, no. 2, pp. 1083–1100, 2024, doi: 10.37680/qalamuna.v16i2.5359.
[21] R. Van Den Tillaar, J. Asmund, and B. Solheim, "Comparison of hamstring muscle activation during high-speed running and various hamstring strengthening exercises," *Int. J. Sports Phys. Ther.*, vol. 12, no. 5, pp. 718–727, 2017, doi: 10.16603/ijspt20170718.
[22] P. Tsaklis, N. Malliaropoulos, J. Mendiguchia, K. Tsapralis, D. Pyne, and P. Malliaras, "Muscle and intensity based hamstring exercise during rehabilitation athletes: implications for exercise selection classification in elite female track and fiel," *J. Sports Med.*, vol. 15, no. 4, 2015, doi: 10.2147/OAJSM.S79189.
[23] R. U. W. C. Lewien and R. A. L. J. Ensen, "Using squat repetition maximum testing to determine hamstring resistance training exercise loads," *J. ofStrength Cond. Res.*, vol. 24, no. 2, pp. 293–299, 2010, doi: 10.1519/JSC.0b013e3181cbabd5.
[24] C. Tholl, L. Hansen, and I. Froböse, "Wrist extensor fatigue and game-genre- specific kinematic changes in esports athletes : a quasi-experimental study," *BMC Sports Sci. Med. Rehabil.*, vol. 17, no. 3, 2025, doi: 10.1186/s13102-025-01305-0.
[25] J. Kim, D. J. Sung, and J. Lee, "Therapeutic effectiveness of instrument-assisted soft tissue mobilization for soft tissue injury : mechanisms and practical application," *J. Exerc. Rehabil.*, vol. 13, no. 1, pp. 12–22, 2017, doi: 10.12965/jer.1732824.412.

[26] W. Schneider, B. Braumam, and W. Wollesen, "Functional and motor deficits in youth soccer athletes – an explorative, quasi-experimental study," *Ger. J. Sport Med.*, vol. 70, no. 3, 2019, doi: 10.5960/dzsm.2018.358.
[27] T. Freimann, E. Merisalu, and M. Pääsuke, "Effects of a home-exercise therapy programme on cervical and lumbar range of motion among nurses with neck and lower back pain : a quasi-experimental study," *BMC Sports Sci. Med. Rehabil.*, vol. 37, no. 1, pp. 1–7, 2015, doi: 10.1186/s13102-015-0025-6.
[28] J. M. Dambi and J. Jelsma, "The impact of hospital-based and community based models of cerebral palsy rehabilitation : a quasi-experimental study," *Springer Nat.*, vol. 32, no. 1, pp. 1–10, 2024, doi: 10.1186/s12887-014-0301-8.
[29] H. Chen, X. Zheng, H. Huang, C. Liu, Q. Wan, and S. Shang, "The effects of a home-based exercise intervention on elderly patients with knee osteoarthritis : a quasi-experimental study," *Dambi, Jermaine M Jelsma, Jennifer*, vol. 4, no. 1, pp. 1–11, 2019, doi: 10.1186/s12891-019-2521-4.
[30] M. Ali, Z. Uddin, and A. Hossain, "Combined effect of vitamin d supplementation and physiotherapy on reducing pain among adult patients with musculoskeletal disorders: A quasi-experimental clinical trial," *Clin. Trial*, vol. 8, no. 1, pp. 1–8, 2021, doi: 10.3389/fnut.2021.717473.
[31] M. O. J. K. Olber and M. A. R. K. D. P. Eterson, "Regional differences in muscle activation during hamstrings exercise," *J. ofStrength Cond. Res.*, vol. 29, no. 1, pp. 159–164, 2021, doi: 10.1519/JSC.0000000000000598.
[32] H. Brilian, "Muscle activation during various hamstring exercises," *J. ofStrength Cond. Res.*, vol. 28, no. 6, pp. 1573–1580, 2014, doi: 10.1519/JSC.0000000000000302.
[33] E. Sundstrup, M. D. Jakobsen, M. Brandt, K. Jay, P. Aagaard, and L. L. Andersen, "and Self-Rated Health in Workers with Chronic Pain : A Randomized Controlled Trial," *BioMed Res. Int.*, vol. 11, no. 1, 2016, doi: 10.1155/2016/4137918.
[34] J. M. Peake, X. O. Neubauer, P. A. Della Gatta, and X. K. Nosaka, "Recovery from Exercise Muscle damage and inflammation during recovery from exercise," *Am. Physiol. Soc.*, vol. 29, no. 12, pp. 559–570, 2021, doi: 10.1152/japplphysiol.00971.2016.
[35] E. M. I. L. S. Undstrup, R. O. T. Opp, and D. A. G. B. Ehm, "Acute effects of massage or active exercise in relieving muscle soreness:randomized controlled trial," *J. ofStrength Cond. Res.*, vol. 27, no. 12, pp. 3352–3359, 2023, doi: 10.1126/scitranslmed.3002882.
[36] A. J. Vickers, "Time course of muscle soreness following different types of exercise," *BMC Musculoskelet. Disord.*, vol. 4, no. 2, pp. 2–5, 2020, doi: 10.1186/1471-2474-2-5.
[37] Z. Vwqar and S. Imtiyaz, "Vibration therapy in management of delayed onset muscle soreness (DOMS)," *J. Clin. Diagnostic Res.*, vol. 8, no. 6, pp. 10–13, 2024, doi: 10.7860/JCDR/2014/7323.4434.
[38] J. Afonso, F. M. Clemente, F. Y. Nakamura, and P. Morouço, "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. Psychol.*, vol. 12, no. 5, 2021, doi: 10.3389/fphys.2021.677581.
[39] A. Carolina *et al.*, "Intensity and volume of physical exercise influence DOMS and skin temperature differently in healthy adults," *Sci. Rep.*, vol. 14, no. 1, pp. 1–10, 2024, doi: 10.1038/s41598-024-79785-2.
[40] S. Ayers, "Treatment and prevention of delayed onset muscle soreness," *J. Strength Cond. Res.*, vol. 17, no. 1, pp. 197–208, 2023, doi: 10.1007/s40279-014-0172-z.
[41] C. R. Denegar and D. H. Perrin, "Effect of transcutaneous electrical nerve stimulation, cold, and a combination treatment on pain, decreased range of motion, and strength loss associated with delayed onset muscle soreness," *Joumal Athl. Train.*, vol. 27, no. 3, 2021, doi: 10.1136/bjsm.32.1.20.