Effects of Dry Needling on Hamstring Pain Sensitivity and Flexibility of Professional Athletes

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Abstract
Dry needling therapy is an up-to-date therapeutic method aimed at the rehabilitation of a wide range of pathologies and sports injuries. The form of minimally invasive therapy can also be recommended to professional athletes in order to optimize sports recovery and their reintegration into elite sports. Currently, there are a multitude of strategies for managing and preventing sports injuries. The current study aims to identify the short-term effects of a complex therapeutic approach that combines dry needling therapy with manual therapy and stretching. The subjects of the research represented 64 professional athletes with at least one official appearance during the last three competitive seasons in the first three championships in Romania. They were divided into two groups: group A – combined dry needling treatment, manual therapy + stretching; group B – manual therapy + stretching. The main measurements were the level of pain during passive stretching assessed by means of the numerical pain rating scale (NRS) and the flexibility by means of knee extension goniometry. The impact of dry needling therapy highlighted statistically significant differences in terms of passive stretching resistance values and hamstring flexibility ($p<0.05$). The results confirm the importance of dry needling therapy as part of a combined treatment in the rehabilitation of athletes with different categories of muscle injuries that cause pain and limitation of functionality in the lower limbs.

Keywords: *sport rehabilitation, flexibility, dry needling, manual therapy, stretching.*

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1. Introduction

The complexity of sports injuries determines the need for the intervention of physiotherapists as an active, essential part of the interdisciplinary sports team. Injuries can vary in terms of severity: from mild injuries that have only the presence of pain as a symptom, without requiring the intervention of the medical staff, to serious injuries that cause the athlete to no longer take part in sports activities (Davies et al., 2020). Currently, there are a multitude of strategies for managing and preventing sports injuries. Sports injuries can have unpleasant consequences not only on the health, but also on the lifestyle of the players, including an increased risk of depression or anxiety, with financial losses certainly present. A recent systematic review suggests the negative impact of sports injuries on sports performance (Drew, Raysmith & Charlton, 2017).

Muscular injuries represent a large part of sports injuries (10-55%), their treatment being of major importance, as the inability of athletes to participate in sports competitions can be of the order of weeks or months. This category of trauma is very common in sports, especially in football. A number of epidemiological studies suggest that 1.8-2.2 muscle injuries occur in 1000 hours of training or competition (30% of all injuries) (Guillin & Rochcongar, 2017). Traumas are usually produced by a strong eccentric contraction or excessive stretching of the muscle fibers. These situations produce excessive mechanical stress and occur during sudden acceleration or deceleration. Muscle strains tend to occur most frequently in the biarticular muscles (rectus femoris, hamstrings, gastrocnemius) but being the fact that they can generate a higher level of muscle tension through the passive positioning of the joints (Delos, Maak & Rodeo, 2013; Fields & Rigby, 2016).

Dry needling (DN) is a modern treatment performed with dry needling and was designed to relieve muscle pain. During dry needling, a practitioner inserts several threadlike needles into the skin. Thread needles are fine, short, stainless steel needles that do not inject fluid into the body. That is why the term “dry” is used.

A review on the current literature (PubMed, Medline, PEDro, Ebsco in the years 2010-2021, English only) identifies a number of previous studies that present a multitude of advantages of the dry needling therapy in the treatment of the muscle pain or other pathological context (Table 1).

A systematic meta-analysis carried out in 2017 presents a brief but sufficient presentation to describe this type of therapy. Practitioners place needles into "trigger points" in muscle or tissue. Dry needling is sometimes called intramuscular stimulation (Gattie et al., 2017). Dy needling is a very effective therapy for treating muscles and fascia, where the therapist inserts the needle into the painful point, thereby stimulating oxygen supply to the fascia and tense muscle fibers and fascia (Iacob et al., 2021).

Table 1. The dry needling therapy use in the hamstring pain or tightness

Study	Subjects	Output measures	Results
Alaei et al.	Healthy subjects, hamstring tightness (n=32)	AKET, muscle compliance, passive peak torque, stretch tolerance	Improvements in all outcomes was better for the DN group than for the SS (static stretching) group
Bazzaz-Yamchi et al.	Healthy subjects, hamstring tightness (n=10)	VAS, PKE hamstring tightness	A single session of deep DN improved pain and function and increased hamstring flexibility
Geist et al.	Hamstring extensibility deficits (n=27)	Hamstring extensibility – goniometry, hop tests	It does not appear dry needling results in increased extensibility
Ansari et al.	Healthy subjects with shortened hamstrings (n=15)	The active knee extension test, muscle compliance, passive peak torque, and stretch tolerance	This is the first study that demonstrates the beneficial effects of DN on hamstring flexibility, muscle compliance, and stretch tolerance without added stretching
Mason et al.	Hamstring pain and active trigger points (n=39)	Pain scale	Lack of significant improvements
Jayaseelan & Ricardo	Proximal hamstring tendinopathy (n=2)	Pain and functionality scales	Short- and long-term pain reduction and functional benefits

There are some studies which confirm that dry needling is effective in improving hamstring flexibility compared with static stretching. With one session of dry needling patients can have an effective treatment for hamstring tightness and increase of flexibility (Alaei et al., 2020). There is also a scientific evidence that a single session of deep dry needling improved pain and overall function and increased hamstring flexibility. This pilot study supports the use of DN in patients with low back pain and hamstring tightness; however, future research with a rigorous study design of randomized controlled trial is required to confirm the findings (Bazzaz-Yamchi et al., 2021).

Another study that covers up the effects of dry needling among asymptomatic individuals with hamstring tightness reveals that dry needling results do not appear in increased extensibility beyond that of stretching alone in asymptomatic individuals. Our study findings suggest that dry needling may improve certain dimensions of functional performance, although no clear conclusion can be made (Geist et al., 2017). There are other studies that demonstrates the beneficial effects of dry needling in hamstring flexibility, muscle compliance, and stretch tolerance without any stretching added. The beneficial effects of DN should encourage clinicians to use this therapy as a novel strategy for increasing muscle flexibility (Ansari et al., 2020).

Mason et al., supports the effectiveness of DN and stretching vs. stretching alone on hamstring flexibility in patients with knee pain ended up with the results that two sessions of dry needling did not improve hamstring range of motion or other knee pain-related impairments more than sham dry needling in a young active population with atraumatic knee pain (Mason et al., 2016). There is a study which presents the rehabilitation of proximal hamstring tendinopathy utilizing eccentric training, lumbopelvic stabilization and trigger point dry needling. The specific treatment provided short- and long-term pain reduction and functional benefits. Further research is needed to determine the effectiveness of this cluster of interventions for this condition (Jayaseelan & Ricardo, 2013).

Even with multiple effects addressed for healthy individuals with muscle tightness or in the rehabilitation of a vast spectrum of pathologies, there is currently no strong scientific foundation to support the importance of a combined treatment that focuses on dry needling therapy in the rehabilitation of muscle injuries in professional athletes.

2. Material and method

2.1. Participants

The subjects of the research were 64 professional sport players (19-35 years old), having the main criteria for selection of a muscle injury located in the posterior part of the thigh. Confirmation of the clinical and functional diagnosis and in most cases imaging was necessary in establishing the treatment plan and involved in verifying the inclusion criteria.

In addition to the diagnosis of hamstring muscle injury, the participants were selected based on the other following inclusion criteria: (1) specific muscle pain in the posterior thigh; (2) limited functionality during hip flexion and knee extension; (3) professional sport activity ongoing; (4) at least one official appearance during the last three competitive seasons in the first three championships in Romania (football, basketball, handball, futsal); (6) fully agreement of the subjects related to the acceptance of dry needling therapy; (7) lack of basic contraindications in safe dry needling therapy (needly phobia, lymphedema, mental illness, infectious diseases, other medical emergencies). The exclusion criteria included situations in which the subjects had to interrupt the institutionalized rehabilitation plan due to pandemic considerations (infection with the Covid-19 virus or direct contact with infected persons, placement in institutionalized/home quarantine).

Subjects consisted of two groups randomly devided which benefited of a different treatment protocols (Table 2).

Table 2. Baseline characteristics of the research subjects

Variable (unit)	Group A (n=34)	Group B (n=30)
Gender (M/F)	24/10	21/9
Age (years)	28.21 ± 9.82	29.54 ± 8.96
Weight (kg)	77.14 ± 9.62	78.45 ± 8.98
Height (cm)	185.14 ± 9.75	183.72 ± 8.22
Sport type	Football = 32 Basketball = 7 Handball = 5 Futsal = 3 Tennis = 9 Others = 8	

2.2. Therapeutic intervention

The research methodology followed very strictly the therapeutic and ethical principles specific to the research activity and physiotherapy area. The study design consisted in the following stages: identification of the subject group according to established inclusion and exclusion criteria; analysis and selection of test methods and evaluation of subjects; performing the initial and final testing, implementation of the rehabilitation program for every group of subjects; presentation and interpretation of data; drawing up conclusions. The research was carried out between June 2020 and April 2022 in several locations in order to establish a representative group of subjects and follow the most suitable means of assessment and treatment. Active collaboration with a group of sports physiotherapists engaged in the recovery of performance athletes was necessary to implement the treatment protocol and constantly monitor the subjects' functional parameters.

The current study aims to identify the short-term effects of a complex therapeutic approach that combines dry needling therapy with manual therapy and stretching.

Subjects consisted of two groups randomly devided. The therapeutic plan for the rehabilitation of muscle injuries usually includes 3 stages: the acute stage, the functional rehabilitation stage and the stage aimed at sports reintegration. In order to highlight the effect of the combined therapy, which had dry needling as a priority means, the functional parameters were analyzed in two tests: initial (baseline) and after 6 weeks (completion of the functional rehabilitation phase). After this phase, the sports reintegration took place within the sports clubs. In this 3rd phase the therapeutic interventions through the chosen protocol were more sporadic, with a lower frequency.

Both groups followed a therapeutic strategy for approximately 6 weeks, three sessions of 60 minutes per week. Group A received a dry needling treatment specific for trigger points area, combined with manual therapy and active exercices (stretching, isometric and eccentric contractions), while group B benefited of a more classical treatment with electroterapy (for acute phase), manual therapy and active exercises. Manual therapy techniques including deep tissue massage, trigger point and stretching were used in the functional rehabilitation phase for both groups during every therapy session (for approximately 15-20 minutes).

The main objectives of the first two phases of the rehabilitation were implemented in accordance with the principles of rehabilitation, for all research subjects. For the acute phases, the most important were limitation of tissue damage, pain reduction, control of the inflammatory response, protection of the affected area. As a part of functional rehabilitation stage we targeted, complete elimination of pain and symptoms, increasing muscle strength of thigh muscles, flexibility on active knee and hip movements, development of neuromuscular control, progressive intensity in functional and sport coordination efforts.

This study consisted of a treatment protocol for the myofascial pain syndrome and trigger points at minimum 5 cm distance from the injury spot for agonist, antagonist and synergist muscles, including low back muscles. The intervention program included specific dry needling therapy for the trigger points of the following muscles: femoral biceps, semitendinosus, semimembranosus, quadriceps, gastrocnemius, gluteus maximus, gluteus medius, gluteus minimus, quadratus lumborum, iliopsoas and sporadically at the level of the back muscles (trapezius, large dorsal, spinal erectors). The initial position of the subjects was supine, ventral or heterolateral, depending on the technique specific to each application. Dry needling was performed using Seirin B type needles: No.8 (0.30) x 30 mm and No.8 (0.30) x 50 mm. The technique was performed safely, taking into account the precautions specific to the segments: the branches of the spinal nerve roots, the blood vessels, the retroperitoneal cavity, the kidneys, the lungs.

The entire team of physiotherapists who supported the development of the research constantly monitored, the fulfillment of the objectives and the observance of the methodology being adapted according to the particularities of the patients and their level of compliance with the treatment.

2.3. Assessment

The outcome measures were assessed both before and after the 6-week interventions were completed. In order to test the values of pain during passive stretching and flexibility, it was necessary to perform the initial and final NRS (numerical pain rating scale) performance and the adapted goniometry of the knee.

Testing the posterior thigh muscles required positioning the patient in the supine position. Passive stretching performed by the therapist described flexion of the thigh to the pelvis with the knee fully extended (similar to the Lasegue test). The self-evaluation of each patient was required on a numerical scale ranging from a minimum of 0 (no pain) to a maximum of 10 (severe pain).

The flexibility of the hamstrings was analyzed by measuring the amplitude of the active knee extension movement from the initial position of flexion to 90^0, and the hip is flexed to 90^0. This measurement was performed with subjects in the supine position on the therapy bed/table. The value of the goniometry included the performance of the maximum active extension movement without/until the onset of pain.

2.4. Statistical analysis

Evaluation of the therapeutic effect for both groups was made using SPSS software (SPSS Inc., Chicago, IL) with a p - value of < 0.05 as reference for statistical significance. More than this, there was used a relevant volume of statistical tests as follows: mean (arithmetic mean), standard deviation (SD), T test (Independent-Samples T Test) and the Pearson correlation coefficient.

3. Results

This section includes the most relevant results that analyzed the functional parameters of the subjects within the initial and final evaluation.

Table 3. Differences between initial and final measurement of the group A

Variables	N	Test	M	SD	t-value	*p*-value	95% Confidence Interval Min	95% Confidence Interval Max
Active knee extension (^{0})	34	Initial	21.81	5.12	14.894	.000	17.150	22.600
		Final	1.94	1.48				
NRS_A		Initial	6.69	.873	21.590	.000	4.867	5.883
		Final	1.31	.479				

Group A (N = 34) includes the group of subjects who required physiotherapy and dry needling treatment following muscle injuries in the hamstrings area. Table 3 shows the results of group A obtained using the Independent-Samples T Test. The value of the active knee extension angle shows a statistically significant evolution between the initial assessment (M = 21.81, SD = 5.12) and the final assessment (M = 1.94, SD = 1.48). The group of subjects registered a significant decrease in range of motion and flexibility deficit (approximately 19^0); t(30) = 14.894, *p* =.000. The score of the numerical pain assessment scale during the passive stretching movement of the posterior thigh muscles showed significant differences between the initial (M = 6.69, SD = .873) and the final (M = 1.31, SD = .479) testing; t(66) = 21.590, *p* = .000, evolution also confirmed by the displayed results in the Table 3.

Table 4. Differences between initial and final measurement of the group B

Variables	N	Test	M	SD	t-value	*p*-value	95% Confidence Interval Min	95% Confidence Interval Max
Active knee extension (^{0})	30	Initial	20.96	4.56	14.427	.001	12.740	16.546
		Final	6.32	2.09				
NRS_B		Initial	6.93	1.01	11.698	.002	2.604	3.682
		Final	3.79	.995				

Table 4 presents the results of group B (N = 30) obtained using the Independent-Samples T Test which analyses the differences between means for active knee extension and numeric pain rating scale results. The final goniometry assessment describes still a deficit of 6^0 in active knee extension, which explains a limited range of motion (M = 6.32, SD = 2.09), especially if we compare the values with those obtained by the group A. Even if the group of subjects registered an adequate decrease in range of motion and flexibility deficit (approximately 14^0); t(58) = 14.427, *p* =.001, this difference, even statistically significant, does not confirm the complete rehabilitation of the subjects after 6 weeks of treatment. The score of the numerical pain assessment scale during the passive stretching movement of the posterior thigh muscles showed a good difference between the initial (M = 6.93, SD = 1.01) and the final (M = 3.79, SD = .995) testing; t(58) = 11.698, p = .002. These values confirm the presence of a statistically significant difference, but there is a pain level of 3-4/10 after 6 weeks of treatment also suggests that the rehabilitation was rather incomplete.

The results recorded within the 95% Confidence Interval validate the homogeneity of the subject groups in relation to the two main treatment measurements.

To evaluate the linear relationship between the final value of the knee goniometry and the NRS scale following passive stretching, the Pearson correlation coefficient (r) was calculated. A strong and statistically significant positive correlation was thus identified, r(32) = .82, p = .000 within the final results belonging to group A of subjects. The same parameters were analyzed in order to interpret the Pearson correlation coefficient (r) and for group B where r(28) = .76, p = .006. The results of both groups indicate a favorable correlation between the reduction of the knee mobility deficit and the sensitivity to the passive stretching performed by the physiotherapist. These statistical interpretations confirm the fact that both measurements are essential in the analysis of therapeutic efficiency and influence each other in the rehabilitation process.

4. Discussions

The criteria for completion of the rehabilitation protocol included: confirmation of the imaging examination (Schut et al., 2016), restoration of maximum amplitude for the range of motion and flexibility (the maximum accepted value of the deficit compared to the healthy limb of 0-5^{0}); significant reduction of pain when performing passive stretching (maximum accepted value was 2 units), restoration of muscle strength (minimum 90-95% compared to the contralateral limb) and performance of specific functional tests (Ernlund & Vieira, 2017; Wong, 2015).

The current research is also an appropriate means of confirming the usefulness of the methods for measuring and evaluating the level of pain and functionality. The analysis of the flexibility of the muscles with the role of antagonist was carried out in several systematic studies to test the functionality within the evaluation of the subjects. The correct value of the goniometer is a relevant indicator for the objectives of the rehabilitation plan. To interpret the deficit on active knee extension movements, initial measurements were taken on both the affected and the unaffected lower limb (Table 3). The initial values were comparable to the mean extension deficit in the study by Malliaropoulous et al. (2010) or Aguilar (2012).

Flexibility is a parameter that can be measured through the goniometry of actively performed movements, in the direction of activation of the antagonist muscles (Maniar, 2016). These items were monitored throughout the rehabilitation plan but representative measurements were taken at the beginning and end of the treatment plan in the specific rehabilitation clinic/office.

The subjects in group A benefited from a very effective combined treatment that improved the parameters describing pain during passive stretching, known also as stretch tolerance and flexibility measured by goniometry. Comparing the results with those reported for the period 10-30 days after trauma from the studies developed by Reurink (2015), Silder (2013), determines an advantage for group A from the current research.

The statistical interpretation of the results of group B of subjects identifies the presence of a small functional deficit at the end of the 6 weeks of evaluation (Table 4). This lack of movement practically placed the group of subjects in the need to extend the therapeutic plan by another week in order to fulfill one of the main criteria for completing the treatment: a maximum of 5 degrees of movement deficit compared to the healthy limb. The final results of the scale that evaluated the level of pain during the passive stretching performed by the physiotherapist also suggested that the subjects in group B did not perhaps benefit from the most effective treatment plan.

The usefulness and applicability of the two measurements as testing methods is also suggested by the strong direct proportional correlation that is established between their final results. Statistical analysis through the Pearson coefficient confirms that the two components that describe the functionality and symptoms of the affected member influence each other. In other words, it is necessary to establish a therapeutic plan in accordance with the specific principles of sport rehabilitation and which has as its objective both the reduction of pain during passive stretching and the increase of flexibility.

This difference in the final results, even of a few degrees or units in the NRS scale, can issue a series of interesting perspectives, all these small differences being extremely important in the rehabilitation of athletes. Group B benefited from a treatment considered suitable, but the involvement of the dry needling therapy for the other subjects in group A represented a real advantage. In addition to the potentially extremely beneficial purely therapeutic effects that practically shortened by one week the period of unavailability of the subjects in group A, it is necessary to analyze the behavioral factors or that describe the level of therapeutic compliance of the two groups of subjects. An extremely interesting aspect for further research can be the analysis of all the factors involved in the rehabilitation process.

5. Conclusions

The impact of dry needling therapy highlighted statistically significant differences in terms of passive stretching tolerance values and hamstring flexibility ($p < 0.05$). The results confirm the importance of dry needling therapy as part of a combined treatment in the rehabilitation of athletes with different categories of muscle injuries that cause pain and limitation of functionality in the lower limbs.

The favorable evolution of functional parameters was also confirmed by the Pearson correlation coefficient, which indicated a simultaneous matching of flexibility rehabilitation and pain reduction to minimal values, especially for the group A of subjects.

The statistical interpretation confirmed the fact that the subjects in group A benefited from a superior therapeutic plan as well as the efficiency of the subjects in group B, the latter needing to extend the therapeutic plan by another week. These highlights allow the establishment of very useful future perspectives, since shortening the treatment even by a week or a few days can weigh enormously in the athletes' rehabilitation.

The efficiency of the means of intervention based on a wide spectrum of principles (mechanical, physiological, biochemical) is proven by the optimizing effect of the treatment and predicting a rapid progress in accordance with the principles of rehabilitation. The combined treatment plan based on dry needling therapy can represent a therapeutic option for other categories of patients as well.

References

Aguilar, A.J., Di Stefano, L.J., Brown, C.N., Herman, D.C., Guskiewicz, K.M., Padua, D.A. (2012). A dynamic warm-up model increases quadriceps strength and hamstring flexibility. *J Strength Cond Res, 26(4)*, 1130-41. doi: 10.1519/JSC.0b013e31822e58b6.

Alaei, P., Nakhostin, Ansari, N., Na ghdi, S., Fakhari, Z., Komesh, S., Dommerholt, J. (2020). Dry Needling for Hamstring Flexibility: A Single-Blind Randomized Controlled Trial. *Journal Sport Rehabilitation, 3*, 452-457. doi: 10.1123/jsr.2020-0111.

Ansari, N.N., Alaei, P., Naghdi, S., Fakhari, Z., Komesh, S., Dommerholt, J. (2020). Immediate Effects of Dry Needling as a Novel Strategy for Hamstring Flexibility: A Single-Blinded Clinical Pilot Study. *The Journal Sport Rehabilitation, 29(2)*, 56-161. doi: 10.1123/jsr.2018-0013.

Bazzaz-Yamchi, M., Naghdi, S., Nakhostin-Ansari, A., Hadizadeh, M., Ansari, N.N., Moghimi, E., Hasson, S. (2021). Acute and Short-Term Effects of Dry Needling in Patients with Chronic Nonspecific Low Back Pain and Hamstring Tightness: A Pilot Study. *Scientific World Journal, 7*, 259-956. doi: 10.1155/2021/7259956.

Bravo-Sánchez, A., Jiménez-Diaz, F., Abián-Vicén, J. (2021). Is Dry Needling Applied by Physical Therapists Effective for Pain in Musculoskeletal Conditions? A Systematic Review and Meta-Analysis. *The Journal of Physio Therapy, 101(3)*, 70. doi:10.1093/ptj/pzab070.

Cushman, D., Rho, ME. (2015). Conservative Treatment of Subacute Proximal Hamstring Tendinopathy Using Eccentric Exercises Performed With a Treadmill: A Case Report. *Journal Orthopedic Sports Physio Therapy, 45(7)*, 557-62. doi: 10.2519/jospt.2015.5762.

Davies, A., Lawrence, T., Edwards, A., Lecky, F., McKay, C. (2020). Serious sports-related injury in England and Wales from 2012-2017. *Injury Epidemiology, 7*. https://doi.org/10.1186/s40621-020-00243-4.

Delos, D., Maak, T. G., Rodeo, S. A. (2013). Muscle injuries in athletes: enhancing recovery through scientific understanding and novel therapies. *Sports health, 5(4)*, 346–352. https://doi.org/10.1177/1941738113480934.

Drew, M.K., Raysmith, B., Charlton, P. (2017). Injuries impair the chance of successful performance by sportspeople: a systematic review. *British Journal of Sports and Medicine, 51(16)*, 1209-1214.

Ernlund, L., Vieira, L.A. (2017). Hamstring injuries: update article. *Revista brasileira de ortopedia, 52(4)*, 373–382. https://doi.org/10.1016/j.rboe.2017.05.005.

Fields, K.B., & Rigby, M.D. (2016). Muscular Calf Injuries in Runners. *Current sports medicine reports, 15(5)*, 320–324. https://doi.org/10.1249/JSR.0000000000000292

Gattie, E., Cleland, J.A., Snodgrass, S. (2017). The Effectiveness of Trigger Point Dry Needling for Musculoskeletal Conditions by Physical Therapists: A Systematic Review and Meta-analysis. *The Journal of Orthopaedic and Sports Physical Thererapy, 47(3)*, 133-149. doi: 10.2519/jospt.2017.7096.

Geist, K., Bradley, C., Hofman, A., Koester, R., Roche, F., Shields A., Frierson, E., Rossi, A., Johanson, M. (2017). Clinical Effects of Dry Needling Among Asymptomatic Individuals With Hamstring Tightness: A Randomized Controlled Trial. *The Journal Sport Rehabilitation, 26(6)*, 507-517. doi: 10.1123/jsr.2016-0095.

Guillin, R., Rochcongar, P.B. (2017). Muscle Injuries in Sport Athletes. *Sports Health, 5*, doi:10.1177/1941738113480934.

Iacob, G.S., Măzăreanu, A. (2021). The comparison between manual trigger point and dry needling in treating upper and middle back myofascial pain syndrome in sport players. *Journal of Physical Rehabilitation and Sports Medicine, 3*. DOI:10.5281/zenodo.5552884.

Jayaseelan, D.J., Moats, N., Ricardo, C.R. (2014). Rehabilitation of proximal hamstring tendinopathy utilizing eccentric training, lumbopelvic stabilization, and trigger point dry needling: 2 case reports. Journal Orthopedic Sports Physio Therapy, 44(3), 198-205. doi: 10.2519/jospt.2014.4905.

Kalichman, L., Vulfsons, S. (2010) Dry needling in the management of musculoskeletal pain. *Journal American Board Famacie Medicine, 23(5)*, 640-646. doi:10.3122/jabfm.2010.05.090296.

López-González, L., Falla, D., Lázaro-Navas, I., Lorenzo-Sánchez-Aguilera, C., Rodríguez-Costa, I., Pecos-Martín, D., Gallego-Izquierdo, T. (2021). Effects of Dry Needling on Neuromuscular Control of Ankle Stabilizer Muscles and Center of Pressure Displacement in Basketball Players with Chronic Ankle Instability: A Single-Blinded Randomized Controlled Trial. *International Jounal Environ Res Public Health, 18(4)*, 2092. doi:10.3390/ijerph18042092.

Malliaropoulos, N., Papacostas, E., Kiritsi, O. (2010). Posterior Thigh Muscle Injuries in Elite Track and Field Athletes. *The American Journal of Sports Medicine, 38(9)*, 1813-1819. doi:10.1177/0363546510366423.

Maniar, N., Shield, A. J., Williams, M. D., Timmins, R. G., & Opar, D. A. (2016). Hamstring strength and flexibility after hamstring strain injury: a systematic review and meta-analysis. *British journal of sports medicine, 50(15)*, 909–920. https://doi.org/10.1136/bjsports-2015-095311.

Mason, J.S., Crowell, M., Dolbeer, J., Morris, J., Terry, A., Koppenhaver, S., Goss, DL. (2016). The effectiveness of dry needling and stretching vs. stretching alone on hamstring flexibility in patients with knee pain: a randomized controlled trial. *International Journal Sports Physio Therapy, 11(5)*, 672-683.

Reurink, G., Goudswaard, G.J., Moen, M.H. (2015). Dutch HIT-study Investigators.Rationale, secondary outcome scores and 1-year follow-up of a randomised trial of platelet-rich plasma injections in acute hamstring muscle injury: the Dutch Hamstring Injection Therapy study. *Br J Sports, 49*, 1206-12.

Schut, L., Wangensteen, A., Maaskant, J. (2017). Can Clinical Evaluation Predict Return to Sport after Acute Hamstring Injuries? A Systematic Review. *Sports Med, 47*, 1123–1144.

Silder, A.Y., Sherry, M.A., Sanfilippo, J. (2013). Clinical and morphological changes following 2 rehabilitation programs for acute hamstring strain injuries: a randomized clinical trial. *J Orthop Sports Phys Ther*, *43*, 284–99.

Wong, S., Ning, A., Lee, C., Feeley, B. T. (2015). Return to sport after muscle injury. *Current reviews in musculoskeletal medicine, 8(2)*, 168-175.