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**Application of Medical Dry Needling in Subacromial
Impingement Syndrome of the Shoulder Joint**

Author’s Abstract

**for awarding the educational and scientific degree Doctor
in the academic specialty Health Care Management**

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List of Frequently Used Abbreviations

SAPS – Subacromial Pain Syndrome

MDN – Medical Dry Needling

SJ – Shoulder Joint

GHJ – Glenohumeral Joint

VAS – Visual Analogue Scale

MMT – Manual Muscle Testing

MTrP – Myofascial Trigger Point

ROM – Range of Motion

PT – Physiotherapy

KT – Kinesiotherapy

MRI – Magnetic Resonance Imaging

EG – Experimental Group

CG – Control Group

DN – Dry Needling

DDN – Deep Dry Needling

SDN – Superficial Dry Needling

CGRP – Calcitonin Gene-Related Peptide

TNF- α – Tumor Necrosis Factor Alpha

UCLA-SRS – University of California and Los Angeles Shoulder Rating System

SPADI – Shoulder Pain and Disability Index

SITS – Supraspinatus, Infraspinatus, Teres Minor, Subscapularis

μ V – Microvolts

ACh – Acetylcholine

INTRODUCTION

Subacromial Impingement Syndrome (SAPS) is among the most common shoulder conditions and a leading cause of pain, functional limitation, and reduced work capacity in adults of active age. Data from modern literature indicate that SAPS accounts for 44–65% of all shoulder pain cases, making it a significant clinical and socio-economic issue. Disruptions in shoulder complex biomechanics, the presence of myofascial trigger points, muscular imbalance, and alterations in scapulohumeral rhythm contribute to chronic symptomatology and complicate effective treatment.

In current rehabilitation practice, methods aimed at restoring musculoskeletal balance, reducing pain, and optimizing biomechanical function have gained importance. One such method is Medical Dry Needling (MDN) – a minimally invasive therapeutic technique intended to deactivate myofascial trigger points (MTrPs), modulate pain mechanisms, and improve local tissue function. Due to its capacity to influence both peripheral and central pain pathways, MDN is viewed as a promising adjunct modality in treating SAPS.

Despite rising interest, research evidence regarding the physiological mechanisms and treatment efficacy of MDN remains partially fragmented. Many existing studies suffer from small sample sizes, lack of randomization, or short follow-up periods. This highlights the need for well-structured interventional studies assessing the true role of dry needling in multimodal rehabilitation programs for SAPS.

The present dissertation aims to evaluate the therapeutic effect of MDN as part of a combined physiotherapeutic intervention and to assess its impact on pain, muscle strength, range of motion, and functional capacity in patients with SAPS. A prospective randomized controlled trial (RCT) with short- and long-term follow-up was conducted, allowing for an objective evaluation of the dynamics and durability of therapeutic outcomes.

By integrating clinical, instrumental, and functional assessment methods, the study provides a comprehensive analytical framework that supports formulating scientific conclusions about the role of MDN in managing subacromial impingement syndrome. The results have the potential

to enhance rehabilitation strategies and inform the development of evidence-based clinical protocols integrating MDN into modern physiotherapy practice.

GOALS, OBJECTIVES, HYPOTHESES, SUBJECT AND OBJECT

1.1. Research Goal

To evaluate the effect of Medical Dry Needling (MDN) as an adjunct to traditional physiotherapy in the non-surgical management of patients with Subacromial Impingement Syndrome (SAPS).

1.2. Research Objectives

1. Conduct a comprehensive theoretical analysis of modern scientific sources regarding SAPS—its etiology, pathogenesis, clinical presentation, biomechanics, and functional outcomes.
2. Review and systematize current evidence on the use, mechanisms, and clinical efficacy of MDN in musculoskeletal disorders.
3. Select and describe adequate measurement tools for clinical and functional assessment in SAPS patients.
4. Develop an experimental treatment protocol combining MDN with standard physiotherapy techniques, tailored to the anatomy and function of the shoulder complex.
5. Conduct a prospective, interventional, randomized controlled clinical trial with two parallel groups (experimental and control) adhering to ethical and methodological standards.
6. Evaluate the therapeutic effect of the combined intervention based on pain, muscle strength, range of motion, and functional capacity.
7. Assess short-term (8 weeks) and long-term (6 months) sustainability of treatment effects.

1.3. Research Hypotheses

- Hypothesis 1 (Muscle Strength)
H₀: No significant difference in muscle strength gains between physiotherapy alone and

physiotherapy combined with MDN.

H₁: Physiotherapy combined with MDN leads to greater improvement in muscle strength compared to physiotherapy alone.

- Hypothesis 2 (Pain Reduction)

H₀: No significant difference in pain reduction (VAS, SPADI) between groups.

H₁: Combined therapy with MDN achieves greater and longer-lasting pain reduction.

- Hypothesis 3 (Functional Outcome)

H₀: No significant difference in functional improvement (SPADI, UCLA) between groups.

H₁: The MDN group achieves superior improvement in functional scores and overall recovery.

1.4. Subject and Object

1.4.1. Object of Study

Patients diagnosed with Subacromial Impingement Syndrome (SAPS) of the shoulder, confirmed by an orthopedic specialist.

1.4.2. Subject of Study

The effect of Medical Dry Needling as part of non-surgical treatment for SAPS.

MATERIAL, METHODS AND RESEARCH TOOLS

2.1. Study Material

To achieve the stated goals and objectives, an experimental design was developed ensuring data comparability between groups and longitudinal tracking of change dynamics. The structure of the investigation complied with the principles of evidence-based medicine and the requirements for high internal and external validity.

The present study was conducted as a prospective, interventional, randomized, controlled, parallel-group clinical trial (Randomized Controlled Trial, RCT; allocation 1:1) involving two parallel groups:

- Experimental group (EG, n = 40): traditional physiotherapy + medical dry needling
- Control group (CG, n = 40): traditional physiotherapy only

Measurements evaluating treatment impact were performed at four time points:

- T1 – before intervention (baseline)
- T2 – after 3 weeks (end of therapy)
- T3 – 8 weeks post-therapy (short-term follow-up)
- T4 – 6 months post-therapy (long-term follow-up)

Randomization followed a simple/block principle (operationally described in the methodology).

2.1.1. Population and Criteria

To ensure a homogenous sample and high data reliability, the study population consisted of patients with clinically confirmed Subacromial Impingement Syndrome (SAPS). All participants were examined by an orthopedic specialist and underwent preliminary screening.

Inclusion criteria

- Clinically confirmed *Subacromial Impingement Syndrome*
- Symptom duration ≥ 3 months
- Age 25–65 years
- Pain intensity ≥ 4 points on the Visual Analogue Scale (VAS)
- Voluntary participation and signed informed consent

Exclusion criteria

- Recent trauma to the shoulder girdle (fracture/dislocation)
- Neurological disorders involving the upper limb
- Cardiovascular disease causing functional limitation
- Active infections
- Corticosteroid therapy within the past 3 months
- Diagnosed fibromyalgia
- Psychiatric disorders

- Needle phobia
- Cervical or shoulder surgery within 1 year
- Pregnancy

2.1.4. Location, Organization, and Stages

Measurements and interventions were conducted at “Dobrich Physio Center” Ltd., equipped for physiotherapy and rehabilitation procedures. All sessions were performed by a licensed physiotherapist certified in Medical Dry Needling (MDN).

To guarantee adherence to protocol, all interventions were performed by the same therapist; assessments were carried out by an independent evaluator blinded to group allocation.

The interventional phase lasted 15 working days (3 weeks). The study took place between January – July 2025, with follow-ups at 8 weeks and 6 months.

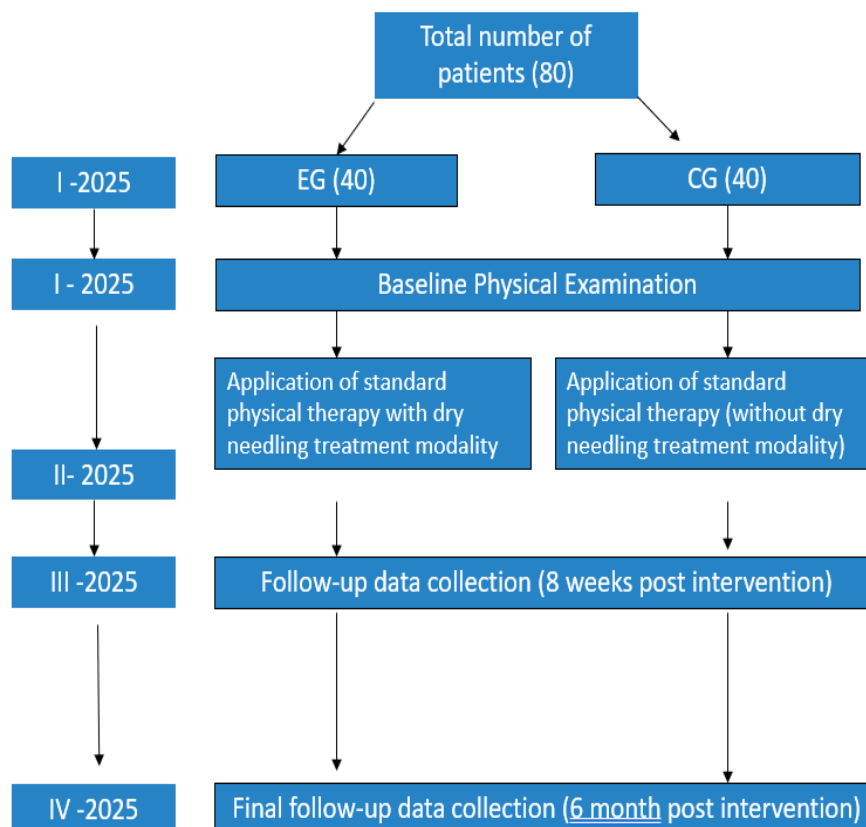


Fig 1. Stages of intervention data collection

Figure 1.1. Phases and timing of intervention

T1 – Pre-intervention, Q1 2025 – baseline physiotherapeutic examination and measurements:

- Demographic data (age, sex, symptom duration)
- Diagnostic tests (Hawkins–Kennedy, Neer, Jobe, Lift-off)
- Muscle strength, range of motion, pain (VAS), functional capacity (SPADI, UCLA)

T2 – 3rd therapy week, Q1 2025 – completion of treatment phase following the group-specific protocols.

T3 – 8 weeks after intervention, Q2 2025 – intermediate follow-up for short-term effects.

T4 – 6 months after intervention, Q3 2025 – final follow-up evaluating sustainability of results.

Stage	Period	Main Activities	Purpose
T1	Before therapy	Baseline assessment	Define reference values
T2	After 3 weeks	End of therapy	Short-term effect
T3	After 8 weeks	Follow-up	Mid-term effect
T4	After 6 months	Final assessment	Long-term effect

2.2. Methods and Instruments

2.2.1. Assessment Tools and Tests (Grouped by Criteria)

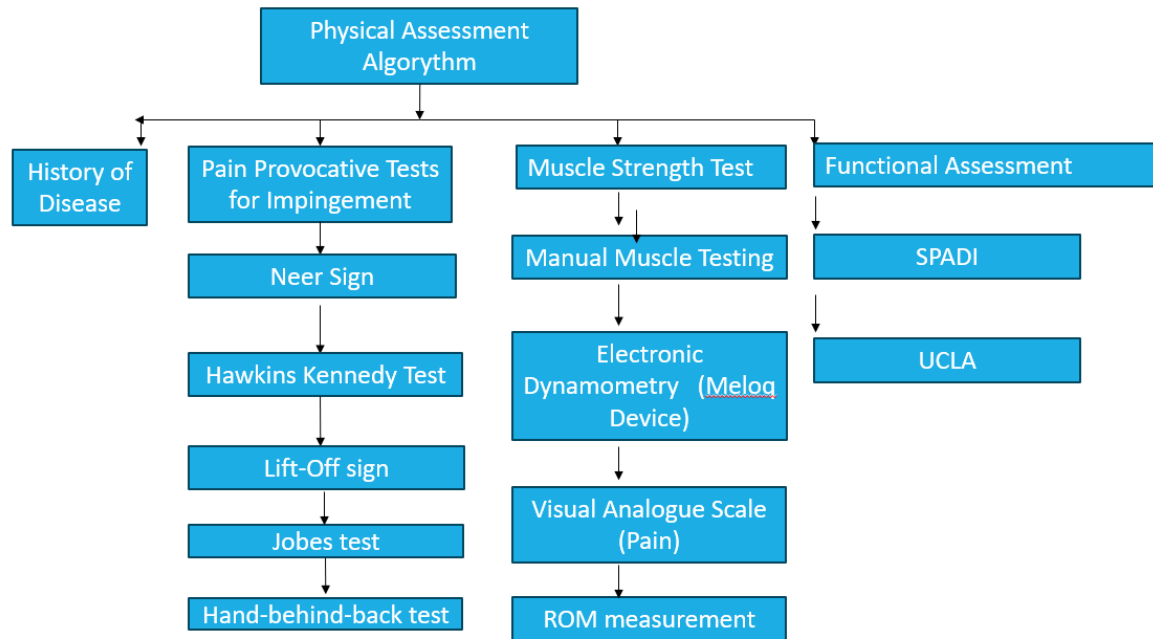


Figure 1.2. Evaluation algorithm for assessing shoulder impingement syndrome

Provocative and Diagnostic Tests for SAPS

- Hawkins–Kennedy Test: shoulder and elbow flexed 90°, maximal internal rotation; pain → compression of *m. supraspinatus* under the coraco-acromial arch.
- Neer Test: forced shoulder flexion causing compression of *tuberculum majus* against the acromion; pain → overload of *m. supraspinatus*.
- Jobe’s (Empty Can) Test: 90° abduction in the scapular plane, internal rotation; downward pressure → pain/weakness of *m. supraspinatus*.
- Lift-off Sign: internal rotation with dorsum of hand on back; pain or inability → lesion of *m. subscapularis*.

Range of Motion & Mobility

- Hand-Behind-Back (HBB): internal rotation and adduction behind back; level L5–S1 → restriction; level Th7–8 → normal.

- Goniometry (SFTR by Moor): flexion, extension, abduction, internal/external rotation measured with standard two-armed goniometer.

Muscle Strength

- Manual Muscle Testing (MMT): 6-point scale (0–5).
- Dynamic Dynamometer (Meloq 2023): quantitative assessment (N/m) for rotators, flexors, and abductors.

Pain

- Visual Analogue Scale (VAS 0–10): 0 = no pain, 10 = unbearable pain; target intensity 3–5.

Functional Scales

- SPADI (Shoulder Pain and Disability Index): 0–100 points; clinically meaningful change \approx 13 points.
- UCLA Shoulder Rating Score: 35 points total; ≥ 27 = good–excellent outcome.

2.3. Interventions

Two therapeutic protocols were applied:

1. Control Group (CG): traditional physiotherapy.
2. Experimental Group (EG): same physiotherapy + Medical Dry Needling (MDN).

Each session: once daily, 30 minutes, for 3 weeks (15 sessions).

2.3.1. Control Group – Traditional Physiotherapy

Therapeutic Aims

Pain reduction, restoration of physiological mobility, re-establishment of muscle balance, and improvement of functional independence.

Specific Objectives

- Reduce pain in the affected limb.
- Increase active and passive ROM.
- Correct muscular imbalance between stabilizers and mobilizers.

- Restore strength, endurance, and coordination.
- Improve scapulothoracic control and rhythm.
- Reinststate functional movement patterns for daily activity integration.

Applied Physiotherapy Techniques

- Joint Mobilization (Kaltenborn method): to restore accessory motion and joint kinematics.
- Active Exercises (no resistance): coordination & control.
- Active Exercises with Weights: progressive strengthening.
- Elastic Band Exercises: graded resistance, proprioceptive training.
- Multi-angular Isometric Exercises: static strengthening.
- Post-Isometric Relaxation (PIR): tone reduction and improved ROM.
- Apparatus-Based Myofascial Therapy (Acheaway® USA, 2023): thermal-vibrational fascial release (40–50 °C, 0–6 Hz), 5 min per patient, using Arnica gel (*DocSave Germany*).

Methodological Guidelines

Exercises progressed in intensity and complexity, individualized per tolerance. Each session followed the same structure for both groups (Arias-Buria et al., 2017): active phase ≈ 30 min.

Dynamic → eccentric → isometric progression, high repetitions / low–medium load to promote analgesia and prevent overload.

Two sets × 10 repetitions (dynamic); two sets × 5–10 isometric (8–10 s hold).

Joint Mobilization (Kaltenborn):

- Caudal & traction mobilizations (2×10 reps).
- Ventral/dorsal glides from varying positions (2×8–10).
- Scapular elevation–depression + protraction–retraction (2×8).
- Distraction with external and internal rotations (2×10 each).

Example Exercise Series:

- Dynamic external rotation 1×15 → eccentric 1×15 → isometric 1×10 (10 s hold).
- Multi-angular isometric abduction 1×5 positions (5–8 s).
- Abduction at 90° – 8–10 small-range linear + circular movements.
- Scapular protraction/retraction 2×15 (in supine) or on fitball.

Positions in 35–40° scaption minimized compression vectors on *m. supraspinatus* / *infraspinatus*.

Exercise sequencing followed reciprocal activation principles.

2.3.2. Experimental Group – Physiotherapy + Medical Dry Needling

Identical physiotherapy to CG plus MDN according to the following protocol.

MDN Intervention

Three sessions (total) – once per week – performed after precise palpatory localization of active MTrPs.

Based on Halle et al. (2020) and Kamali et al. (2019).

Targeted muscles:
m. supraspinatus, *m. infraspinatus*, *m. teres minor*, *m. subscapularis*, *m. latissimus dorsi*, *m. biceps brachii* (long head), and *m. trapezius* (upper part).

Needling continued until Local Twitch Response (LTR) was elicited – the indicator of precise MTrP penetration.

Mean duration ≈ 10 min per patient, followed by 30 min physiotherapy.

2.3.3. Protocol for Applying Medical Dry Needling (MDN)

Sterile single-use silicone-coated acupuncture needles
(*NonDolens Cloud & Dragon 0.25×30, 0.30×40, 0.30×50 mm, DocSave Berlin/Düsseldorf, Germany*).

Guiding tubes used for precision and comfort; areas disinfected with 70% ethanol; appropriate hazardous-waste disposal ensured.

Technique: repetitive “fishing” punctures until LTR exhausting; priority given to hypoactive/inhibited muscles to reduce reflex inhibition. Average session \approx 10 minutes.

Detailed operational descriptions for each muscle (*infraspinatus*, *supraspinatus*, *teres minor*, *subscapularis*, *latissimus dorsi*, *trapezius – ascending part*, *biceps brachii – long head*) with patient positioning, insertion angles and safety precautions were standardized in Appendix A.

2.4. Statistical Analysis Plan

- Check normality & homogeneity of variances.
- Repeated-measures MANOVA with within-factor Time and between-factor Group; linear/quadratic/cubic contrasts where relevant.
- Between-group comparisons ($\Delta T1-T2$; $\Delta T3-T4$) – ANCOVA or independent t-tests with covariates.
- Effect size (η^2 / partial η^2 , Cohen’s d) and 95% CI.
- Significance $\alpha = 0.05$; corrections for multiple comparisons.

2.4.1. Data Management, Safety, and Adverse Events

- Standardized data-collection forms, double entry.
- Adverse-event documentation (local soreness, hematoma, etc.) with response algorithm.
- Confidentiality per applicable data-protection law.

2.5. Appendix A – Detailed Operational Descriptions of Dry Needling Techniques

1. m. infraspinatus: Patient in side-lying; needle advanced to *spina scapulae* until LTR elicited.
2. m. supraspinatus: Needled near *acromion* through full muscle depth to *spina scapulae*. LTR obtained.
3. m. teres minor: Prone; arm flexed 90° (shoulder) / 45° (elbow); isolated between spina and axillary border; needle inserted directly \rightarrow LTR.
4. m. subscapularis: Supine; elbow flexed, hand behind head; scapula protracted laterally to expose ribs; perpendicular lateral insertion.

5. m. latissimus dorsi: Supine with 70° abduction; pinch grip, perpendicular insertion → LTR; variation in side-lying for slender subjects.
6. m. trapezius (upper part): Prone or side-lying; skin-fold lifted cranially away from thorax; perpendicular insertion into palpated MTrP → LTR.
7. m. biceps brachii (long head): Supine; elbow ≈ 45°, forearm supinated; long head isolated pinch grip, needled → involuntary contraction (LTR).

Average procedure ≈ 10 min per session.



RESULTS AND DISCUSSION

The total number of participants was **80**, equally divided into two groups — **Experimental (EG, n = 40)** and **Control (CG, n = 40)**.

Age distribution was comparable between groups; the predominant range was **42 – 48 years** (EG 28%, CG 18%).

Gender ratio was balanced — 20 men and 20 women in each group (1:1).

Mean age in EG was 46.28 ± 11.4 years; in CG – 47.45 ± 12.5 years.

All participants had the **dominant right upper limb** affected, ensuring group homogeneity.

Table 2.1 – Demographic distribution

	Experimental group		Control group	
	N	%	n	%
Participants Age				
25 - 34	6	15	7	18%
35 - 41	7	18	8	20%
42 - 48	11	28	7	18%
49 - 55	6	15	7	18%
56 - 62	6	15	6	15%
above 62	4	10	5	13%
Gender				
Male	20	48%	20	52,5%
Female	20	53%	20	47,5%
Affected upper limb				
right	40	100%	40	100%

Homogeneity in baseline variables confirmed the **internal validity** of the trial; therefore, any post-treatment differences can be attributed to the therapeutic intervention.

3.1. Provocative and Diagnostic Tests for SAPS

3.1.1 Hawkins–Kennedy test

As shown below, both groups displayed significant intra-group improvement ($p < 0.001$). However, the higher Cochran's Q value in EG (245.394) indicates a stronger recovery dynamic directly linked to the inclusion of dry needling.

Table 2.2 – Cochran's Q results for Hawkins–Kennedy pain response

Group	Stage of Testing	No pain (1)	With pain (0)
Experimental	Test 1 (pre-intervention)	0	40
	Test 2 (3 weeks)	35	5
	Test 3 (8 weeks post)	35	5
	Test 4 (6 months post)	37	3
Control	Test 1 (pre-intervention)	0	40
	Test 2 (3 weeks)	24	16
	Test 3 (8 weeks post)	23	17
	Test 4 (6 months post)	22	18

Statistical data:

Group	N	Cochran's Q	df	Sig. (p)
Experimental	40	245,394 ^a	7	0,000
Control	40	126,051 ^a	7	0,000

All patients were initially positive for the current physical testing. Directly at the end of the treatment intervention (3 weeks), 35 of 40 EG patients became symptom-free versus 24 in CG. At 6 months, EG improved further (37 pain-free), whereas CG regressed (22 pain-free), confirming a **durable analgesic effect** of MDN.

3.1.2 Neer test

At baseline, all subjects were positive to the Neer sign.

By the third week: EG – 39 pain-free vs CG – 25.

Six months later: EG – 100% negative; CG – 26 negative / 14 residual pain.

Group	Stage of testing	Без болка (1)	С болка (2)
Experimental	Test 1 (baseline)	0	40
	Test 2 (3-rd week)	39	1
	Test 3 (8 weeks post)	38	2
	Test 4 (6 months post)	40	0
Control	Test 1 (baseline)	0	40
	Test 2 (3-rd week)	25	15
	Test 3 (8 weeks post)	29	11
	Test 4 (6 month post)	26	14

Статистически показатели:

Group	N	Cochran's Q	df	Sig. (p)
Experimental	40	270,609 ^a	7	0,000
Control	40	89,017 ^a	7	0,000

^a Value „1“ is perceived as „success“ (no presence of pain); $p < 0,05$ – statistically significant difference

Hence, MDN yielded faster and more persistent symptom resolution.

3.1.3 Jobe (Empty Can) test

Statistically significant recovery occurred in both groups ($p < 0.001$), yet the EG showed higher $Q = 271.522$ vs 159.501 (CG).

Pain and weakness of *m. supraspinatus* resolved earlier and remained stable only in EG.

3.1.4 Lift-off (Gerber) test

All participants were positive at baseline testing.

After 3 weeks: EG – 39 pain-free; CG – 23.

At 6 months: EG maintained 39 / 1, while CG fell to 25 / 15.

$Q_{EG} = 233.614$ vs $Q_{CG} = 156.475$ ($p < 0.001$) → **sustained recovery of *m. subscapularis*.**

3.1.5 Discussion of Diagnostic Tests

The **combined approach (PT + MDN)** outperformed standard physiotherapy owing to deactivation of myofascial trigger points within the rotator cuff muscles, leading to restoration of neuromuscular coordination and scapulohumeral rhythm. This explains the absence of pain in Hawkins-Kennedy, Neer, Jobe, and Lift-off tests across follow-ups.

High Q -values and durable outcomes in EG confirm a **strong, long-lasting therapeutic effect** mediated by both peripheral and central mechanisms.

3.2. Range of Motion (ROM) and Mobility Tests

3.2.1 Hand-Behind-Back (HBB) Test – Internal Rotation Function

Both groups improved

significantly ($p < 0.05$), but χ^2 in EG was approximately double that in CG, indicating stronger intervention effect.

Table 3.1 – Friedman’s Test (HBB)

Group	Stage of testing	Mean Rank
Experimental	Test 1 (baseline)	7,50
	Test 2 (3-rd week)	3,50
	Test 3 (8 weeks post)	3,50
	Test 4 (6 months post)	3,50
Control	Test 1 (baseline)	5,96
	Test 2 (3-rd week)	4,18
	Test 3 (8 weeks post)	3,68
	Test 4 (6 months post)	3,88

After 3 weeks, 34 EG participants regained near-normal range (Th8 level) vs 24 in CG; The tests at 6 months post intervention also indicated a difference between the groups → EG(37) vs CG(27).

Cochran's Q = 266.000 (EG) vs 156.475 (CG) ($p < 0.001$) → EG achieved broader and more persistent mobility restoration.

3.2.2 Goniometric ROM (SFTR-Moor) Results

Baseline values showed no significant differences between groups.

Initial ROM deficits confirmed functional limitations

(flexion $\approx 133^\circ$, abduction $\approx 112^\circ$, external rotation $\approx 49^\circ$, internal rotation $\approx 54^\circ$).

Table 3.3. Measured ROM of Shoulder joint at baseline in EG and CG

Testing	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
Flexion	Experimental	40	133,10	19,186	,432
	Control	40	136,08	14,092	,432
Abduction	Experimental	40	112,90	17,331	,532
	Control	40	110,63	14,987	,532
External Rotation	Experimental	40	49,15	12,695	,953
	Control	40	49,30	9,536	,953
Internal Rotation	Experimental	40	53,60	11,967	,520
	Control	40	55,20	10,090	,520

The mean values for flexion (133.10° in the experimental group and 136.08° in the control group) and abduction (112.90° in the experimental group and 110.63° in the control group) are lower than the normal physiological ranges ($160\text{--}180^\circ$ for flexion and $150\text{--}180^\circ$ for abduction), confirming the presence of a functional deficit in all patients as a result of the subacromial impingement syndrome (SAPS).

A similar tendency is observed in external and internal rotation (averaging approximately 49° and 54° , respectively), whose values are significantly reduced compared to the normal ranges (about $70\text{--}90^\circ$ for external and $60\text{--}70^\circ$ for internal rotation).

After 3 weeks (T2)

Table 3.4 Measured ROM of shoulder joint during 3rd week *end of intervention in EG and CG.

Testing	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
Flexion	Experimental	40	166,75	12,370	,039
	Control	40	160,50	14,146	,039
Abduction	Experimental	40	144,28	13,074	,000
	Control	40	128,60	14,968	,000
External Rotation	Experimental	40	79,15	9,363	,000
	Control	40	63,43	9,473	,000
Internal Rotation	Experimental	40	82,95	7,100	,000
	Control	40	69,68	10,455	,000

The experimental group reached a mean flexion range of 166.75°, which is close to the physiological norm (170–180°). In comparison, the control group achieved 160.50°, indicating a slower recovery of range of motion. The difference between the groups is statistically significant ($p = 0.039$), emphasizing the effect of the added dry-needling intervention in improving mobility within the sagittal plane.

For abduction, the results again favor the experimental group (144.28° versus 128.60°). The improvement of more than 15° in the experimental group indicates faster resolution of pain syndrome and muscular contracture, which typically limit movement in SAPS. The high statistical significance ($p < 0.001$) confirms the effectiveness of the combined intervention.

External rotation of the shoulder joint — the movement most sensitive to pain in SAPS — showed the greatest improvement in the experimental group, rising from approximately 49° at the beginning of the study to 79.15° at the end of the third week. The control group reached only 63.43°, reflecting a considerably weaker recovery of mobility. The difference of about 16° is clinically meaningful, demonstrating faster and more complete functional recovery of the *m. infraspinatus* and *m. teres minor* in patients treated with medical dry needling.

For internal rotation, a clear advantage was also observed in the experimental group — 82.95° compared to 69.68° in the control group ($p < 0.001$). The improvement of more than 13° in the experimental group suggests a more effective reduction of muscular inhibition and better restoration of *m. subscapularis* function, a key stabilizer within the shoulder complex.

At the end of the protocol EG nearly reached physiological norms; CG lagged $\approx 15 - 20^\circ$.

At 8 weeks (T3)

The results obtained, presented in Table 3.5, show further improvement in the experimental group (EG) and weaker but stabilizing dynamics in the control group (CG). The differences between the groups remain statistically significant ($p < 0.001$) for most movements, except for flexion, where a tendency towards leveling was observed ($p = 0.069$).

Table 3.5 Differences in quantitative data for ROM of shoulder joint during 8 weeks post intervention testing between EG and CG.

Testing	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
Flexion	Experimental	40	166,88	12,168	,069
	Control	40	161,53	13,706	,069
Abduction	Experimental	40	144,95	12,510	,000
	Control	40	130,40	14,489	,000
External Rotation	Experimental	40	80,55	8,545	,000
	Control	40	66,48	8,724	,000
Internal Rotation	Experimental	40	83,78	6,467	,000
	Control	40	71,33	8,954	,000

The most pronounced difference was observed in external rotation – 80.55° for EG versus 66.48° for CG ($p < 0.001$). This represents over 21° greater improvement in the dry needling group. This result confirms that the combined approach effectively restores the function of the m. infraspinatus and m. teres minor, responsible for this movement, while simultaneously reducing compression on the m. supraspinatus tendon.

The experimental group reached an average of 83.78° , which is almost within the physiological norm. However, the control group achieved only 71.33° , which indicates a slower recovery process of the internal rotators, especially m. subscapularis. The difference of over 12° is statistically and clinically significant ($p < 0.001$).

EG sustained gains; CG improved modestly. $p < 0.001$ for all except flexion ($p = 0.069$). External rotation difference $> 21^\circ$ and clinically meaningful.

At 6 months (T4)

Abduction showed a clearly pronounced and statistically significant advantage of EG (144.28°) over CG (131.95°), $p < 0.001$. The improvement in the experimental group remained almost identical to that of the eighth week, which confirms the durability of the effect and the lack of regression in the restored function. The control group, although with progress, retained about

10% lower range of motion, which suggests a partial restoration of the muscle-joint balance (Table 3.6).

Table 3.6 Differences in quantitative data for ROM of shoulder joint during 6 months post intervention testing between EG and CG.

Testing	Group	N	Mean	Std. Deviation	Sig. (2-tailed)
Flexion	Experimental	40	166,75	12,370	,062
	Control	40	161,13	14,164	,062
Abduction	Experimental	40	144,28	13,074	,000
	Control	40	131,95	14,231	,000
External Rotation	Experimental	40	79,15	9,363	,000
	Control	40	68,73	9,951	,000
Internal Rotation	Experimental	40	82,95	7,100	,000
	Control	40	72,63	9,726	,000

This movement again stands out as a key indicator of the success of the intervention. The mean value in EG is 79.15°, which is close to the physiological norm, while KG reaches only 68.73° ($p < 0.001$). The difference of about 10° is both statistically and clinically significant. It reflects better rotator cuff stability and a lower degree of pain response in patients treated with dry needling.

The results for internal rotation also confirm the long-term effect of the combined approach – EG (82.95°) vs. CG (72.63°), $p < 0.001$. This indicates a more complete recovery of the function of the m. subscapularis and better scapulohumeral coordination, which is important for preventing recurrence of the syndrome.

During the three-week treatment protocol, the experimental group (EG), which received an additional medical dry needling modality to the standard physiotherapy plan, noted a significant increase in shoulder joint flexion – an average of 33° (from 133° to 166°). The control group (CG), treated with the standard physiotherapy protocol alone, also reported improvement, but at a slower rate – an average of 24° (from 136° to 160°).

Regarding shoulder abduction, the EG again demonstrated a more pronounced progress. The initial value of 112° reached 144° at the end of the protocol (+32°), while in the CG the increase

was more limited – from 110° to 128° (+18°). Although the difference between the two groups seems small (16°), it is in favor of the EG and indicates a faster recovery.

External rotation showed the largest differences between groups. In the EG, the range of motion increased by 30° (from 49.15° to 79.15°), while in the CG it increased by only 14.13° (from 49.30° to 63.43°). This means that the effect of the intervention in the EG was approximately twice as large as in the CG.

Internal rotation in EG patients also showed significant improvement, from 53° to 82° (+29°) over the three-week period. This score increased by 1 degree at the first post-treatment follow-up (week 8 after therapy), or from 82.95° to 83.78°, returning to 82.95° at the 6-month retest.

Follow-up after 8 weeks and 6 months showed that the results remained stable in EG. A minimal decrease (1–2°) was observed in some movements, which, however, was not statistically significant and could be explained by physiological variations within the maximum range of motion. In contrast, CG showed limited progress after the end of therapy. In flexion, the values remained at 161°, while in abduction and rotation, a minimal increase (1–2°) was observed, without significant clinical significance.

All gains maintained in EG (ROM within normal limits), meanwhile XG showed partial maintainance with 10–20° deficit.

3.2.6 Repeated-Measures MANOVA on ROM

Table 3.7 MANOVA – Multivariate analysis of dispersion of the time effect on each group

Effect	Criterion	Value	F	df (Hypothesis)	df (Error)	Sig. (p)	Partial Eta Squared
Time	Pillai's Trace	0,981	1279,858 ^a	3	76	0,000	0,981
	Wilks' Lambda	0,019	1279,858 ^a	3	76	0,000	0,981
	Hotelling's Trace	50,521	1279,858 ^a	3	76	0,000	0,981
	Roy's Largest Root	50,521	1279,858 ^a	3	76	0,000	0,981
Time × group	Pillai's Trace	0,972	889,557 ^a	3	76	0,000	0,972
	Wilks' Lambda	0,028	889,557 ^a	3	76	0,000	0,972

Effect	Criterion	Value	F	df (Hypothesis)	df (Error)	Sig. (p)	Partial Eta Squared
	Hotelling's Trace	35,114	889,557 ^a	3	76	0,000	0,972
	Roy's Largest Root	35,114	889,557 ^a	3	76	0,000	0,972

Time effect: $p < 0.001$; $\eta^2 = 0.981$ → ROM changes throughout therapy highly significant.

Interaction Time × Group: $\eta^2 = 0.972$ → EG displayed faster and more stable improvement.

The results of the MANOVA analysis show strong effects of both the time factor and the time × group interaction. The time factor has a statistically significant effect on all studied shoulder joint movements (Pillai's Trace = 0.981; $F(3,76) = 1279.86$; $p < 0.001$; $\eta^2 = 0.981$), which indicates significant changes in the dynamics of the volume of movement during the course of therapy. The interaction between time and group was also highly significant (Pillai's Trace = 0.972; $F(3,76) = 889.56$; $p < 0.001$; $\eta^2 = 0.972$), indicating that the pattern of change differed between the two groups—i.e., the experimental group demonstrated more intense and more sustained improvement than the control group.

Mauchly's test $W = 0.027$, $\chi^2 = 278.10$ ($p < 0.001$) → Greenhouse–Geisser correction applied.

Within-subject contrasts revealed all trends (linear, quadratic, cubic) significant ($p < 0.001$), confirming a multiphase adaptation process — rapid gain, plateau, and long-term stability.

Highest effect for quadratic trend $\eta^2 = 0.980$, showing most improvement in early weeks then stabilization.

Table 0.1 Test of Within-Subjects Contrasts – Range of motion time difference

Източник (Source)	Контраст (Time)	Type III Sum of Squares	df	Mean Square	F	Sig. (p)	Partial Eta ²
Време (Time)	Линеен	33 096,706	1	33 096,706	334,281	0,000	0,811
	Квадратичен	95 669,028	1	95 669,028	3910,089	0,000	0,980
	Кубичен	4 157,026	1	4 157,026	395,741	0,000	0,835
Време × Група (time × group)	Линеен	75 226,776	1	75 226,776	759,801	0,000	0,907
	Квадратичен	59 051,278	1	59 051,278	2413,485	0,000	0,969
	Кубичен	7 818,981	1	7 818,981	744,352	0,000	0,905
Грешка (Error Time)	Линеен	7 722,669	78	99,009			
	Квадратичен	1 908,444	78	24,467			
	Кубичен	819,344	78	10,504			

The results of the within-subjects contrasts analysis (Table 3.27) show clearly expressed and statistically significant changes over time for all trends examined—linear, quadratic, and cubic ($p < 0.001$). This confirms that the dynamics of recovery in range of motion are not unidirectional but follow a multistage model of adaptation that includes phases of rapid improvement, subsequent stabilization, and long-term maintenance of outcomes.

The high F value for the quadratic trend ($F = 3910.089$; $p < 0.001$; $\eta^2 = 0.980$) shows that changes over time follow a nonlinear pattern, where the most significant increase in range of motion occurs during the first weeks of therapy, after which improvement stabilizes.

The high partial η^2 for the quadratic component ($\eta^2 = 0.980$) confirms that 98% of the variance in the indicator is due to time, reflecting a very strong therapeutic effect. Similarly, the significant values for the linear ($\eta^2 = 0.811$) and cubic ($\eta^2 = 0.835$) trends indicate that the recovery process is gradual yet complex, with functional improvement unfolding in phases and showing minor fluctuations over time—typical of the adaptation of soft tissue and joint structures.

The time \times group interaction is also highly significant for all temporal components ($p < 0.001$), indicating that the pattern of change over time differs between the two studied groups. The experimental group demonstrated higher F values ($F = 759.801$ for the linear, $F = 2413.485$ for the quadratic, and $F = 744.352$ for the cubic trend) and very high η^2 values (0.907–0.969), which points to an exceptionally strong therapeutic effect of the combined intervention. These results mean that the effect of time on recovery depends on the type of therapy—the application of dry needling in combination with physiotherapy induces not only faster but also more stable kinematic adaptation of the shoulder joint.

The high η^2 values (ranging from 0.811 to 0.980) and extremely low p-values (<0.001) confirm that the observed improvements are not only statistically significant but also clinically meaningful. They attest to the long-lasting impact of combined therapy on the functional capacity and mobility of the shoulder joint in patients with subacromial impingement syndrome (SIS).

The cubic contrasts ($\eta^2 = 0.835$ –0.905) further support the assumption that the recovery process follows a multifaceted adaptation model, involving not only mechanical but also neuromuscular restructuring. This is consistent with studies by Cagnie et al. (2013) and Fernández-de-Las-

Peñas et al. (2015), which report that therapies combining dry needling with active kinesitherapy trigger a cascade of positive changes in muscle conductivity and coordination.

Discussion

The analysis of the obtained results confirms the hypothesis that adding dry needling to the standard physiotherapy protocol leads to significantly better therapeutic outcomes compared to traditional physiotherapy alone. The strong effect of time and the statistically significant interaction between time and group indicate that the applied intervention not only accelerates the pace of recovery but also results in a greater final degree of improvement in the experimental group.

In addition to the direct effect on muscle trigger points, the inclusion of dry needling in the therapeutic plan may also have indirect mechanisms of action—such as improving local microcirculation, reducing peripheral and central sensitization, and stimulating neurophysiological responses. These mechanisms likely explain the more pronounced dynamics in range of motion and functional recovery observed in the experimental group.

At the same time, it should be noted that the study results apply to a specific sample and clinical context. Future research with a larger number of participants, long-term follow-up, and comparison with other intervention methods could contribute to a deeper understanding of the therapeutic potential of dry needling.

Long-term follow-up results (at the 8th week and 6th month) confirm the durability of the effect in the experimental group, where the achieved values remain close to the maximum physiological range of motion. In contrast, in the control group, improvements are limited and the final outcome remains significantly below the physiological norm (a deficit of 20–30 degrees). This corresponds with findings in international literature (Halle et al., 2020; Para-Gonzales et al., 2022), which also emphasize that combined interventions result in faster and more stable effects compared to standard physiotherapy protocols.

The present results clearly demonstrate the advantage of combined interventions, where dry needling is integrated with standard physiotherapy protocols. This integrated approach shows not only higher clinical effectiveness but also potential for faster return of patients to daily and professional activities, which are typically severely affected in SIS. The focus here is on the need for a multimodal approach in prevention and rehabilitation—combining traditional

methods with innovative techniques—to achieve optimal recovery and long-term maintenance of musculoskeletal health.

Adding MDN to physiotherapy accelerated tissue adaptation, enhanced joint kinematics, and sustained outcomes over 6 months. Results support a multimodal approach combining mechanical and neurophysiological components.

3.3. Muscle Strength Assessment

3.3.1 Manual Muscle Testing (MMT)

Table 3.12 Average values from manual muscle testing (MMT) of the muscles involved in shoulder joint movements at 6 months after treatment

Tested movement	Group	N	Mean	SD (Standard Deviation)	Sig. (2-tailed)
Flexion	Experimental	40	5,00	,000	,320
	Control	40	4,98	,158	,323
Abduction	Experimental	40	4,83	,385	,001
	Control	40	4,48	,506	,001
External rotation	Experimental	40	4,75	,439	,000
	Control	40	3,98	,800	,000
Internal rotation	Experimental	40	4,93	,267	,000
	Control	40	4,35	,622	,000

During abduction, a consistent advantage of the experimental group (EG) is observed, where the mean value remains at 4.83 points, while in the control group (CG) it reaches 4.48 points. The difference of 0.35 points is statistically significant ($p < 0.01$) and indicates that the patients in the EG maintain better functionality of the *m. supraspinatus* and *m. deltoideus pars acromialis*. Although the control group continues to improve its results compared to earlier measurements, it still does not reach the full muscle strength required for normal scapulohumeral rhythm (Table 3.12).

The results for external rotation again confirm a clearly pronounced superiority of the EG, which maintains an average score of 4.75 points, while the CG reaches 3.98 points. The difference of 0.77 points is highly statistically significant ($p < 0.001$) and clinically meaningful, since external rotation is one of the movements most affected in subacromial impingement

syndrome. Patients in the control group still demonstrate moderate muscle weakness (about 20% below normal), which suggests incomplete recovery of the *m. infraspinatus* and *m. teres minor*, and consequently, a residual deficit in shoulder joint stabilization.

The experimental group achieves almost maximal values—4.93 points, while the CG reaches 4.35 points ($p < 0.001$). This reveals better endurance of the muscle strength of the *m. subscapularis* in patients treated with dry needling and shows that they retain functional control even after completing active therapy. The difference of 0.58 points is an indicator of more complete stabilization of the glenohumeral joint in the EG.

Summary Discussion of the MMT Results with Added Sources

In the follow-up periods, the results for all parameters and both groups remain stable, with no substantial changes in any of the post-therapy measurements. This indicates that the application of medical dry needling in the experimental group (EG) leads to rapid and sustained recovery of muscle strength—measured through the Manual Muscle Testing (MMT) scale—compared to the control group (CG), which received only traditional physiotherapy.

At the beginning of the study, both groups demonstrated similar baseline muscle strength values—between 3.4 and 4.8 points—corresponding to moderate to mild muscle weakness. The lowest values were observed during external rotation, which is consistent with the typical clinical manifestations of subacromial impingement syndrome (SIS), where the *m. supraspinatus* and *m. infraspinatus* are most commonly affected. These initial results confirm the comparable starting position of both groups and allow an objective assessment of the effect of the different treatment approaches.

Already by the third week, there is a significant increase in muscle strength across all movements in both groups, but the improvement is more pronounced in the experimental group:

- EG reaches nearly maximal values — 5.00 points for flexion, 4.83 points for abduction, 4.75 points for external rotation, and 4.93 points for internal rotation.
- CG also shows progress, but abduction, external, and internal rotation remain below normal levels (3.8 to 4.4 points).

These results indicate that dry needling included in the EG protocol accelerates muscle recovery by reducing myofascial inhibition and restoring neuromuscular control, consistent with the mechanisms described by Gerber et al. (2015) and Shah et al. (2008).

By the eighth week after treatment, a stable therapeutic effect is observed in the EG and a slower but continuing improvement in the CG:

- EG maintains the achieved levels of muscle strength in all movements, which demonstrates good tissue adaptation and functional stability.
- CG reports slight additional improvements, but abduction (4.45 points) and external rotation (3.85 points) remain below normal, indicating residual weakness and partial incomplete recovery of the rotator cuff.

This difference suggests that the effect of standard physiotherapy emerges later and is less stable, while the addition of dry needling to the therapeutic protocol accelerates and sustains muscle strength within optimal limits.

The long-term results, observed six months after treatment, confirm the durability of the achieved effect in the EG:

- EG maintains almost maximal values for all movements (5.00 points for flexion, 4.83 points for abduction, 4.75 points for external rotation, and 4.93 points for internal rotation).
- CG also improves its results compared to previous periods, but in abduction (4.48 points), external rotation (3.98 points), and internal rotation (4.35 points), normal levels are still not reached.

These data indicate that patients who received dry needling achieved a lasting restoration of muscle balance, while those in the control group showed delayed and incomplete stabilization—probably due to ongoing muscle inhibition and partially preserved myofascial trigger points.

After the descriptive analysis of the results from the Manual Muscle Testing (MMT), which revealed a clear increase in muscle strength over time, it became necessary to conduct a more in-depth statistical examination of these changes. Although the mean MMT values provide objective information about the recovery of muscle function, they do not fully reflect within-group differences and the dynamics of progress between the different measurements. Therefore, the Friedman test was added to the analysis as a non-parametric method for dependent samples, allowing the determination of whether the observed improvements in muscle strength between treatment stages (baseline, 3rd week, 8th week, and 6th month) are statistically significant rather than the result of random variation.

Summary for muscle strength recovery for the different time periods following the intervention:

Baseline (T1)

Both groups showed reduced strength (3.4 – 4.8 points).

Lowest scores in external rotation (≈ 3.4). Differences non-significant ($p > 0.05$).

After 3 weeks (T2)

EG approached maximal values (flex 5.0, abd 4.83, ER 4.75, IR 4.93);

CG lower (abd 4.38, ER 3.80, IR 4.30) with $p < 0.001$ for all except flexion.

At 8 weeks (T3)

EG kept strength \approx normal; CG remained 20 – 25 % below normal in rotations.

At 6 months (T4)

EG maintained values (flex 5.00, abd 4.83, ER 4.75, IR 4.93); CG still lower (abd 4.48, ER 3.98, IR 4.35).

Differences statistically significant ($p < 0.01$).

Both groups showed significant improvement ($p < 0.001$), but the larger χ^2 for EG illustrates a stronger and more stable gain.

3.3.2 Isometric Dynamometry (Meloq Device)

The mean values for flexion are similar—51.38 N/m in the experimental group (EG) and 51.18 N/m in the control group (CG)—which confirms the homogeneity of the sample and the comparability of participants at the initial stage of therapy. For abduction and external rotation, no statistically significant differences were observed ($p > 0.05$), whereas for internal rotation a slight but statistically significant difference was found ($p = 0.048$) in favor of the control group.

The follow-up results at subsequent stages are as follows:

- At the 8th week after treatment, muscle strength during external rotation reached 60.63 N/m in the EG compared to 52.13 N/m in the CG;
- At the 6th month after therapy, the values remained stable — approximately 60 N/m in the EG and 51.70 N/m in the CG.

The largest increases were observed in internal rotation, where the mean strength reached 66.23 N/m in the EG versus 57.88 N/m in the CG ($p < 0.001$). This indicates accelerated recovery of

the *m. subscapularis* and *m. pectoralis major* muscles, which play an active role in this movement.

A substantial improvement was also registered for external rotation — the movement most commonly affected in subacromial impingement syndrome (SIS). The experimental group achieved a mean value of 59.85 N/m, whereas the control group reached only 49.48 N/m ($p < 0.001$). This represents nearly a 20% higher result in favor of the EG, indicating faster functional recovery of the *m. infraspinatus* and *m. teres minor*.

All differences between the groups were statistically significant ($p < 0.001$), confirming the hypothesis that dry needling therapy has a positive effect in accelerating muscle recovery.

At the 8th week, the most noticeable improvement was again observed in external rotation — the movement typically most severely affected in SIS. The experimental group reached 60.63 N/m, while the control group achieved 52.13 N/m, which corresponds to more than 16% higher muscle strength in the EG ($p < 0.001$). This confirms that patients who received medical dry needling recovered the function of the external rotators (*m. infraspinatus* and *m. teres minor*) more rapidly, due to reduced muscle inhibition and improved neuromuscular control.

Regarding internal rotation, a significant difference was observed in favor of the experimental group (EG: 67.28 N/m) compared to the control group (CG: 58.88 N/m) ($p < 0.001$). This movement is crucial for the stability and kinematic balance of the shoulder joint, and the improvement suggests better synergy between the *m. subscapularis* and the scapular-stabilizing muscles (Table 3.16).

All reported differences are statistically significant, indicating that the effect of dry needling intervention is not only short-term but also maintained over time. At this stage of the study, no regression of muscle strength was observed, suggesting stable tissue adaptation and effective remodeling of muscle fibers.

At the sixth follow-up month, internal rotation again showed an advantage for the EG (65.40 N/m) over the CG (59.08 N/m) ($p = 0.001$). This trend demonstrates that the dry needling method exerts a long-term effect on the regeneration and optimization of the muscle tone of the *m. subscapularis*, as well as on the balance between the internal and external rotators—an essential factor for maintaining a stable scapulohumeral rhythm.

Across all measurements, the values in the EG remained close to those observed at the eighth week, showing the absence of regression and emphasizing the durability of the achieved

outcomes. This means that once attained, the improvement in muscle strength is preserved over time, even after the completion of active treatment.

Table 3.18 MANOVA – Multivariate analysis of the effects of dispersion between time and time vs group interaction

Effect	Criterion	Value	F	Df (Hypothesis)	Df (Error)	Sig. (p)
Time	Pillai's Trace	0,890	205,570 ^a	3	76	0,000
	Wilks' Lambda	0,110	205,570 ^a	3	76	0,000
	Hotelling's Trace	8,115	205,570 ^a	3	76	0,000
	Roy's Largest Root	8,115	205,570 ^a	3	76	0,000
Time × Group	Pillai's Trace	0,528	28,364 ^a	3	76	0,000
	Wilks' Lambda	0,472	28,364 ^a	3	76	0,000
	Hotelling's Trace	1,120	28,364 ^a	3	76	0,000
	Roy's Largest Root	1,120	28,364 ^a	3	76	0,000

Hint: P value ($p < 0,001$ indicates significant effects for the time factor as well as the interaction of time vs group).

The results show that the factor of time has an exceptionally strong influence on all studied indicators. All statistical criteria—Pillai's Trace (0.890), Wilks' Lambda (0.110), Hotelling's Trace (8.115), and Roy's Largest Root (8.115)—demonstrated a high degree of consistency and significance of change ($F(3,76) = 205.570$; $p < 0.001$).

These values unequivocally confirm that over time there is a substantial improvement in muscle function in both groups of patients (Table 3.18). This is due to the physiological response of the body to the prolonged application of physiotherapeutic interventions, which lead to restoration of muscle balance, pain reduction, and enhancement of the biomechanical parameters of the shoulder joint.

Even more significant from a clinical perspective is the effect of the time \times group interaction, which shows statistically significant differences between the two groups at all time points (Pillai's Trace = 0.528; Wilks' Lambda = 0.472; Hotelling's Trace = 1.120; Roy's Largest Root = 1.120; $F(3,76) = 28.364$; $p < 0.001$).

Pillai's Trace and Wilks' Lambda are the most commonly used indicators for interpreting MANOVA results. In the present study, the high value of Pillai's Trace (0.890) for the time factor indicates that over 89% of the variance in the dependent variables can be explained by the effect of time. Conversely, the low value of Wilks' Lambda (0.110) means that the likelihood of the differences between time points being due to chance is minimal ($p < 0.001$).

For the time \times group interaction, Pillai's Trace (0.528) shows that approximately 53% of the variance in the results is explained by the difference between the groups in their recovery dynamics—further confirming the higher effectiveness of the combined therapy.

In summary, the MANOVA analysis results reveal clearly expressed, statistically significant changes over time and between groups. The time factor demonstrates that therapy in general is effective, while the time \times group interaction shows that the addition of medical dry needling to the standard physiotherapy protocol is the key element ensuring faster, more complete, and more stable functional recovery of muscle strength and endurance in patients with subacromial impingement syndrome (SIS).

Summary Discussion of MMT – Meloque

The increase in external rotation by more than 20% compared to baseline values indicates a rapid recovery of the *m. infraspinatus* and *m. teres minor* muscles, which are the main stabilizers of the glenohumeral joint.

Physiologically, the lasting effect observed in patients from the experimental group (EG) can be explained by the activation of endogenous analgesic mechanisms and the structural reorganization of muscle fibers following the application of dry needling. The process of fibroblast migration and collagen fiber remodeling leads to the restoration of the organized microstructure of the muscle, which enhances its contractile efficiency and endurance. At the same time, the reduction of inflammatory mediators and the suppression of central pain transmission contribute to optimal, pain-free motor activity.

Patients in the experimental group, who received medical dry needling as part of the combined physiotherapy protocol, demonstrated a faster increase in muscle strength as early as the end of

the third week of treatment, as well as more durable maintenance of the achieved values during the follow-up periods (8th week and 6th month). This trend clearly distinguishes the experimental group from the control group, which was treated only with the standard physiotherapy protocol (Figure 4).

For internal rotation, the baseline values differed between the two groups—40.93 N/m for the EG and 45.05 N/m for the CG. Despite the lower initial value, patients in the EG showed a significantly greater increase in muscle strength, reaching 66.23 N/m by the end of the third week, compared to 57.88 N/m in the CG. This represents an increase of 25.3 N/m for the EG versus 12.85 N/m for the CG, highlighting the more intensive and effective recovery associated with the combined approach.

During the follow-up periods, the EG maintained the achieved results—with a slight increase to 67.28 N/m at the eighth week and a minimal, statistically insignificant decline to 65.40 N/m at the sixth month. The control group showed a weaker progression, reaching 59.00 N/m at the eighth week and maintaining the same values after six months.

In summary, all statistical and clinical evidence leads to one clear conclusion: The inclusion of medical dry needling in the standard physiotherapy program for patients with subacromial impingement syndrome (SIS) has a statistically and clinically significant long-term effect on the recovery of muscle strength and endurance.

This combined intervention:

- Accelerates neuromuscular adaptation and reduces muscle inhibition;
- Improves biomechanical coordination and muscular balance;
- Provides faster functional recovery and a lasting therapeutic effect.

The strength of the effect ($\eta^2 > 0.5$ in all analyses) confirms that the improvement is not only statistically significant but also clinically meaningful.

Therefore, medical dry needling can be regarded as an effective adjunctive method in the comprehensive physiotherapy treatment of patients with SIS.

Summary for muscle strength recovery with dynamometry

Baseline:

No group differences ($p > 0.05$) except slightly higher IR in CG ($p = 0.048$).

After 3 weeks:

EG showed marked strength rise in all directions ($p < 0.001$):

- Flexion 58 N/m vs 56 CG
- Abduction 42.7 vs 38.6 CG
- External Rotation 59.85 vs 49.48 CG
- Internal Rotation 66.23 vs 57.88 CG

At 8 weeks:

Improvements continued (EG ER 60.63 vs 52.13 CG; IR 67.28 vs 58.88; $p < 0.001$).

At 6 months:

Values remained stable (EG ER 59.85 vs CG 51.70; IR 65.40 vs 59.08; $p < 0.001$).

No regression occurred in EG.

3.3.2.3 MANOVA for Time and Time \times Group Effects on Strength

Effect	Criterion	Value	F	df (H)	df (E)	p
Time	Pillai 0.890	205.57	3	76		< 0.001
Time \times Group	Pillai 0.528	28.36	3	76		< 0.001

Time effect \rightarrow significant improvement in both groups.

Interaction \rightarrow EG benefited to a much higher extent ($p < 0.001$).

Repeated-measures ANOVA for external rotation confirmed significant time ($F = 491.5$) and interaction effects ($F = 42.3$; $p < 0.001$).

Contrasts showed all temporal trends (linear, quadratic, cubic) significant ($p < 0.001$), indicating non-linear improvement — rapid initial gain then plateau and retention.

Between-subjects effect: $F(1,78) = 18.738$, $p < 0.001$ \rightarrow EG had significantly higher average strength throughout.

Interpretation: Combining MDN with PT yielded $\approx 20\%$ greater strength recovery and long-term maintenance through enhanced neuromuscular activation and reduced inhibition.

3.4. Dynamics of Pain Syndrome According to the Visual Analogue Scale (VAS) – Nonparametric Analysis

At the beginning of therapy (T1), participants in the experimental group (EG) demonstrated higher pain values during flexion (VAS = 12.88) compared to the control group (CG) (VAS = 8.21). This indicates that the experimental group began the dry needling intervention

with a more pronounced pain syndrome—on average 7 points versus 5.5 points in the control group.

For abduction, the values were similar (EG = 14.55; CG = 14.14), as well as for external rotation (EG = 15.31; CG = 15.19) and internal rotation (EG = 14.90; CG = 14.31). This confirms that both groups started with practically identical baseline pain levels, ensuring sample homogeneity and allowing for objective comparison in subsequent analyses.

In terms of abduction, patients from the experimental group showed a clear and consistent reduction in pain values measured by the Visual Analogue Scale (VAS). The mean baseline value at the start of the study was 14.55 index units (\approx 4.5 VAS points). By the end of the therapeutic protocol (third week), it decreased to 7.45 index units (\approx 1.8 VAS points). At the first follow-up (eighth week), additional improvement was recorded—6.73 index units (\approx 1.5 VAS points)—which remained stable at the second follow-up, six months after the completion of therapy (Fig. 3.2).

Patients from the control group started with a similar initial value of 14.14 index units (\approx 4.4 VAS points). By the end of the treatment course, their pain decreased to 7.98 index units (\approx 2.9 VAS points), followed by a minimal additional improvement—7.54 index units at the eighth week and 7.28 index units (\approx 2.1 VAS points) at the sixth month.

In both groups, a significant reduction in pain during abduction was observed, with mean values falling below the clinically significant threshold of 3 VAS points, considered as the absence of movement-related pain. However, the experimental group achieved a faster and more pronounced analgesic effect during the active treatment phase and maintained consistently low values during follow-up, whereas the control group demonstrated a slower and less complete recovery.

These results confirm that the combined therapeutic approach—including dry needling and physiotherapy—leads to faster and more lasting pain relief compared with the isolated application of standard physiotherapy (Figure 5).

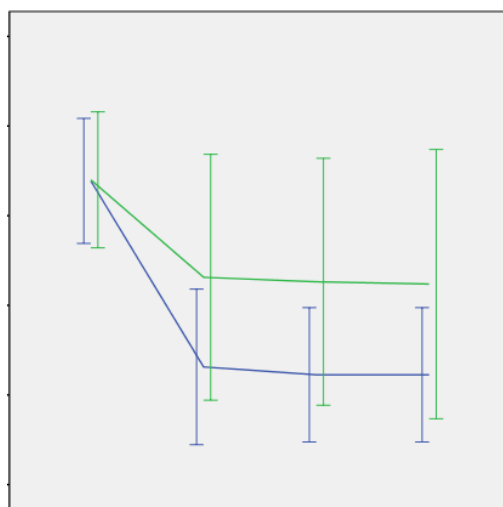


Figure 5. Mean Values on the Visual Analogue Scale (VAS) During Abduction Movement for the Experimental (blue) and Control (green) Groups Over Time

For external rotation, both groups began with almost identical baseline values — EG = 15.31 index units (≈ 5.4 VAS points) and CG = 15.19 index units (≈ 5.3 VAS points). This confirms that participants in both groups started with the same level of pain, demonstrating the homogeneity of the sample. It should be noted that external rotation is the movement most commonly affected in subacromial impingement syndrome (SIS).

At the end of the dry needling treatment course (third week), patients in the experimental group (EG) achieved significant improvement — 8.20 index units (≈ 2.4 VAS points), which corresponds to almost pain-free movement. At the first follow-up (eighth week), a further decrease was observed to 7.74 index units (≈ 2.1 VAS points). After six months, there was a slight increase to 8.07 index units (≈ 2.2 VAS points), but this change was not statistically significant since the values remained below the clinical pain threshold (VAS < 3), reflecting good tissue adaptation.

In the control group (CG), the reduction was less pronounced — from 15.19 to 11.36 index units (≈ 3.9 VAS points) at the end of the treatment phase. This indicates that the pain reduction was partial and did not reach a level characteristic of functional recovery. Values around 4 VAS points are interpreted as moderate pain intensity. In the follow-up stages, a slight improvement was noted — 9.93 index units (≈ 3.5 VAS points) at the eighth week, which remained stable at the sixth month, without reaching a completely pain-free level.

Although both groups showed a reduction in pain, the experimental group reached optimally low values for external rotation — 2.1 VAS points by the end of the third week, while the control group

reported significantly higher levels — 3.9 VAS points for the same period. The difference between the two groups persisted during the follow-up stages — 2.2 VAS points for the EG versus 3.5 VAS points for the CG.

For internal rotation, the initial results were again similar between the groups — EG = 14.90 index units (\approx 5.1 VAS points) and CG = 14.31 index units (\approx 5.1 VAS points). By the end of the third week, patients in the EG achieved a significant reduction to 6.08 index units (\approx 1.2 VAS points), whereas in the CG the values decreased to 7.54 index units (\approx 2.3 VAS points).

At the first follow-up (eighth week), additional improvement was observed — EG: 5.57 index units (\approx 1.0 VAS point) and CG: 6.71 index units (\approx 2.0 VAS points). After six months, a slight regression occurred in both groups — EG: 6.06 index units (\approx 1.2 VAS points) and CG: 6.95 index units (\approx 2.1 VAS points), but the difference between them remained clinically significant.

The faster decline in pain values in the experimental group can be explained by the neurophysiological mechanism of dry needling, which involves the secretion of endogenous opioids and endorphins that inhibit pain signal transmission. When an active myofascial trigger point—such as in the *m. trapezius*—is punctured, a marked decrease in the concentration of TNF- α and calcitonin gene-related peptide (CGRP) (from 170 pg/ml to 92 pg/ml within just 15 minutes after manipulation) is observed. This leads to suppression of pro-inflammatory cytokines and reduced activity of pain mediators from the kinin group. This biochemical mechanism explains the faster adaptation to pain stimuli and the lower pain threshold in patients from the experimental group.

Although both groups ultimately reached values considered pain-free (VAS < 3), the experimental group demonstrated faster and more durable analgesia. This indicates that the combined therapeutic approach of dry needling and physiotherapy not only accelerates pain reduction but also ensures a long-term stabilizing effect through restoration of *m. subscapularis* function and improved muscular balance within the shoulder complex.

Summary for pain indicators during intervention

Baseline VAS \approx 5 – 5.5 points (identical between groups).

In abduction movement: EG reduced from \sim 4.5 \rightarrow 1.8 points after 3 weeks, further to 1.5 (8 wk) and 1.5–1.8 after 6 mo.

CG reduced from 4.4 \rightarrow 2.9 \rightarrow 2.1 VAS; slower and less complete analgesia.

External rotation: EG 5.4 \rightarrow 2.4 VAS (3 wk) \rightarrow 2.1 (8 wk) \rightarrow 2.2 (6 mo);

CG 5.3 \rightarrow 3.9 \rightarrow 3.5 \rightarrow 3.5 VAS.

Internal rotation: EG 5.1→1.2 → 1.0 → 1.2 VAS; CG 5.1→2.3 → 2.0 → 2.1 VAS.

Thus EG achieved near-painless motion (VAS < 3) by week 3 and retained it.

Biochemically, dry needling reduces local TNF- α and CGRP levels by \approx 40-50%, mitigating inflammatory nociception.

Hence, combined therapy provides **faster and longer-lasting analgesia**.

3.5. Functional Scales

3.5.1 SPADI

The results presented in Table 3.22 show that at the beginning of the study, both groups had similar baseline SPADI values. Patients in the experimental group (EG) started treatment with high pain scores of 77.33 points and disability scores of 75.47 points, resulting in an overall functional index of 76.35 points. The control group (CG) showed comparable values—pain = 75.00 points, disability = 78.70 points, and total = 77.12 points—indicating homogeneity between the groups before therapy began.

By the end of the third week, a substantial improvement was observed in the EG: pain decreased to 11.90 points, disability to 12.46 points, and the overall functional result to 12.26 points. This represents a reduction of approximately 65 points in pain, 63 points in disability, and 64 points in the total index, indicating a significant clinical improvement.

In the control group, a positive trend was also noted, but with a less pronounced effect. At the end of treatment, pain, disability, and total SPADI scores were 26.95, 27.00, and 26.97 points, respectively. This corresponds to an improvement of about 48–51 points, yet the final values remained considerably higher compared with the EG.

The differences between the two groups are clearly expressed: pain in the EG was approximately 17 points lower than in the CG; disability was over 11 points lower; and the total functional index was about 14 points lower in the EG compared to the CG.

These differences persisted at subsequent measurement points (T3 and T4), where the experimental group maintained a stable therapeutic effect, while the control group showed slower and incomplete recovery.

Table 3.22. Descriptive Analysis of the Functional SPADI Scale (Shoulder Pain and Disability Index) – Total Score (SPADI Total Results)

Measurement	Group	N	Mean value	Standard Deviation
Test 1 (baseline)	Experimental	40	76,35	5,93
	Control	40	77,12	4,40
	Total	80	76,74	5,20
Test 3 (3 rd week of testing)	Experimental	40	12,27	5,50
	Control	40	26,97	8,44
	Total	80	19,62	10,24
Test 3 (8 weeks post intervention)	Experimental	40	8,73	6,25
	Control	40	25,61	9,47
	Total	80	17,17	11,65
Test 4 (6 months post intervention)	Experimental	40	7,01	7,50
	Control	40	23,65	10,80
	Total	80	15,33	12,46

Note: Lower SPADI scores reflect better functional condition and lower levels of pain and disability. The data show a significant improvement in the experimental group (EG) as early as the third week of treatment, which remains stable at subsequent measurement points.

From a statistical perspective, Box’s Test of Equality of Covariance Matrices indicates a significant difference between the covariance matrices of the two groups (Box’s M = 48.133; F = 4.546; p < 0.001), confirming the presence of a statistically significant effect of the therapeutic approach.

Table 3.23. Descriptive Analysis of the SPADI Subscales – “Pain” and “Disability” (Lower values indicate better functional condition and reduced pain.)

Measurement	Group	N	Pain (Mean ± SD)	Disfunction (Mean ± SD)
Test 1 (baseline)	Experimental	40	77,33 ± 5,84	75,47 ± 6,12
	Control	40	75,00 ± 4,92	78,70 ± 4,53
Test 2 (3 weeks – end of intervention)	Experimental	40	11,90 ± 5,47	12,46 ± 5,66
	Control	40	26,95 ± 8,40	27,00 ± 8,41
Test 3 (8 weeks post intervention)	Experimental	40	9,20 ± 5,88	8,15 ± 6,05
	Control	40	25,20 ± 9,21	26,00 ± 9,73

Measurement	Group	N	Pain (Mean ± SD)	Disfunction (Mean ± SD)
Test 4 (6 months post intervention)	Experimental	40	7,05 ± 6,95	7,00 ± 7,47
	Control	40	23,40 ± 10,45	23,89 ± 10,78

Note: In the experimental group (EG), a pronounced and sustained decrease in both SPADI subscales is observed as early as the end of the third week, indicating rapid pain reduction and restoration of functional activity. The control group (CG) also shows improvement, but the rate of change is slower, and the final values remain considerably higher.

During the follow-up periods (8th week and 6th month), the EG shows a further slight reduction and stabilization of scores — values reach between 7 and 9 points, demonstrating long-term maintenance of the therapeutic effect. This pattern indicates that the application of dry needling not only accelerates the recovery process but also provides long-term stability of outcomes (Table 3.23).

In contrast, improvement in the CG occurs more slowly and to a lesser extent. At the end of the third week, the values remain relatively high (around 27 points on both subscales), and even after six months, pain and disability do not fall below 23 points.

In summary, the results for the “Pain” and “Disability” subscales confirm the high effectiveness of the combined therapeutic approach and highlight the clinical advantage of adding dry needling to standard physiotherapy in patients with subacromial impingement syndrome (SIS).

3.5.1 Assessment of the Dynamics and Statistical Significance of Changes Over Time in Pain and Functional Capacity of the Shoulder Joint Between the Experimental and Control Groups, Measured by the SPADI Index

All multivariate criteria — Pillai’s Trace, Wilks’ Lambda, Hotelling’s Trace, and Roy’s Largest Root — show fully consistent values, indicating high model stability and reliability. The obtained data are presented in Table 3.24. An F-value = 1973.133, with $p < 0.001$ and Partial Eta Squared = 0.987, confirms that time has an extremely significant effect on the SPADI results. In other words, more than 98% of the variance in functional outcomes can be explained by the change over time. This result demonstrates that the therapeutic process itself leads to a substantial reduction in pain and functional deficit, regardless of group membership.

At the same time, the time × group interaction is also statistically significant (F = 34.857; $p < 0.001$; Partial Eta Squared = 0.579), meaning that the two groups —

experimental (EG) and control (CG) — change differently over time. The effect size ($\eta^2 = 0.579$) is high, indicating that 57.9% of the differences in the dynamics of results can be attributed to the interaction between time and the type of therapeutic intervention (Table 3.24).

Table 3.24. Multivariate Analysis of Variance (MANOVA) for the SPADI Index (Factors: Time and Time \times Group Interaction)

Table 3.24. Multivariate Analysis of Variance (MANOVA) for SPADI Index

Factors: Time and Time \times Group Interaction

	Value	df (raistical df (Error))	df (Hypthesis)	Partial η^2
Effect	Value	F	Significance	Partial η^2
Statistical Criterion	0.987	1973.133a	3.000	0.987
Pillai's Trace	0.013	1973.133a	3.000	<0.001
Wilks' Lambda	0.013	1973.133a	76.000	<0.001
Hotelling's Trace	77.887	76.000	76.000	0.007
Time x Group	77.887	34.857a	76.000	<0.001
Wilks's Lambda	0.421	34.857a	76.000	<0.001
Hotelling's Trace	0.476	34.857a	36.000	0.579
Roy's Largest Root	1.376	3.106	76.000	0.579

a Exact statistic.

These results confirm that although time has a universally positive effect on recovery, the effect is significantly stronger and faster in patients from the experimental group (EG), in whom medical dry needling was added to physiotherapy. This interaction demonstrates that it is precisely the combination of time and therapeutic modality that determines the pace and extent of functional recovery.

The results of the Within-Subjects Contrasts analysis show that all examined models of change — linear, quadratic, and cubic — are statistically significant ($p < 0.001$), confirming a genuine dynamic in the SPADI index over time. This indicates that the therapeutic interventions applied in both groups lead to substantial improvement in functional condition and reduction of pain in patients with rotator cuff syndrome.

The exceptionally high F-values (ranging from 1,353 to 4,635) and partial η^2 values above 0.94 demonstrate an extremely strong effect of time on the observed changes. These findings mean that more than 94% of the variation in SPADI scores is attributable to the time factor, i.e., to the therapeutic procedures themselves (Table 3.25).

Particularly noteworthy are the results for the time \times group interaction, where statistically significant differences are observed in all three analytical models. The linear and quadratic components show a strong effect size ($\eta^2 = 0.498$ and 0.494), indicating that the two groups evolve differently over time — with a stronger and faster treatment effect in patients from the experimental group (EG) who received dry needling as part of their therapeutic protocol. The cubic model ($\eta^2 = 0.115$) shows a weaker but still statistically significant effect, which may reflect subtle, continuous changes observed during the long-term follow-up period (up to six months).

Table 3.25. Test of Within-Subjects Contrasts for the SPADI Index (Factors: Time and Time \times Group Interaction)

Source	Type Effect	df	Type III Sum of Squares	F	Significance Square p)	Partial Eta Squared
Time	Linear	1	139412.624	1	<0.001	0.982
Time	Linear	1	39412.624	1	4361.624	<0.983
Quadratic	Quadratic	1	61112.040	1	4635.311	<0.001
Cubic	11687.772	1	11687.72	1	1353.687	<0.001
Time \times Group	2477.053	1	1003.236	1	77.496	0.094
Cubic	87.236	1	1003.236	1	76.095	0.994
Error (Time)	2493.151	78	31.963	1	0.002	0.115
Error (Time)	1028.354	78	13.184			
	673.454	78	8.634			

Summary for SPADI functional scale:

Lower scores mean better function.

EG improved by ≈ 64 points overall, versus ≈ 50 in CG.

MANOVA \rightarrow **Time effect:** $F = 1973.1, p < 0.001, \eta^2 = 0.987$.

Time \times Group: $F = 34.857, p < 0.001, \eta^2 = 0.579$ \rightarrow different recovery patterns; superior for EG.

Levene's test $p < 0.05$ for all sessions \rightarrow lower variance in EG \Rightarrow more consistent response.

Clinically, EG achieved rapid, uniform pain/function gains; CG showed slower, more variable progress.

3.5.2 UCLA Shoulder Rating System

Before the start of the therapeutic intervention, when assessing pain and functional changes using the UCLA Shoulder Rating Scale, patients in both groups showed similar baseline results — experimental group (EG): 15.60 ± 3.10 and control group (CG): 15.15 ± 1.35 . This confirms the homogeneity of the sample and the comparable functional level between the groups at the beginning of the study. These values are well below the 27-point threshold that denotes satisfactory function and correspond to the presence of pronounced pain and limited mobility in all participants (Table 3.27).

Stage of intervention	Group	N	Mean Value	Standard Deviation
Test 1 (baseline)	Experimental	40	15,60	3,10
	Control	40	15,15	1,35
Test 2 (3 weeks after treatment)	Experimental	40	31,33	3,20
	Control	40	27,10	3,69
Test 3 (8 weeks after treatment)	Experimental	40	31,55	3,20
	Control	40	27,53	3,94
Test 4 (6 months after treatment)	Experimental	40	32,05	3,29
	Control	40	27,98	3,55

Note: *UCLA – Shoulder Rating System; n – number of participants; SD – standard deviation.*
A result of ≤ 27 points is considered *unsatisfactory*, 27–33 points – *good*, and ≥ 33 points – *excellent functional outcome*.

At the end of the treatment phase, a noticeable increase in the total UCLA score was observed in both groups:

- Experimental Group (EG): 31.33 ± 3.20

- Control Group (CG): 27.10 ± 3.69

The difference of more than 4 points is both statistically and clinically significant, indicating that adding dry needling therapy to the standard physiotherapy protocol results in faster and more complete recovery. Patients in the EG already fall within the range of *good functional recovery*, while those in the CG barely reach the threshold of satisfactory function.

At the first follow-up (8th week), the results remained stable:

- EG: 31.55 ± 3.20
- CG: 27.53 ± 3.94

This indicates a sustained therapeutic effect in the experimental group, whereas improvement in the control group remained limited and less pronounced. Maintaining a high score in the EG suggests lasting pain reduction and recovery of shoulder movement function (Table 3.27).

At the six-month follow-up, the EG continued to improve its results — 32.05 ± 3.29 , reaching the upper limit of the “good” category, and approaching an “*excellent*” functional outcome (≥ 33 points).

The control group recorded 27.98 ± 3.55 , with no significant change compared to the previous stage, indicating a lack of long-term adaptation and a weaker therapeutic effect.

The mean improvement in the EG — from 15.6 to 32.05 points — represents an increase of more than 16 points, which far exceeds the *minimal clinically important difference* ($MCID = 6\text{--}10$ points).

In the CG, progress was smaller — from 15.15 to 27.98 points — an increase of about 12.8 points, corresponding to *moderate but incomplete functional recovery*.

By the end of the treatment protocol, the average total UCLA score in the experimental group (EG) was 31.33 points, corresponding to the “*good functional recovery*” category according to the scale criteria (27–33 points).

This value is approximately 4 points higher than that of the control group (CG) — 27.31 points, which received only the standard physiotherapy protocol.

Table 3.28 Multivariate analysis (MANOVA) regarding the influence of time and time over each group for UCLA score

Effect	Criterion	Value	F	df (hypothesis)	df (Error)	Sig. (p)	Partial Eta Squared
Time	Pillai's Trace	0,977	1064,672	3	76	< 0,001	0,977
	Wilks' Lambda	0,023	1064,672	3	76	< 0,001	0,977
	Hotelling's Trace	42,027	1064,672	3	76	< 0,001	0,977
	Roy's Largest Root	42,027	1064,672	3	76	< 0,001	0,977

Effect	Criterion	Value	F	df (hypothesis)	df (Error)	Sig. (p)	Partial Eta Squared
(time × group)	Pillai's Trace	0,521	27,546	3	76	< 0,001	0,521
	Wilks' Lambda	0,479	27,546	3	76	< 0,001	0,521
	Hotelling's Trace	1,087	27,546	3	76	< 0,001	0,521
	Roy's Largest Root	1,087	27,546	3	76	< 0,001	0,521

Note: *UCLA – Shoulder Rating System*; *n* – number of participants; *SD* – standard deviation.

A result of ≤ 27 points is considered *unsatisfactory*, 27–33 points – *good*, and ≥ 33 points – *excellent functional outcome*.

At the end of the treatment phase, a noticeable increase in the total UCLA score was observed in both groups:

- Experimental Group (EG): 31.33 ± 3.20
- Control Group (CG): 27.10 ± 3.69

The difference of more than 4 points is both statistically and clinically significant, indicating that adding dry needling therapy to the standard physiotherapy protocol results in faster and more complete recovery. Patients in the EG already fall within the range of *good functional recovery*, while those in the CG barely reach the threshold of satisfactory function.

At the first follow-up (8th week), the results remained stable:

- EG: 31.55 ± 3.20
- CG: 27.53 ± 3.94

This indicates a sustained therapeutic effect in the experimental group, whereas improvement in the control group remained limited and less pronounced. Maintaining a high score in the EG suggests lasting pain reduction and recovery of shoulder movement function (Table 3.27).

At the six-month follow-up, the EG continued to improve its results — 32.05 ± 3.29 , reaching the upper limit of the “good” category, and approaching an “*excellent*” functional outcome (≥ 33 points).

The control group recorded 27.98 ± 3.55 , with no significant change compared to the previous stage, indicating a lack of long-term adaptation and a weaker therapeutic effect.

The mean improvement in the EG — from 15.6 to 32.05 points — represents an increase of more than 16 points, which far exceeds the *minimal clinically important difference* ($MCID = 6-10$ points).

In the CG, progress was smaller — from 15.15 to 27.98 points — an increase of about 12.8 points, corresponding to *moderate but incomplete functional recovery*.

By the end of the treatment protocol, the average total UCLA score in the experimental group (EG) was 31.33 points, corresponding to the “*good functional recovery*” category according to the scale criteria (27–33 points).

This value is approximately 4 points higher than that of the control group (CG) — 27.31 points, which received only the standard physiotherapy protocol.

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Notes

- MANOVA – Multivariate Analysis of Variance; df – degrees of freedom; $p < 0.001$ – statistically significant difference.
- Partial η^2 indicates the strength of the effect: above 0.14 = large effect (Cohen, 1988).

Effect of Time

All multivariate criteria (Pillai’s Trace, Wilks’ Lambda, Hotelling’s Trace, and Roy’s Largest Root) show an extremely strong effect of time on the functional indicators:

- $F = 1064.672$
- $p < .001$
- Partial Eta Squared = .977

An η^2 value of 0.977 means that 97.7% of the variance in functional outcomes is explained by the time factor, which represents an exceptionally strong effect, demonstrating that the interventions (in both groups) produced significant changes in functional condition during the follow-up period (Table 3.28).

Interaction: Time \times Group

The effect of the interaction between time and group is also statistically significant:

- $F = 27.546$
- $p < .001$
- Partial Eta Squared = .521

An $\eta^2 = 0.521$ denotes a moderate-to-strong effect, meaning the two groups changed differently over time depending on the type of therapy applied. In other words, the positive influence of time was expressed to a different extent in the experimental (EG) and control (CG) groups — differences that are both measurable and clinically meaningful.

This statistically confirms the clinically observed trend:

- The EG demonstrated a more pronounced and sustained improvement,
- while the CG showed slower, more limited progress that did not persist long-term.

Combined Clinical and Statistical Analysis Shows That:

1. The experimental group (EG) achieved higher levels of functional recovery in both the short and long term.
2. The MANOVA results demonstrate that time has a major impact on change, but the effect is significantly stronger in the EG — directly linked to the addition of dry needling as an adjuvant therapeutic modality.
3. The control group (CG) improved its functional condition but did not reach the stability and durability of recovery observed in the EG.
4. Differences in recovery dynamics between groups indicate that dry needling leads to more pronounced pain reduction, improved muscle activation, and more effective tissue adaptation.

CONCLUSIONS

Based on the conducted prospective randomized controlled study, the statistical analysis of the obtained results, and their interpretation within the framework of modern rehabilitation concepts, the research hypotheses and objectives were verified. Analysis of the empirical data allowed an objective assessment of the effectiveness of the developed therapeutic model and the degree to which the aims of the study were achieved. On this basis, the following conclusions were formulated regarding the validity of the hypotheses and the fulfillment of the objectives.

Regarding the hypotheses

- Statistical analysis revealed a significantly greater increase in muscle strength in the EG compared to the CG. The null hypothesis is rejected, and the alternative hypothesis is accepted. Adding medical dry needling to standard physiotherapy results in more pronounced recovery of strength parameters.
- A statistically and clinically significant pain reduction (VAS, SPADI) was observed in the EG, maintained throughout the follow-up periods. The null hypothesis is rejected. Combined dry needling therapy produces a more pronounced and longer-lasting analgesic effect.
- The results of the functional scales (SPADI, UCLA) show greater improvement in the EG at the end of treatment and during long-term follow-up. The null hypothesis is rejected. The combined therapeutic approach leads to higher functional capacity and more complete recovery.

Regarding the research objectives

1. Theoretical analysis of current scientific sources substantiates the need for a comprehensive, biomechanically oriented approach in the treatment of subacromial impingement syndrome (SIS).
2. The dry needling method is a scientifically supported intervention with proven effects on myofascial trigger points, pain mechanisms, and neuromuscular function.
3. The developed methodological framework provides an objective, reliable, and reproducible system for clinical and functional assessment of patients with SIS.
4. The created experimental therapeutic protocol, combining physiotherapy with medical dry needling, represents a scientifically substantiated integrative therapy strategy.
5. The conducted prospective randomized controlled trial ensures high internal validity and methodological reliability of the obtained results.
6. The combined therapeutic approach demonstrates statistically and clinically significant superiority compared to standard physiotherapy regarding pain reduction, muscle strength, range of motion, and functional capacity.
7. The therapeutic effect achieved in the EG is faster and more lasting, both short-term and long-term.
8. The dry needling method is established as an effective adjuvant modality within

a multimodal rehabilitation approach, provided it is applied through standardized protocols and high professional competency.

CONTRIBUTIONS OF THE DISSERTATION WORK

As a result of the conducted theoretical and experimental research, the following scientific and applied practical contributions of the dissertation have been formulated.

They stem from the original conceptual framework, the developed therapeutic model, and the evidence-based analysis of its clinical effectiveness. The contributions reflect both the expansion of existing scientific knowledge in rehabilitation for SIS and the development of practical solutions with clinical value.

I. Scientific (Theoretical) Contributions

1. The theoretical model of the pathokinesiology of SIS was expanded through an integrated analysis of biomechanical forces, muscle imbalance, scapulohumeral discoordination, and the role of myofascial trigger points in maintaining chronic pain.
2. The role of medical dry needling as a neurophysiologically and biomechanically determined adjuvant intervention in a multimodal rehabilitation model for SIS was scientifically substantiated and conceptually explained.
3. Current scientific knowledge about the clinical, functional, and medico-social significance of SIS was systematized, and a structured conceptual framework for an integrated therapeutic approach was proposed.

II. Applied (Practical) Contributions

1. An original phase-structured diagnostic-therapeutic algorithm was developed and clinically validated for patients with SIS, integrating medical dry needling with traditional physiotherapeutic methods.
2. An objective, standardized, and reproducible functional evaluation system was introduced, combining clinical tests, instrument-based measurements, and validated functional indices, thus enhancing diagnostic accuracy and monitoring of therapeutic effectiveness.

3. Through a prospective randomized controlled trial, the superiority of the combined therapy (physiotherapy + medical dry needling) over standard physiotherapy for SIS was experimentally and statistically demonstrated for the first time nationally.

4. The durability of the therapeutic effect was confirmed via mid- and long-term follow-up (up to 6 months), proving both the clinical effectiveness and practical applicability of the developed model.

RECOMMENDATIONS

Clinical practice – for practitioners:

- Become familiar with the proposed methodology and treatment algorithm for SIS, aimed at achieving faster and more effective outcomes in future patients.
- Given the frequency of the condition, promote patient awareness about the therapeutic protocol including medical dry needling.
- Acquire post-graduate qualification and specialization specifically related to dry needling application before implementing it in clinical practice.
- When applying physiotherapeutic and rehabilitation care, correctly and adequately assess the need for dry needling as part of treatment.
- Clearly define and evaluate indications for the use of the dry needling method.

For Medical Universities:

- Integrate the medical dry needling method into modern education and practice.
- Organize post-graduate training for students, residents, and rehabilitation specialists focused on the use of dry needling in SIS.
- Ensure that specialists are familiar with the results of this study and the methodology for applying dry needling in SIS, enabling step-by-step theoretical and practical integration of the method into contemporary teaching and clinical practice.

PUBLICATIONS AND PARTICIPATION IN SCIENTIFIC FORUMS RELATED TO THE DISSERTATION WORK

- Ivanov D. *Physiotherapy Combined with the Dry Needling Method in Shoulder Impingement Syndrome*. Varna Medical Forum, 2024, 13(2): 319-325.
<http://dx.doi.org/10.14748/vmf.v13i1.10179>
- Ivanov D. *Development and Neurophysiological Effect of Medical Dry Needling as a Therapeutic Modality*. Journal of Varna Medical College, 2025, 8(1): 21-27.
<http://dx.doi.org/10.14748/jmk.v8i1.10583>