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Post-traumatic stiffness in the elbow joint

ABSTRACT

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SCIENTIFIC JURY

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CONTENTS

LIST OF ABBREVIATIONS USED IN THE TEXT

PTES Posttraumatic Elbow Stiffness

HO Heterotopic Ossification

EMF Electromagnetic Field

AMCL Anterior Medial Collateral Ligament

CPM Continuous Passive Motion

DASH Disabilities of the Arm, Shoulder and Hand

DOUN Delayed-onset ulnar neuritis

IASTM Instrument Assisted Soft Tissue Mobilization

IFC Interferential Current

LES The Liverpool elbow score

MCL Medial Collateral Ligament Complex

MEPS Mayo Elbow Performance Score

MET Muscle Energy Technique

NMES Neuromuscular electrical stimulation

PMCL Posterior Medial Collateral Ligament

PNF Proprioceptive Neuromuscular Facilitation

RCA Radiocapitellar articulation

SD Standard deviation

TENS Transcutaneous electrical nerve stimulation

UHA Ulnohumeral articulation

VAS Visual Analog Scale

The dissertation contains 9 tables, 19 figures, and 7 graphs.

INTRODUCTION

Post-traumatic elbow stiffness (PTES) is a common complication following trauma or surgical intervention on the elbow joint and represents a challenge for modern medicine.

The elbow joint has a complex structure that plays an important role in upper limb movements (Sharma et al., 2020). Trauma to this area causes damage to the joint architecture and compromise it. This usually manifests as limited range of motion (Keenan et al., 2019).

An epidemiological study from 2018 found a correlation between the presence of a traumatic element and the development of elbow stiffness in a range of 10% to 30% (Lindau et al., 2018).

According to two studies from 2021 and 2022, the condition can affect people of any age, but it is more common among active middle-aged, mainly males, due to their participation in higher-energy activities that increase the risk of elbow joint trauma. (Harris et al., 2021; Zhang et al., 2022).

The correlation between severity of the injury, inflammatory process, adhesions (fibrosis) formation process and period of immobilization of the elbow joint are important for the restoration of elbow joint motor function (Fitzgerald et al., 2020; Kumar et al., 2023). A 2013 study examined 19,063

patients who underwent surgical treatment of the elbow joint due to trauma. Approximately 1.4% of them required reoperation within 7 months due to joint contracture *(* Schrumpf MA*et al. 2013)* .

Another common cause of elbow stiffness, following trauma or surgery, is heterotopic ossification (HO). Studies show that about 3% of elbow joint dislocations and up to 20% of fracture-dislocations are complicated by HO. Approximately 5–10% of patients with isolated traumatic brain injury develop HO in the elbow area. In patients with combined traumatic brain and elbow injuries, the incidence of HO development reaches 76–89% (Everding NG et al., 2013; Liu EY et al., 2018).

Two independent studies from 2003 and 2011 examine the frequency of elbow stiffness and the need for follow-up treatment. It was found that range of motion improved in all patients within one year after injury. In 12% of cases, surgical intervention was necessary due to severely impaired range of motion (Myden C et al. 2011).

Proper management of post-traumatic elbow stiffness requires a multidisciplinary approach. Early integration of elements of physical and rehabilitation medicine often leads to improvement in the range of motion and function of the upper limb (Singh et al., 2021). The literature data are insufficient to

accurately describe the time course of elbow stiffness development. Non-surgical treatment is considered appropriate for up to 6 months from the onset of contracture. Studies on animal models show stabilization of joint contractures at 32 weeks (Mittal R, 2017).

The choice of treatment is depends on factors such as the severity of stiffness, the time elapsed since the onset of the injury, and the patient's overall health. (Huang et al., 2020). Post-traumatic elbow stiffness is often a disabling complication following elbow injury. It can lead to both a decrease in the patient's physical capacity and psycho-emotional disorders. A complete understanding of the condition and the application of effective methods for managing PTES is essential for both the medical professional and the rapid recovery of patients.

CHAPTER I. PURPOSE, OBJECTIVES, AND HYPOTHESES OF THE STUDY

2.1 Purpose

To make a comparative assessment of functional recovery according to the factor "start of movement" of the elbow joint: on the 14th day (early onset) and after the 30th day (late onset), with already diagnosed PTES.

2.2 Tasks

The main objectives of the study are:

- To monitor the presence or absence of immediate and long-term effects of early (14th day) and late (30th day) initiation of mobilization.
- To determine the extent to which early initiation (14th day) of mobilization shortens the treatment period for elbow stiffness.
- To perform a comparative analysis of the therapeutic effects of early (14th day) and late (30th day) initiation of mobilization.
- To study the functional activity and quality of life in patients who began mobilization no later than the 14th

day, compared to those who began after the 30th day of the injury.

- To investigate the possibility of side effects and adverse reactions in both types of treatment.

2.3 Hypotheses

- Early mobilization of the elbow joint after trauma/surgery leads to faster and more effective recovery;
- The combination of various factors in conservative treatment contributes to faster recovery of patients in both groups (early and late onset of mobilization);
- Patients with prolonged periods of cast immobilization (after 30 days) have worse outcomes than patients mobilized after the second week (after 14 days).
- Patients who have undergone surgery and undergone prolonged immobilization (more than 3 weeks) have poorer final results in terms of elbow joint function.

CHAPTER II. RESEARCH MATERIALS AND METHODS

3.1 Subject of the study

Comparative assessment between early and late onset of mobilization, in order to determine how much the time factor is esencial for the final recovery outcome of elbow function.

3.2 Study contingent

3.2.1 Criteria for inclusion in the study

- Patients of both sexes, aged between 18 and 70 years with pathology in the elbow joint;
- Patients after acute trauma/surgical intervention;
- Signed informed consent to participate in the study;

3.2.2 Criteria for exclusion from the study

- Refusal to participate in the study;
- Patients with a history of symptoms lasting longer than a week;
- Chronic recurrent complaints;
- Comorbidity
- Inability to understand and follow the instructions in the study;
- Persons under 18 and over 70 years of age;
- Pregnancy;

3.3 Clinical principle of assessment

In order to achieve the set goals and objectives, the necessary data for the study was collected, examined, and analyzed.

1. Anamnestic data: pain, swelling, stiffness, and other subjective complaints of the patient;
2. Functional status:
    - examination of the elbow joint – skin color, deformity, presence of cicatrices;
    - palpation;
    - range of motion of the elbow joint;
3. Pain assessment using the Visual Analog Scale (VAS);
4. Short form of the MEPS (Mayo Elbow Performance Score) questionnaire, completed by patients;

3.4 Study design

1. Study period: April 2024 – April 2025;
2. Place of study: Maichin Dom Hospital, Varna – Department of Orthopedics and Traumatology;
3. According to the study design, the research is prospective;
4. All patients were divided according to gender, age, functional status, and the results were recorded at three time points:
    - T^1(removal of immobilization);
    - T^2 (15 days after removal of immobilization);
    - T^3 (30 days after removal of immobilization);
5. Patients who meet the inclusion criteria are divided into two groups with an equal number of participants (45 in each group).
    - Group "1": Early onset of mobilization – 14 days after trauma/surgery, followed by physical therapy and rehabilitation course, with results recorded at three time points (T^1, $T^2$and T^3).
    - Group "2": Late onset of mobilization – removal of immobilization on the 30th day after trauma/surgical intervention, followed by physical therapy and rehabilitation course and recording of results at three time points (T^1,

$T^2$and T^3).

6. The data from the study are organized in MS Office Excel 2019, and SPSS Statistics for Windows v. 26.0 software was used for their analysis.

3.5. Research methods

3.5.1 Clinical and functional examination:

3.5.1.1 Anamnestic data:

The information is collected based on data provided by the patient and available medical documentation. Particular attention is paid to the time elapsed since the incident and the nature and severity of the symptoms.

3.5.1.2. Functional status:

The examination aims to analyze the affected upper limb, to establish the presence or absence of sparing movement in the elbow area, and then to perform a symmetrical examination of both upper limbs (from the shoulder to the wrist) for the presence of cicatrix, edema, erythema, or ecchymosis.

Palpation aims to identifying painful areas or structures.

Goniometry is a basic method for assessing joint range of motion and, accordingly, motor function. It is performed

using a goniometer and follows the SFTR methodology, which describes movements in different planes: S – sagittal, F – frontal, T – transverse, R – rotation. In the elbow joint, movement occurs mainly in the sagittal plane. In healthy individuals, normal values are approximately S 0-0-145, while S 10-0-145 is considered hyperextension. During the examination, it is important to assess the movement in the radioulnar joint, with rotation denoted by R 90-0-90; the values in supination and pronation reflect the maximum achievable range of motion.

3.5.1.3 Pain assessment using the VAS (Visual Analog Scale)

The visual analog scale (VAS) is a method used to assess the subjective intensity of pain. It consists of a horizontal or vertical line 10 cm long, with the extreme states marked at both ends – "no pain" and "the strongest possible pain." The patient marks a point on the line corresponding to their personal perception of pain. The resulting value is measured and interpreted as follows: 0 – no pain; 1–3 – mild pain; 4–6 – moderate pain; 7–10 – severe pain.

3.5.1.4 Functional assessment scale for the elbow joint: Mayo Elbow Performance Score (MEPS)

The Mayo Elbow Performance Score (MEPS) is a widely used tool for clinical assessment of the functional status of

the elbow joint. It combines objective and subjective indicators, with the total score ranging from 0 to 100 points—a higher score indicates better function.

The scale includes four main criteria:

1. Pain (max. 45 points) – subjective perception of pain is assessed: absent, mild, moderate, or severe.

2. Movements (max. 20 points) – the range of flexion–extension in the elbow joint is measured.

3. Stability (max. 15 points) – determines whether the joint is stable, moderately unstable, or severely unstable.

4. Function (max. 20 points) – assesses the patient's ability to perform daily activities (e.g., eating, personal hygiene, dressing, carrying objects). The total score is up to 100 points, with a higher score indicating better function. The scale allows for the categorization of results into excellent, good, satisfactory, and poor, making it a widely used tool in scientific research and clinical practice.

3.6 Treatment methods

Patients from both study groups underwent a 14-day therapeutic program based on the principles of physical and rehabilitation medicine. The key is the individual approach to every patient, allowing the treatment methods to be adapted to them. The combination of various elements of preformed and

natural factors, as well as kinesitherapy, allows each aspect of the patient's clinical condition to be influenced. The therapeutic strategy for pain symptoms includes the use of physical factors with proven analgesic and anti-inflammatory effects – cryotherapy, laser therapy, low and medium frequency currents with analgesic parameters, ultrasound, and phonophoresis with NSAIDs. The goal is to achieve a rapid reduction in pain symptoms, which in turn allows for early inclusion of active exercises. In cases where the main problem is edema, methods are applied to aid fluid resorption and improve microcirculation. This includes lymphatic drainage techniques, magnetotherapy, and measured local cold applications. Reducing edema is key, as it creates the conditions for restoring mobility and reduces the risk of secondary damage to soft tissues. The therapeutic program for increasing range of motion is focused at gradually joint mobility restoration. Active-passive exercises, manual techniques, stretching, and specialized exercises are used to improve muscle balance. The inclusion of kinesitherapy at an early stage is crucial for preventing permanent contractures and restoring the functional capacity of the limb. Through the systematic combination of physical and rehabilitation medicine methods, a complex effect is achieved – pain reduction, control of the inflammatory process, reduction of the swelling,

range of motion recovery, and improving the patient's functional status.

3.7 Statistical methods:

Both descriptive and analytical statistical methods were applied to process and analyze the collected data.

3.7.1. Descriptive methods

- An **alternative analysis** was performed for categorical variables such as gender and type of intervention (surgical/conservative treatment).
- Quantitative variables (age, goniometry measurements, MEPS results) are presented as **mean and standard deviation (SD)**.
- Categorical indicators, such as **VAS** scores, are presented as **percentages**.
- For better visualization, the results are presented in **tables** and graphs.

3.7.2. Methods for testing hypotheses

- To compare the mean values between the two groups (early and late onset of mobilization), an **t-test for independent samples (two-tailed)** was used.

- To compare results over time within the same group (e.g., day 15 versus day 30), a paired t-test (two-tailed) was applied.
- When comparing categorical variables (e.g., the distribution of patients according to the degree of pain on the VAS), the **chi-square test (two-tailed)** was used.
- All analyses used a **level of statistical significance p < 0.05**.

The data was processed and systematized in **MS Office Excel 2019**, and **IBM SPSS Statistics for Windows, version 26.0** was used for statistical analysis.

CHAPTER III. RESULTS

4.1 Demographic and clinical indicators

For the purposes of the study, two groups were examined: Group 1 and Group 2. The first group included individuals with early onset of mobility (14th day), and the second group included individuals with late onset (30th day). Each group included 45 individuals, distributed by gender as follows: 23 men and 22 women in each group. The age range of the participants was from 18 to 70 years.

The average age in the first group is 46.0±15.2 and 46.1±11.6 in the second. The ratio between surgically and conservatively treated patients in the two therapeutic groups is 20 operated to 25 non-operated (Table 1).

Table 1. Demographic and clinical indicators

	Group "1"	Group "2"	P-value*
Number	45	45	
Gender ratio	23/22	23/22	
Age, mean±SD	46.0±15.2	46.1±11.6	0.969
Operated, ratio Yes/No	20/25	20/25	

**t-test, two-tailed*

4.2 Reported pain scores on the VAS

4.2.1 Reported pain score on the VAS in T^1

When considering the VAS results, upon removal of immobilization, a more painful syndrome was observed in the early mobilization group compared to the late mobilization group. Patients with no pain were observed only in the late mobilization group 30 patients (66.7%). This is due to prolonged immobilization and completed soft tissue healing processes. Individuals with mild pain were reported in both groups – 24 in the first group (53.3%) and the remaining 15 in the second (33.3%). Moderate pain was diagnosed only in the group with early onset of movement due to undergoing healing processes – 21 patients (46,7%) (Table 2).

Table 2. Reported pain score on the VAS at T^1

			Group		Total
			Group "1"	Group "2"	
Pain on VAS, T^1	Missing	Number	0	30	30
		%	0.0%	66.7%	33.3%
	Weak	Number	24	15	39
		%	53.3%	33.3%	43.3%
	Moderate	Number	21	0	21
		%	46.7%	0.0%	23.3%
Total		Number	45	45	90
		%	100.0%	100.0%	100.0%

*P-value <0.001**

**Shi-Square test, 2-sided*

4.2.2 Reported pain score on the VAS in T^2

When evaluating the results on the 15th day after of conservative treatment completion, a change in pain symptoms was observed. In the group with late mobilization, the trend remained the same—30 patients (66.7%) were pain-free, and the remaining 15 (46.7%) experienced mild pain. In the early mobilization group, 21 patients (46.7%) still experienced moderate pain, 23 (51.1%) experienced mild

pain, and only 1 patient reported no pain (2.2%). This shows a retention of the reported pain indicators in Group 1, which is due to the inclusion of active and passive movements (Table 3).

Table 3. Reported pain score on the VAS at T^2

			Group		Total
			Group "1"	Group "2"	
Pain on VAS, T^2	Missing	Number	1	30	31
		%	2.2%	66.7%	34.4%
	Weak	Number	23	15	38
		%	51.1%	33.3%	42.2%
	Moderate	Number	21	0	21
		%	46.7%	0.0%	23.3%
Total		Number	45	45	90
		%	100.0%	100.0%	100.0%

*P-value <0.001**

**Shi-Square test, 2-sided*

4.2.3 Reported pain score on the VAS in T^3

On the 30th day (T^3) after removal of immobilization, a significant decrease in pain symptoms was observed in both

groups. In Group 1, there was an increase in the number of patients reporting no pain to 38 (84.4%), and the number of patients reporting mild pain decreased to 7 (15.6%) compared to T^2. In the second group, the trend toward improvement in this symptom was less pronounced: 36 (80%) patients reported no pain and 9 (20%) patients reported mild pain. The data from the treatment show that in T^1 and T^2 there is a statistically significant difference between Group 1 and Group 2 in terms of pain – P-value<0.05, while in T^3there is no such difference (Table 4).

Table 4. Reported pain score on the VAS at T^3

			Group		Total
			Group "1"	Group "2"	
Pain on VAS, T^3	Missing	Number	38	36	74
		%	84.4%	80.0%	82.2%
	Weak	Number	7	9	16
		%	15.6%	20.0%	17.8%
	Moderate	Number	0	0	0
			0	0	0
Total		Number	45	45	90
		%	100.0%	100.0%	100.0%

*P-value =0.581**

**Shi-Square test, 2-sided*

4.3 Functional results and Mayo Elbow Performance Score (MEPS)

4.3.1. Reported functional results and MEPS in T^1.

The functional results, measured by elbow joint goniometry in T^1 , in both groups are approximately similar. Both groups showed significant elbow stiffness, with the range of motion in the sagittal plane below 60º for flexion/extension and in the transverse plane below 100º for pronation/supination. The reported mean values in Group 1 are as follows: flexion - 95.8±3.5, extension - 72.8±3.6, and range of motion FE - 23.0±4.8; the average values for pronation and supination are 45.4±6.8 and 26.7±6.7, and the range of motion PS is 72.1±6.1. The results obtained from the goniometry of patients in Group 2 are: flexion - 94.3±3.5, extension - 75.6±4.6, and the range of motion in this axis is 18.8±5.1. The average values for pronation and supination are 40.1±6.5 and 28.6±5.9, and the range of motion in this axis is 68.7±9.6 (Table 5).

The average MEPS scores were 38.0±7.6 for the first group and 49.0±9.8 for the second group. The values obtained in Group 1 were due to pain syndrome and the development of

mild to moderate contracture, despite the short period of immobilization. In the second group, the results are associated with the contracture that developed due to the longer period of immobilization. In the intergroup comparison, better results are observed in T^1 (when immobilization is removed) in Group 2. A statistically significant difference (P-value<0.05) was observed in extension, pronation, range of motion in the sagittal and transverse planes, as well as in the Mayo Elbow Performance Score values (Table 5).

Table 5. Reported results in T^1

Indicators	Group "1" mean±SD	Group "2" mean±SD	P-value*
Flexion	95.8±3.5	94.3±3.5	0.053
Extension	72.8±3.6	75.6±4.6	0.002
Pronation	45.4±6.8	40.1±6.5	> 0.001
Supination	26.7±6.7	28.6±5.9	0.161
Arc PS	72.1±6.1	68.7±9.6	0.044
Arc FE	23.0±4.8	18.8±5.1	> 0.001
MEPS	38.0±7.6	49.0±9.8	> 0.001

**t-test 2-sided*

4.3.2 Reported functional outcomes and MEPS in T^2.

According to the reported results in T^2 (after a 14-day physiotherapeutic course), an improvement in the results in

Group 1 was observed, both within the group and in comparison with the data from the second group. In Group 1, the values are as follows: flexion - 109.3±6.6, extension - 51.2±8.2, and range of motion FE - 58.1±13.1; the average values for pronation and supination are 71.8±7.5 and 57.2±10.4, and the range of motion PS is 129.0±13.8. The results obtained from the goniometry of patients in Group 2 are: flexion - 105.4±5.2, extension - 59.4±10.1, and the range of motion in this axis is 46.0±13.6, respectively. The mean values for pronation and supination are 65.6±10.2 and 49.6±10.1, respectively, and the range of motion in this axis is 115.1±18.3. The average MEPS results are 63.6±11.7 for Group 1 and 59.7±10.5 for Group 2 (Table 6).

Early mobilization shows better results and a statistically significant difference in almost all measured indicators (flexion, extension, pronation, supination, PS arch, FE arch). Only in the MEPS indicator the difference is not statistically significant. This suggests that early mobilization may be preferable for improving motor indicators, but at this point in the follow-up, there is no evidence of a major impact on overall functional recovery.

Table 6. Reported results in T^2

Indicators	Group "1" mean±SD	Group "2" mean±SD	P-value*
Flexion	109.3±6.6	105.4±5.2	0.003
Extension	51.2±8.2	59.4±10.1	> 0.001
Pronation	71.8±7.5	65.6±10.2	0.001
Supination	57.2±10.4	49.6±10.1	> 0.001
Arc PS	129.0±13.8	115.1±18.3	> 0.001
Arc FE	58.1±13.1	46.0±13.6	> 0.001
MEPS	63.6±11.7	59.7±10.5	0.100

**t-test 2-sided*

4.3.3 Reported functional outcomes and MEPS in T^3.

The functional results of the two groups are as follows: In Group 1, flexion - 131.6±7.1, extension - 18.8±10.1, and range of motion FE - 112.8±16.0; the average values for pronation and supination are 82.6±5.1 and 74.7±8.1, and the range of motion PS is 157.2±10.9. The average results for MEPS are 93.8±8.7. The data obtained from the goniometry of patients in Group 2 are: flexion - 126.2±6.7, extension - 29.4±9.5, and the range of motion in this axis is 96.8±14.6, respectively. The average values for pronation and supination are 74.9±7.2 and 63.8±9.1, respectively, and the range of motion in this axis is 157.2±10.9. The average results for MEPS are 87.2±14.3.

The results obtained show greater improvement in functional outcomes and MEPS in Group 1 compared to Group 2. The data are statistically significant with a P-value 0.05 (Table 7).

Table 7. Reported results in T^3

Indicators	Group "1" mean±SD	Group "2" mean±SD	P-value*
Flexion	131.6±7.1	126.2±6.7	> 0.001
Extension	18.8±10.1	29.4±9.5	> 0.001
Pronation	82.6±5.1	74.9±7.2	> 0.001
Supination	74.7±8.1	63.8±9.1	> 0.001
Arc PS	157.2±10.9	138.7±15.3	> 0.001
Arc FE	112.8±16.0	96.8±14.6	> 0.001
MEPS	93.8±8.7	87.2±14.3	0.010

**t-test 2-sided*

4.4 Comparative analysis of functional results and Mayo Elbow Performance Score (MEPS)

4.4.1 Comparative analysis in T^2 and T^3 for Group "1" (early onset).

All measurement parameters—flexion, extension, pronation, supination, PS arch, FE arch, and MEPS—showed significant

improvement between days 15 and 30. These data emphasize that the therapeutic method is effective and leads to rapid restoration of normal elbow joint function.

An increase in the individual functional indicators of the elbow joint was observed as follows: flexion from 109.3 ± 6.6 to 131.6 ± 7.1, extension from 51.2 ± 8.2 to 18.8 ± 10.1, pronation and supination from 71.8 ± 7.5 to 82.6 ± 5.1 and from 57.2 ± 10.4 to 74.7 ± 8.1, respectively. Measured with motion arcs, the overall improvement in range of motion increases in flexion/extension from 56.1 ± 13.1 to 112.8 ± 16.0, and in pronation/supination it goes from 129.0 ± 13.8 to 157.2 ± 10.8 . The results demonstrate a restoration of range of motion and overcoming of elbow stiffness indicators that limit daily functions.

The significant improvement in MEPS scores (from 63.6 ± 11.7 to 93.8 ± 8.7) represents the recovery of joint function and improved quality of life for patients.

All indicators show a P-value 0.001, confirming that the improvements are not random, but result of effective therapy.

Clinical significance: The magnitude of changes in each measurement parameter (especially in flexion, extension, arch FE, and MEPS) indicates that these results have a real and significant impact on patient recovery and rapid improvement in daily activities.

The results demonstrate that the treatment method applied to these patients is extremely effective in restoring elbow joint function.

The improvements are not only rapid (visible within 30 days) but also significant, indicating high potential for similar approaches in the treatment of similar conditions.

The data from the analysis clearly demonstrate that the applied treatment method leads to significant restoration of elbow joint functionality within a short period of time. This is seen in improved range of motion, rotational abilities, and overall functional assessment of the joint. The therapy is both effective and practical, with clinically and statistically proven significance of the results. These results emphasize the importance of timely and targeted therapy to achieve rapid and maximum restoration of the functional abilities of the affected joint (Table 9).

Table 9. Comparison of results in T^2 and T^3 for Group "1" (early start)

Indicators	T^2 mean±SD	T^3 mean±SD	P-value*
Flexion	109.3±6.6	131.6±7.1	> 0.001
Extension	51.2±8.2	18.8±10.1	> 0.001
Pronation	71.8±7.5	82.6±5.1	> 0.001
Supination	57.2±10.4	74.7±8.1	> 0.001
Arc PS	129.0±13.8	157.2±10.8	> 0.001
Arc FE	56.1±13.1	112.8±16.0	> 0.001
MEPS	63.6±11.7	93.8±8.7	> 0.001

**t-test, paired, 2-sided*

4.4.2 Comparative analysis in T^2 and T^3 for Group "2" (late start).

In the second group of follow up – patients with late onset of movement – a significant improvement in the functional parameters of the elbow joint was also demonstrated between the 15th and 30th day. All of the parameters studied showed changes that were not only statistically significant (P-value 0.001) but also clinically important for the daily functionality of patients.

For all measurement parameters – flexion, extension, pronation, supination, PS arch, FE arch, and MEPS – improvement was observed between days 15 and 30.

An increase in the individual functional indicators of the elbow joint is noted as follows: flexion from 105.4±5.2 to 126.2±6.7, extension from 59.4±10.2 to 29.4±9.5, pronation and supination from 65.6±10.2 to 74.9±7.2 and from 49.6±10.1 to 63.8±9.1. Measured in degrees of movement, the overall improvement in range of motion increased in flexion/extension from 46.0±13.6 to 96.8±14.6, and in pronation/supination from 115.1±18.3 to 138.7±15.3. The results show that the restored range of motion is insufficient to overcome elbow stiffness.

The significant improvement in MEPS scores (from 59.7±10.5 to 87.2±14.3) is evidence both of functional recovery of the elbow joint, with the return of the ability to perform some daily tasks, and of improvement in patients' subjective assessment of their condition.

All indicators show a P-value 0.001, confirming that the improvements are not random but the result of effective therapy.

The data demonstrate that the therapeutic treatment methods applied are effective but prove insufficient to achieve the minimum necessary parameters for functional elbow joint (Table 10).

Table 10. Comparison of results in $T^2$and $T^3$for Group "2" (late start)

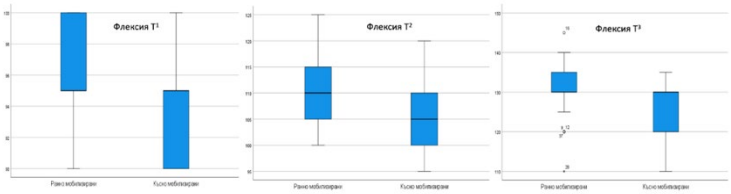
Indicators	On the 15th day mean±SD	On the 30th day mean±SD	P-value*
Flexion	105.4±5.2	126.2±6.7	> 0.001
Extension	59.4±10.2	29.4±9.5	> 0.001
Pronation	65.6±10.2	74.9±7.2	> 0.001
Supination	49.6±10.1	63.8±9.1	> 0.001
Arc PS	115.1±18.3	138.7±15.3	> 0.001
Arc FE	46.0±13.6	96.8±14.6	> 0.001
MEPS	59.7±10.5	87.2±14.3	> 0.001

*t-test, paired, 2-sided

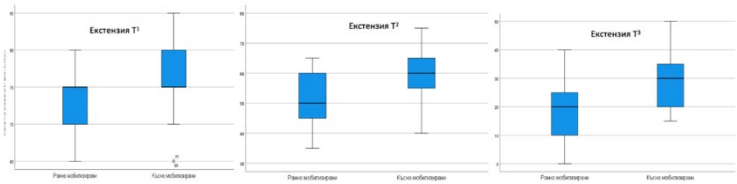
4.4.3 Comparative analysis for T^2 and T^3 for both groups

The summarized results obtained from the comparison of the two groups between T^2 and T^3 reflect significant changes in the clinical and functional status of patients within a 15-day period. The data collected on days 15 and 30 include key indicators for movement and functional assessment of the elbow joint - flexion (Graph. 1), extension (Graph. 2), pronation (Graph. 3), supination (Graph. 4), pronation/supination arc (Graph. 5),

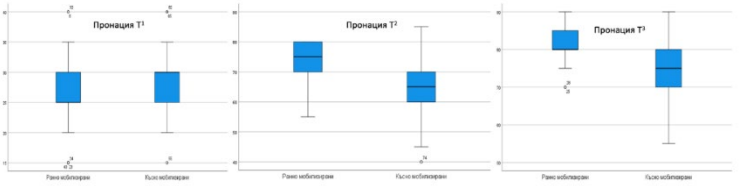
flexion/extension arc (Graph. 6), and a summary functional assessment on the MEPS scale (Graph 7). The results demonstrate statistically significant improvements (**P-value < 0.001**) for all parameters, confirming the effectiveness of the applied therapy for restoring joint function. These changes are particularly significant for the resumption of normal movements in daily functions and for improving the quality of life of patients.



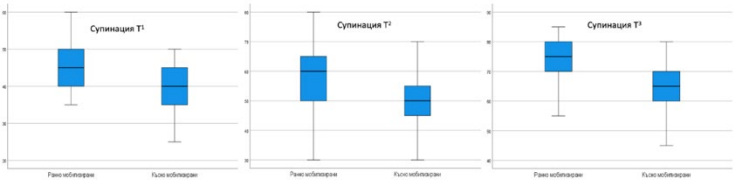
Graph 1. Reported results (flection) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers.



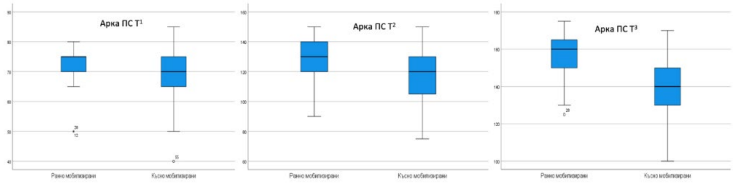
Graph 2. Reported results (extension) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers.



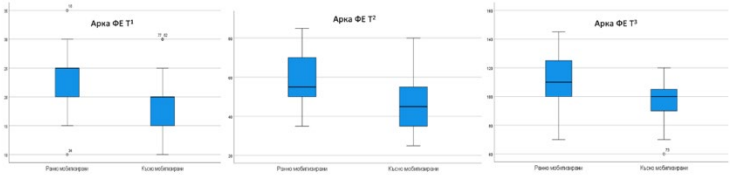
Graph 3. Reported results (pronation) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers



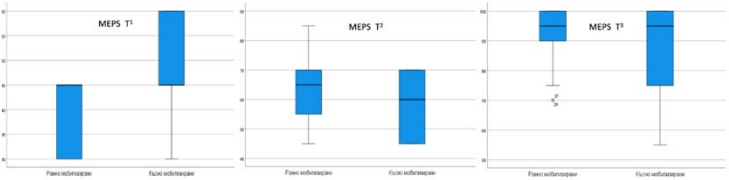
Graph 4. Reported results (supination) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers



Graph 5. Reported results (PS arc) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers



Graph 6. Reported results (arc FE) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers



Graph 7. Reported results (MEPS) in T^1, T^2, T^3 boxplot graph, with quartiles, median, and outliers.

The data from all indicators show a clear trend toward improvement between days 15 and 30. This indicates progress in the range of motion and functionality of the affected joint.

Parameters related to range of motion, such as flexion, extension, PS arch, and FE arch, demonstrate significant changes in the restoration of the range of motion necessary to perform daily activities.

Improvements in pronation and supination highlight significant progress in forearm rotational mobility, which is crucial for restoring patients' functional independence.

The functional assessment according to (MEPS) shows positive changes in the overall recovery of the elbow joint,

including pain, stability, and range of motion. This proves that the therapeutic activity has led not only to physical improvement but also to subjectively perceived recovery (Table 8).

Table 8. Comparison of results in T^2 and T^3 for both groups (total)

Indicators	T^2 mean±SD	T^3 mean±SD	P-value*
Flexion	107.4±6.2	128.9±7.3	> 0.001
Extension	55.3±10.1	24.1±11.1	> 0.001
Pronation	68.7±9.4	78.7±7.3	> 0.001
Supination	53.4±10.9	69.2±10.2	> 0.001
Arc PS	122.1±17.5	147.9±16.2	> 0.001
Arc FE	52.1±14.6	104.8±17.2	> 0.001
MEPS	61.6±11.2	90.5±12.2	> 0.001

**t-test, paired, 2-sided*

When comparing functional indicators (MEPS), early mobilization clearly has an advantage. Patients included in the early rehabilitation protocol achieve significantly higher MEPS values as early as day 15, and by day 30 they show almost complete functional recovery, especially in the non-operative subgroup.

Table 9. Comparison of MEPS results between patients with PTSS after trauma/surgery.

	Operated	MEPS T^2 (mean)	MEPS T^3 (mean)
Early mobilized - Group "1"	Yes	56	89
	No	69	97
Late mobilized – Group "2"	Yes	52	76
	No	66	96

Final conclusion: The data presented clearly demonstrate that the therapy or intervention applied is highly effective in restoring elbow joint function. All measured parameters show significant improvements within the 15-day period, highlighting the rapid recovery and increased functionality of the joint. The statistical significance of the results (**P-value < 0.001**) confirms that the observed changes are not random and can be attributed to the effectiveness of the therapy.

CHAPTER IV. DISCUSSION

5.1 Role of early mobilization in post-traumatic elbow stiffness

Post-traumatic elbow stiffness is one of the most common and severe complications following trauma and surgical interventions in the elbow joint area. It is characterized by limited range of motion, pain, and significant functional deficits that hinder the performance of daily activities and adversely affect the psycho-emotional state of patients. Although surgical methods are used in severe and refractory cases, current literature data categorically place non-surgical treatment as the first choice in the therapeutic approach. Particular attention is paid to the timing of the start of rehabilitation procedures, as a number of studies have found that early introduction of physiotherapy and kinesitherapy is crucial for achieving optimal functional results.

The review article by Siemensma et al. (2023) summarizes the current evidence for the treatment of post-

traumatic elbow stiffness and emphasizes the role of early mobilization as a key factor in preventing contractures. The data from the FuncSiE trial cited by the authors are particularly indicative—mobilization started as early as the second day after the injury leads to significantly faster recovery and better functional outcomes compared to classic three-week immobilization. According to them, conservative treatment is most effective if started within the first six months after the injury, including active and passive mobilization, exercises to control pain and swelling, and various forms of splinting. The best results are reported with static-progressive and dynamic splints, where the average improvement in range of motion reaches about 40°. The authors emphasize that individualized and timely physical therapy is a critical factor for full recovery, while surgical interventions should be are used only when conservative therapy fails.

Faqih et al. (2019) conducted a randomized controlled trial in patients with postoperative elbow stiffness after fractures, immobilized for a minimum of three weeks. The patients were divided into two groups: early rehabilitation immediately after immobilization removal and delayed rehabilitation with a one-week delay. The results show a clear advantage of early intervention – faster pain reduction, more significant recovery of range of motion (flexion +11.7°, extension +8.5°) and a

marked improvement in functionality (18.1 point reduction in DASH). These data support the view that any delay in starting therapy limits functional potential and prolongs the recovery period.

Similar conclusions are drawn by Bhosale and Kolke (2023), who investigate the effectiveness of two techniques—instrument-assisted soft tissue mobilization (IASTM) and Muscle Energy Technique (MET)—applied to patients with postoperative elbow stiffness. Both interventions were combined with standard physical therapy, including active and passive exercises, stretching, and a home program. In just three weeks, both groups demonstrated significant improvements in range of motion, pain, and function, with IASTM showing a better effect on pain during activity and individual functional tasks. This shows that it is not so much the specific technique as the timely initiation of active rehabilitation that is crucial to the final outcome.

Gunjan et al. (2022) examined the effectiveness of MET versus passive stretching in patients with postoperative elbow stiffness. In 42 patients included in the study, the results showed that both approaches improved range of motion, pain, and functionality, but MET was more effective, with an average increase in range of motion of approximately 29° compared to 17° with passive stretching, as well as higher MEPS scores.

These results highlight the importance of active techniques, which, when applied in a timely manner, outperform passive interventions and ensure a more complete recovery.

This dissertation research confirms the trends described in the literature. Patients in therapeutic group "1", in whom mobilization began after the 14th day, achieved faster pain reduction, a more significant increase in range of motion, and better functional scores on the VAS and MEPS scales compared to patients in Group 2, in whom rehabilitation was started after the 30th day. The first group achieved a functional range of motion (30° extension, 130° flexion, pronation and supination ≥50°), allowing them to perform daily activities independently, while in the second group the improvement was more limited and recovery was slower.

A comparison of the literature data and the results of the study leads to the categorical conclusion that early initiation of rehabilitation after immobilization is a decisive factor for the successful treatment of post-traumatic elbow stiffness. Delaying therapy beyond the 30th day compromises the recovery potential and limits the possibility of achieving functional range of motion, probably due to the development of soft tissue contractures and other complications.

5.2 The role of conservative treatment

Conservative treatment is considered the first and mandatory step in post-traumatic elbow stiffness, especially in the early stages after trauma or surgery. This approach is based on individualized physical therapy and rehabilitation, combining various physical factors—electrotherapy, magnetotherapy, laser therapy, ultrasound therapy, cryotherapy, etc.—with a variety of kinesitherapeutic techniques. The combined model has a multidirectional effect: it suppresses pain and inflammation, reduces swelling, promotes muscle tone recovery, and creates optimal conditions for gradual expansion of range of motion. The flexibility of the program, which allows adaptation to individual characteristics and the dynamics of recovery, is a key factor in achieving good results.

The study by Guglielmetti et al. (2020) is one of the few randomized controlled clinical trials that directly compares surgical and conservative treatment for post-traumatic elbow stiffness. It included 30 patients divided into two equal groups—15 treated with surgical release and subsequent rehabilitation and 15 treated with a conservative protocol involving static-progressive and dynamic orthoses, as well as a continuous passive motion (CPM) device. The results show

that surgical release leads to a greater range of motion (average 108° vs. 88° in the conservative group), as well as a higher absolute (+41° vs. +17°) and relative (+59% vs. +27%) improvement. However, clinical scales for pain, functionality, and quality of life (VAS, MEPS, DASH) show no significant differences between the two groups, and the frequency of complications is similar. This means that surgery has an advantage in restoring pure range of motion, but in terms of subjective functional improvement, conservative treatment may be almost equivalent. Another study – by Qi Wang et al. (2024) – followed patients with stiffness and heterotopic ossification resistant to conservative therapy. In these cases, combined treatment (surgical excision + rehabilitation + HO prevention) showed a significant improvement – an increase in the range of motion by more than 80° and a significant improvement in functional indicators. Crucially, the success of surgical treatment is determined by the early and systematic application of rehabilitation, which prevents recurrence and ensures stable results. More broadly, the review by Veltman et al. (2015) emphasizes the importance of orthoses as a means of conservative treatment. In an analysis of 232 patients treated with static-progressive and dynamic splints, an average improvement in range of motion of over 30° was reported, with the final ROM reaching 100–108°, which is

close to the functional threshold required for daily activities. The authors recommend that the conservative approach be applied for at least 12 months before proceeding to surgical intervention.

In the context of Bulgarian rehabilitation practice, the importance of a comprehensive approach in the development of a physiotherapy program stands out. As Ryazkova (2002) emphasizes, the combined application of physical factors—sequentially, alternately, or simultaneously—creates a potentiated effect that significantly improves the final result. The selection of factors, dosage, and localization of impact are crucial for the patient's maximum recovery. This concept is in line with international trends and shows that comprehensive, individualized therapy, applied in a timely manner, leads to statistically significant improvements in both pain reduction and range of motion and functional independence.

The data from the dissertation study show categorical and statistically significant results of conservative treatment of post-traumatic elbow stiffness. A significant reduction in pain symptoms (assessed by VAS), a significant increase in the range of motion in the elbow joint, and an improvement in functional outcomes measured by the Mayo Elbow Performance Score (MEPS) were reported. In addition to the differences between the two therapeutic groups, in which

patients in Group 1 achieved functional capacity more quickly than those in Group 2, there were also important variations in the recovery process among the different etiological subgroups. There was a tendency for better functional results in Group 2 on day 1 (removal of immobilization) due to less severe or absent pain symptoms.

The rehabilitation of patients with post-traumatic elbow stiffness shows more favorable and accelerated dynamics compared to patients with iatrogenic stiffness. This is probably due to the additional tissue trauma caused during surgery, which creates a secondary stress factor and hinders early recovery.

Conservative treatment remains the main therapeutic strategy for post-traumatic elbow stiffness. Although surgery demonstrates better results in terms of range of motion, a conservative approach, applied comprehensively and in a timely manner, can provide similar functional benefits without the risks of surgery. Early inclusion of physical therapy and adaptation of the program to the individual needs of the patient are crucial for the ultimate therapeutic success.

5.3 Practical significance

The results of the study clearly show that early initiation of rehabilitation (around 14th day) leads to faster and more complete functional recovery compared to late initiation of mobilization (after the 30th day). This has direct practical implications and could change clinical practice standards by introducing a protocol for early mobilization in patients with trauma and surgical interventions in the elbow joint area. Based on the data obtained, it is also possible to optimize diagnostic and therapeutic algorithms—early identification of patients at risk of stiffness and their immediate inclusion in rehabilitation programs. The importance of an individualized approach combining various physiotherapy methods (analgesic, anti-edema, anti-inflammatory, and motor) is also emphasized. This strategy has been proven to improve results and has the potential for widespread application in the daily practice of rehabilitation medicine.

5.4 Strengths of the study

The study has several significant advantages. First, the comparative design with two therapeutic groups (early and late onset of mobilization) allows for a direct assessment of the

impact of the timing of therapy initiation on recovery. Second, the effects were measured using objective and established methods—the VAS and MEPS scales, as well as goniometric assessment of range of motion—which ensures the reliability and validity of the results. In addition, the multifactorial rehabilitation approach used is close to actual clinical practice and makes the results applicable in a wide medical setting. The inclusion of patients with both traumatic and iatrogenic elbow stiffness allows for a more complete assessment of effectiveness in different clinical scenarios.

As an additional strength, it should be noted that although this study focuses on the rehabilitation aspect, it creates a clinical and conceptual basis for future interdisciplinary studies. The literature review conducted as part of the dissertation identifies prophylactic radiation therapy as a potentially effective strategy for reducing heterotopic ossification, one of the main structural substrates of persistent elbow stiffness. The integration of this approach into future clinical protocols would allow for a more comprehensive assessment of the prevention and treatment of post-traumatic elbow stiffness.

5.5. Limitations of the study

The relatively small number of patients limits the possibility of fully generalizing the results to the entire population. Another limiting factor is the relatively short follow-up period—there is no data on the long-term effects of therapy (e.g., after 6 or 12 months). The lack of randomization or a limited control group may also have an impact on internal validity. Furthermore, although the main clinical indicators have been assessed, broader aspects such as quality of life or psychological impact, which are also important in such conditions, have not been included.

CHAPTER V. CONCLUSION

Post-traumatic elbow stiffness is a serious complication following trauma and surgical interventions in the elbow joint area, significantly affecting patients' quality of life by limiting their daily activities and working capacity and disrupting their psycho-emotional state. Neglecting timely and targeted treatment can lead to chronicity of the condition, which further complicates the recovery process.

The data accumulated in scientific literature, as well as the results of this dissertation, strongly emphasize the role of early rehabilitation as a key factor for successful recovery. Mobilization, started in the first weeks after immobilization is removed, has clear advantages: it shortens the recovery period, reduces pain, and allows for a faster return to functional joint capacity. This proves that not only the timing of the start of therapy, but also the complexity of the methods used are of decisive importance.

Combined physiotherapy approaches, including physical factors (with anti-inflammatory, analgesic, and anti-edema effects) and various kinesitherapy techniques, have a synergistic effect that promotes accelerated recovery of movement and improvement of upper limb function.

The results obtained show a statistically significant effect on key indicators such as pain (VAS), range of motion, and functionality (MEPS). Of particular interest is the fact that the dynamics of recovery differ between patients with post-traumatic and iatrogenic stiffness. The former show faster and more complete progress, while the latter have a longer recovery process, probably due to the additional tissue trauma caused by the surgical intervention. This highlights the need for an individualized approach and adaptation of therapeutic strategies to the etiology of stiffness.

In summary, combining early mobilization with standardized and comprehensive rehabilitation protocols should be considered the optimal and clinically applicable approach for treating post-traumatic elbow stiffness. This model of behavior ensures not only faster and more effective recovery of joint function, but also a better quality of life for patients, sustainability of the therapeutic effect over time, and a reduced risk of long-term disability.

CHAPTER VI. EXTRACTS

1. A comparative assessment between early (14th day) and late (30th day) initiation of mobilization in patients with post-traumatic elbow stiffness shows that early initiation of rehabilitation leads to better and statistically significant recovery of joint function.
2. The results prove that patients from the group with early mobilization achieve a functional range of motion and higher MEPS scores compared to those mobilized later.
3. The effectiveness of the multidisciplinary approach, involving a combination of physical factors and kinesitherapeutic techniques, is demonstrated in both groups monitored.
4. Recovery in unoperated patients with traumatic elbow stiffness is more favorable compared to those who undergo surgical intervention.
5. No side effects have been identified from the application of the physiotherapy and kinesitherapy methods used. The approach is considered safe, applicable in clinical practice, and effective in both the short and medium term.

CHAPTER VIII. PUBLICATIONS

1. Petkov P. Short-term results after intra-articular fractures of the distal humerus treated by a paratriceps approach. *Scripta Scientifica Medica*. 2025;57(1):48-53. doi:10.14748/kt9p6x77

2. Petkov P, Nedyalkova-Petkova D, Vladeva E, Panayotova-Ovcharova L, Ivanov S. The effects of a physiotherapeutic complex in patient with post-traumatic stiff elbow. *Journal of IMAB*. 2025 Jan-Mar;31(1):6013. doi: 10.5272/jimab.2025311.6013.