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## RESTORATION OF FUNCTIONAL MOBILITY AFTER MINE-BLAST INJURIES OF THE LOWER LIMBS: RESULTS OF REHABILITATION AT THE INPATIENT STAGE

M. S. Navrotska\*, O. Ya. Andriichuk, O. V. Usova, Yu. B. Arieshina

*Lesya Ukrainka Volyn National University, Department of Physical Therapy and Occupational Therapy, Lutsk, Ukraine*

ORCID: [0009-0003-9698-8147](https://orcid.org/0009-0003-9698-8147), e-mail: [marananavrocka@gmail.com](mailto:marananavrocka@gmail.com)

ORCID: [0000-0003-4415-4696](https://orcid.org/0000-0003-4415-4696), e-mail: [andrijchuk.olga@vnu.edu.ua](mailto:andrijchuk.olga@vnu.edu.ua)

ORCID: [0000-0002-6227-0597](https://orcid.org/0000-0002-6227-0597), e-mail: [usova.oksana@vnu.edu.ua](mailto:usova.oksana@vnu.edu.ua)

ORCID: [0000-0001-6375-465X](https://orcid.org/0000-0001-6375-465X), e-mail: [julia.opheart@gmail.com](mailto:julia.opheart@gmail.com)

\*Corresponding author: M.S. Navrotska, e-mail: [marananavrocka@gmail.com](mailto:marananavrocka@gmail.com)

**Abstract.** Mine-blast injury is a complex combination of tissue damage caused by multiple injurious factors of an explosion. Under the conditions of the ongoing war in Ukraine, the number of patients with such injuries has significantly increased, emphasizing the need to improve approaches to physical rehabilitation. The lower limbs, particularly the ankle joint, are most frequently affected, leading to prolonged impairments in weight-bearing capacity and mobility.

**Purpose.** To assess the dynamics of functional mobility and motor activity indicators in patients with lower-limb MBI following an inpatient rehabilitation program.

**Methods.** The study involved 20 male servicemen aged  $33.15 \pm 1.56$  years with ankle fractures resulting from MBI. The rehabilitation program included physical therapy interventions aimed at restoring joint range of motion, muscle strength, and functional mobility. Assessments were conducted using goniometry, manual muscle testing (MMT), and the *Timed Up and Go Test* (TUG). Statistical analysis was performed using methods of variation statistics, the Shapiro–Wilk test, and Pearson’s correlation analysis.

**Results.** After the rehabilitation program, 95% of patients showed improvement in ankle joint flexion amplitude (mean increase —  $8.3^\circ$ ), and all participants demonstrated improvement in extension movements (mean increase —  $9.95^\circ$ ). The strength of flexor muscles increased by 1.05 points ( $p < 0.001$ ), and that of extensors — by 0.8 points. Correlation analysis revealed a strong positive relationship between joint amplitude and muscle strength ( $r = 0.77-0.94$ ). According to the *Timed Up and Go Test*, the average completion time decreased from  $12.8 \pm 1.99$  s to  $9.95 \pm 2.04$  s ( $p < 0.001$ ), indicating a statistically significant improvement in functional mobility and reduced fall risk.

**Conclusions.** As a result of the rehabilitation course, 95% of patients showed an improvement in the amplitude of flexion movements in the supracalcaneal-tibial joint. In most of them (40%), the increase was  $6-10^\circ$ , and in another 25% - more than  $10^\circ$ , which indicates a significant restoration of functional mobility. Only in one patient (5%) the indicators remained unchanged; no cases of decreased mobility were detected.

An improvement in the amplitude of extension in the supracalcaneal-tibial joint was also noted: the average increase was  $9.05^\circ$  (approximately 53.7% of the initial level). In 75% of patients, an increase in the amplitude by more than  $10^\circ$  was observed, which indicates a significant improvement in the functional mobility of the ankle-foot complex.

Thus, the positive dynamics among the majority of patients confirms that the implemented physical therapy program contributed to the improvement of foot support and stabilization of movements during walking. The results obtained are consistent with the concept of gradual recovery of the musculoskeletal system after lower limb injuries, according to which the sequential recovery of mobility, strength and coordination is a key criterion for the effectiveness of rehabilitation intervention.

This combination of changes corresponds to the logic of gradual recovery: local joint function and muscle strength are restored, which are reflected in the integrated parameters of walking speed and confidence.

**Keywords:** mine-blast injury, rehabilitation, ankle joint, goniometry, muscle strength, functional mobility, Timed Up and Go Test.

**Introduction.** In modern military conflicts, a significant amount of ammunition is used, leading to mine and explosive injuries (MEIs). MEIs are a specific type of combined injury, which includes the impact of several

damaging factors of an explosion: shock wave, fragments, high temperature, fire and toxic substances. The combined effect of these factors causes complex damage to various body systems.

In Ukraine, MEIs have become an important domestic problem. Since 2014, when active hostilities began in eastern Ukraine, the number of victims of Russian aggression began to grow rapidly, and after the full-scale invasion in February 2022, the issue of MEIs has become even more urgent [9].

The need to return victims after MEIs to their official duties determines the high requirements for recovery, which is ensured by a complex of rehabilitation measures at all stages of treatment [4, 5].

Traumatic injuries of the extremities are the most common in modern medical practice, which is due to the peculiarities of their pathogenesis, diagnosis, treatment and, especially, rehabilitation. Traumatic injuries are characterized by significant severity of bone and surrounding soft tissue damage, primary microbial contamination of wounds, the presence of foreign objects and a high frequency of early and late complications [2].

Most traumatic injuries are lower limb injuries, among which a significant proportion are calcaneal fractures.

**Research rationale.** The inpatient stage of treatment and rehabilitation of calcaneal fractures is aimed at ensuring proper fusion of bone structures and restoration of joint functions. An important component of this stage is constant clinical observation of the patient and periodic monitoring of the condition of the damaged joint in order to timely identify possible complications and eliminate them. The maximum level of recovery can only be achieved with a multidisciplinary approach and consistency in the provision of rehabilitation care [13].

The key task at the inpatient stage is to ensure the stability of the joint. For this, plaster casts or special orthoses are used to fix the damaged area. In the case of a complicated fracture with displacement, reposition is performed - the anatomical comparison of bone fragments into their physiological position, usually surgically. In such cases, the terms of immobilization can vary significantly [7].

The prognosis is usually favorable provided that the supracalcaneal joint is stable and the bone fragments are in the correct position during healing [6]. The work of a physical therapist with a patient should take into account the peculiarities of consolidation of bone fragments, the stages of wound healing, the general condition of the patient, as well as the specifics of the recovery of military personnel after MVT.

**Purpose of the work:** to assess the dynamics of functional mobility and motor activity indicators in patients with lower limb MPT under the influence of a rehabilitation program at the inpatient stage

**Materials and organization of the study.** The study was conducted at the Faculty of Medicine of the Lesya Ukrainka Volyn National University and the Volyn Regional Hospital of War Veterans. The study involved 20 male servicemen with a supracalcaneal-tibial fracture resulting from MVT. The average age of the participants was  $33.15 \pm 1.56$  years.

All patients were familiarized with the conditions of the study and provided informed consent to participate.

The participants underwent a somatic, traumatological, orthopedic and neurological examination. Comprehensive rehabilitation with the use of physical therapy was carried out in a hospital setting.

To analyze the effectiveness of the rehabilitation program, the dynamics of motor activity indicators were assessed based on the results of goniometry, manual muscle testing and the "Get Up and Go" fall risk test.

The goniometry method is one of the most common in the practice of managing patients with musculoskeletal disorders. The active range of motion in the ankle-calcaneal joint (flexion, extension) was assessed using a universal goniometer.

Manual muscle testing on a scale of 0 to 5 points was used to determine the strength of the muscles involved in flexion and extension of the foot.

The Timed Up and Go Test (TUG) was used to determine the risk of falling. It allows you to assess functional mobility, balance, walking ability, speed and pattern of walking, the need for assistive devices and the overall risk of falling.

According to the prognostic model of Keene D. J. et al. (2019) [6] and data Ramadi A. (2022) [10], the amplitude of movements and the results of the "Get up and go" test are significant predictors of the functional state after fractures of the supratolar joint.

In the process of analyzing the obtained data, a clinically oriented approach was used: the dynamics of the indicators were assessed by the number of people who had improvement, stabilization or no changes. Statistical indicators (mean value and error of the mean) were calculated for a variation series, the distribution of which did not differ from the normal one according to the Shapiro-Wilk criterion at a significance level of  $p \geq 0.1$ . A correlation analysis was performed using the Pearson method.

**Research results.** A supratolar joint fracture occurs under the influence of forces directed perpendicular to the normal axis of movements in the joint. Depending on the mechanism of injury, metatarsal fractures are divided into pronation or adduction (fracture occurs when the foot is turned outward) and supination or abduction (turning the foot with the sole inward).

In most cases, the fracture occurs as a result of an indirect mechanism of injury with a predominance of rotational displacements of the segments with a minor role of axial loads. Such fractures are classified as low-energy injuries, and they are usually accompanied by a minor degree of soft tissue damage [13].

According to ICD-10, metatarsal fractures due to MVT are coded in the following categories: (S90-S99) — injuries of the ankle joint and foot; (S92) — fractures of the foot, excluding the ankle joint; (S92.0) — calcaneal fracture.

According to the recommendations of the World Health Organization and the regulatory documents of the Ukrainian healthcare system, the rehabilitation process should be carried out on the basis of the International Classification of Functioning (ICF). It is used to assess the structures and functions of the body, the patient's activity

and participation in society. The ICF allows you to formulate a rehabilitation diagnosis, determine the goal and objectives of rehabilitation, develop an individual plan and assess the effectiveness of the intervention.

The rehabilitation diagnosis is described using ICF codes, which cover four levels of impairment: structures, functions, activity and participation, environmental factors.

The main ICF codes for impairment of functions associated with a calcaneal fracture: b7100 — mobility of one joint; b7603 — supporting functions of the leg; b28015 — pain in the lower limb.

ICF core body structure codes associated with calcaneal fracture: s75020 — bones of ankle and foot; s75021 — joints of ankle, foot and toes; s75028 — structure of ankle and foot (calcaneus).

ICF core activity and participation codes for individuals with calcaneal fracture: d4500 — walking short distances; d4501 — walking long distances; d4502 — walking on different surfaces; d4552 — running; d4600 — moving around the house.

ICF codes associated with injuries and fractures of the supracalcaneal joint are given in table 1.

**Table 1**

**ICF codes associated with supracalcaneal joint injuries**

ICF		
<b>Functions</b>	<b>b28015</b>	<b>Lower extremity pain</b>
	<b>b7100</b>	<b>Ankle and foot bones</b>
	<b>b7101</b>	<b>Multiple joint mobility</b>
	<b>b7301</b>	<b>Single limb muscle strength</b>
	<b>b7400</b>	<b>Isolated muscle endurance</b>
	<b>b7401</b>	<b>Muscle group endurance</b>
	<b>b7603</b>	<b>Support functions of the leg</b>
<b>Structures</b>	<b>s7502</b>	<b>Ankle and foot structure</b>
	<b>s75020</b>	<b>Ankle and foot bones</b>
	<b>s75021</b>	<b>Ankle, foot and toe joints</b>
	<b>s75022</b>	<b>Ankle and foot muscles</b>
	<b>s75028</b>	<b>Ankle and foot structure (calcaneus)</b>
<b>Activities/ Participation</b>	<b>d4500</b>	<b>Short distance walking</b>
	<b>d4501</b>	<b>Long distance walking</b>
	<b>d4552</b>	<b>Running</b>
	<b>d4502</b>	<b>Walking on different surfaces</b>
	<b>d600</b>	<b>Moving around the house</b>

The general goal of rehabilitation is the effective and early return of patients to everyday activities, social life and professional activities. When planning a physical therapy program as a component of comprehensive rehabilitation, it is recommended to adhere to the following basic principles: early initiation of rehabilitation activities contributes to faster restoration of lost functions and prevention of possible complications; continuity and gradualness of the rehabilitation process ensure a reduction in recovery time, a reduction in the risk of disability and a return to active life; comprehensiveness of activities and a multidisciplinary approach involving a psychologist and a social worker; individuality of the rehabilitation program taking into account the general physical condition of the patient, the initial level of physical fitness, psychological state and features of the course of the post-traumatic period; organization of classes in a team, which contributes to the formation of a sense of support, belonging to the group and reducing discomfort associated with the consequences of the injury; gradual return to occupational activity and social interaction, which provides a positive psycho-emotional state; constant monitoring of the adequacy of loads and the effectiveness of rehabilitation measures. To prescribe differentiated and optimal rehabilitation treatment, a correct assessment of the patient's condition is necessary [7].

Setting physical therapy goals for a metatarsal fracture

due to a mine-explosive injury involves determining short-term and long-term goals. The short-term goal is to increase the amplitude of movements of the metatarsal joint during the first seven days. The long-term goal is to restore proper gait over longer distances by the time of discharge (after two weeks).

During the individual selection of the level of physical activity, modern recommendations were used [12], which confirm the effectiveness of early targeted physical exercises compared with usual care [8].

To assess the baseline and results of the implemented rehabilitation program, the range of motion in the supracalcaneal-tibial joint was determined using a standard method, provided that the joint was stable. At the stage of the initial rehabilitation examination, the average active flexion index was  $32.75 \pm 13.83^\circ$ . After the completion of the therapeutic intervention, this index increased to  $41.05 \pm 11.74^\circ$ .

Clinically-oriented analysis showed the following dynamics: improvement (final indicators greater than baseline), i.e. an increase in amplitude from  $2^\circ$  to  $14^\circ$ , was recorded in 19 patients (95%); no changes (final indicators equal to baseline), i.e. stability of mobility ( $50^\circ \rightarrow 50^\circ$ ), was detected in one patient (5%); deterioration (final indicators less than baseline) was not observed.

Detailed data on the dynamics of the degree of improvement of active flexion in the supracalcaneal joint

are given in table 2.

Table 2

Dynamics of restoration of active flexion in the supracalcaneal joint

Growth range	Number of patients	Share (%)	Short Description
+1° – +5°	6	30 %	Slight Improvement
+6° – +10°	8	40 %	Moderate Improvement
+11° – +15°	5	25 %	Significant Improvement
> +15°	0	0 %	—
No changes	1	5 %	Stable

The average extension in the supracalcaneal-tibial joint according to goniometry during the initial examination was  $15.90 \pm 7.56^\circ$ . Repeated measurement showed an increase in this indicator to  $25.85 \pm 5.36^\circ$ . All patients (100%) showed positive dynamics.

The most common was an increase within 11–15° (40% of participants), which reflects a pronounced

tendency to restore joint mobility. Five patients recorded a significant improvement of more than 15°, which may be due to their high involvement and active participation in the physical therapy program.

Detailed indicators of the dynamics of improvement in active extension in the supracalcaneal-tibial joint are given in table 3.

Table 3

Dynamics of recovery of active extension in the supracalcaneal joint

Growth range	Number of patients	Share (%)	Short Description
+1° – +5°	1	5 %	Slight improvement
+6° – +10°	6	30 %	Moderate improvement
+11° – +15°	8	40 %	Significant improvement
+16° – +20°	5	25 %	Significant improvement
No changes	0	0 %	—

Determination of muscle strength is an important indicator that reflects the existing motor disorders and the dynamics of their changes in the process of implementing the rehabilitation program. To assess muscle strength, the method of manual muscle testing with a traditional scoring scale was used.

During the initial rehabilitation examination, the average strength of the muscles that provide flexion in the supracalcaneal joint was  $2.40 \pm 0.94$  points. After the completion of the therapeutic intervention, this indicator significantly improved ( $p < 0.001$ ) by 1.05 points (43.7%)

and reached the level of  $3.45 \pm 1.32$  points.

Clinically-oriented analysis of the obtained data showed the following dynamics: improvement (final indicators > baseline) - an increase in strength by 1–3 points in 15 patients (75%); no changes (final values = baseline) — strength remained at the same level in 4 people (20%); in 1 patient (5%) no significant dynamics were noted due to a pronounced baseline strength deficit.

Detailed results of the dynamics of the strength of the muscles that provide flexion in the supracalcaneal joint are given in table 4.

Table 4

Dynamics of the strength of the muscles that provide flexion in the supracalcaneal joint

Growth range	Number of patients	Share (%)	Short Description
+1 бал	11	55 %	Moderate improvement
+2 балли	3	15 %	Significant improvement
+3 балли	1	5 %	Significant improvement
No changes	4	20 %	Stable
0	1	5 %	No change

Determination of the strength of the muscles that provide extension in the supracalcaneal joint, carried out at the beginning of the study using MMT, showed that

the average indicator was  $3.60 \pm 0.94$  points. At the end of the study, this indicator significantly improved by 0.8 points (22.2%) and reached  $4.40 \pm 0.99$  points. Analysis

of individual data showed the following: improvement (final indicator > baseline) - an increase in strength by 1 point was recorded in 13 people (65%); no changes (final = baseline) - the previous level of strength was maintained

in 7 people (35%); no deterioration was detected. Detailed data on the dynamics of the strength of the muscles that provide extension in the supracalcaneal joint are given in table. 5.

Table 5

**Dynamics of muscle strength providing extension in the supracalcaneal joint**

Growth range	Number of patients	Share (%)	Short Description
+1 бал	13	65 %	Moderate improvement
No changes	7	35 %	Stable
Deterioration	0	0	None

In order to assess the impact of the physical therapy program on the indicators of functional mobility, walking, balance, and risk of falling, the "Get Up and Go" test was performed. At the initial stage of rehabilitation, the average test time was 12.8±1.99 s, and at the end of the study – 9.95±2.04 s. A detailed clinically-oriented analysis of the test results revealed the following indicators:

improvement (final < baseline) - a reduction in test time by 1–5 s was noted in all (100%) patients. The average test time decreased by 2.9 seconds (22.6%), which exceeds the minimal clinically significant difference (2.1 s). A detailed analysis of the dynamics of the "Get Up and Go" test results is presented in table 6.

Table 6

**Dynamics of the results of the «Get Up and Go» test**

Time reduction range (s)	Number of patients	Proportion (%)	Brief description
-1 – -2	5	25 %	Minor improvement (partial recovery of gait)
-3 – -4	10	50 %	Moderate improvement in functional mobility
-5 і більше	5	25 %	Significant improvement, recovery of balance and movement control
No changes	0	0	No change

The obtained data indicate that there is a synchronous development of functional indicators in different planes of movement, which confirms the effectiveness of the implemented physical therapy program. The changes revealed indicate a significant improvement in balance control, step symmetry and coordination skills in most patients, which creates the prerequisites for a safe return to everyday and official activity of military personnel after ankle-foot injuries.

The rehabilitation program with the use of physical therapy tools has confirmed its effectiveness in restoring mobility, muscle strength and functional mobility of the lower limb. Early activation, gradual dosage of the load and performance of exercises in a closed kinematic chain contributed to a stable improvement in the studied indicators and a reduction in the risk of falls after removal of immobilization.

The results obtained are consistent with the data of systematic reviews, which indicate that early mobilization after stabilization of fractures in the supratolar joint significantly improves the amplitude of movements without increasing the risk of complications [1, 12], and early dosed loading accelerates the return of patients to active life [3].

**Discussion of results.** According to the results of the assessment of the strength of the muscles that provide foot flexion, 75% of patients showed an improvement in func-

tional capabilities, 20% - stabilization of indicators, and 5% (1 patient) did not observe significant changes. Most often, the strength increased by 1 point (55%), which corresponds to the transition from a moderate decrease to a satisfactory level of functional activity.

The dynamics of the strength indicators of the foot extensors also indicate positive changes in 65% of patients, while the remaining (35%) showed preservation of the initial level without negative trends. Deterioration of strength was not observed in any case. The average value of muscle strength increased by 0.9 points, which is about 25% of the initial level.

Such dynamics of goniometry and MMT indicators confirm the effectiveness of the physical therapy program aimed at improving the biomechanical characteristics of the supracalcaneal joint.

Functional mobility is an important marker of the risk of falls and the level of independence in daily activities. The "Get Up and Go" test was performed to determine it. After completing the inpatient rehabilitation phase, all patients (n = 20) had a reduction in test time, indicating a decrease in the risk of falls and improvement in functional mobility. The most common improvement was 3–4 s (50% of patients), which confirms the effectiveness of the program for restoring coordination, balance, and strength of the lower extremities. The results obtained have high statistical reliability (p < 0.001) and clinical significance

and are consistent with the data of studies indicating that the “Get Up and Go” test is a sensitive tool for predicting functional recovery after lower limb injuries [15].

**Conclusions.** As a result of the rehabilitation course, 95% of patients showed an improvement in the amplitude of flexion movements in the supracalcaneal-tibial joint. In most of them (40%), the increase was 6–10°, and in another 25% - more than 10°, which indicates a significant restoration of functional mobility. Only in one patient (5%) the indicators remained unchanged; no cases of decreased mobility were detected.

An improvement in the amplitude of extension in the supracalcaneal-tibial joint was also noted: the average increase was 9.05° (approximately 53.7% of the initial level). In 75% of patients, an increase in the amplitude by more than 10° was observed, which indicates a significant improvement in the functional mobility of the ankle-foot complex.

Thus, the positive dynamics among the majority of patients confirms that the implemented physical therapy program contributed to the improvement of foot support and stabilization of movements during walking. The obtained results are consistent with the concept of gradual restoration of the musculoskeletal system after lower limb injuries, according to which the consistent restoration of

mobility, strength and coordination is a key criterion for the effectiveness of rehabilitation intervention.

The prospects for further scientific research include rehabilitation monitoring of patients for 6–12 months after the end of the inpatient phase in order to determine the stability of the results obtained and identify factors affecting the preservation of functional mobility.

**Conflict of interest.** The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship, or other, which could affect the study and its results presented in this article

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## ВІДНОВЛЕННЯ ФУНКЦІОНАЛЬНОЇ МОБІЛЬНОСТІ ПІСЛЯ МІННО-ВИБУХОВИХ ТРАВМ НИЖНІХ КІНЦІВОК: РЕЗУЛЬТАТИ РЕАБІЛІТАЦІЇ НА СТАЦІОНАРНОМУ ЕТАПІ

М. С. Навроцька\*, О. Я. Андрійчук, О. В. Усова, Ю. Б. Арешина

*Волинський національний університет імені Лесі Українки, кафедра фізичної терапії та ергоterapiї, м. Луцьк, Україна*

ORCID: [0009-0003-9698-8147](https://orcid.org/0009-0003-9698-8147), e-mail: [marananavrocka@gmail.com](mailto:marananavrocka@gmail.com)

ORCID: [0000-0003-4415-4696](https://orcid.org/0000-0003-4415-4696), e-mail: [andrijchuk.olga@vnu.edu.ua](mailto:andrijchuk.olga@vnu.edu.ua)

ORCID: [0000-0002-6227-0597](https://orcid.org/0000-0002-6227-0597), e-mail: [usova.oksana@vnu.edu.ua](mailto:usova.oksana@vnu.edu.ua)

ORCID: [0000-0001-6375-465X](https://orcid.org/0000-0001-6375-465X), e-mail: [julia.opheart@gmail.com](mailto:julia.opheart@gmail.com)

\**Кореспондуючий автор*: М.С. Навроцька, e-mail: [marananavrocka@gmail.com](mailto:marananavrocka@gmail.com)

**Резюме.** Мінно-вибухова травма є складним поєднанням ушкоджень, спричинених дією декількох уражальних факторів вибуху. В умовах війни в Україні кількість пацієнтів із такими травмами значно зросла, що актуалізує потребу вдосконалення підходів до їхньої фізичної реабілітації. Найчастіше ураження стосуються нижніх кінцівок, особливо надп'яtkово-гомількового суглоба, що зумовлює тривалі порушення опороздатності та мобільності.

**Мета дослідження.** Оцінити динаміку показників функціональної мобільності та рухової активності пацієнтів із МВТ нижніх кінцівок під впливом програми реабілітації на стаціонарному етапі.

**Методи.** У дослідженні брали участь 20 військовослужбовців чоловічої статі віком  $33,15 \pm 1,56$  року з переломами надп'яtkово-гомількового суглоба внаслідок МВТ. Реабілітаційна програма включала засоби фізичної терапії, спрямовані на відновлення амплітуди рухів, сили м'язів і функціональної мобільності. Оцінювання проводили за допомогою гоніометрії, мануального м'язового тесту (ММТ) та тесту «Встань і йди» (Timed Up and Go Test). Статистичний аналіз здійснювали методами варіаційної статистики, із використанням критерію Шапіро-Уїлка та кореляційного аналізу Пірсона.

**Результати.** Після реалізації програми фізичної терапії у 95 % пацієнтів відзначено покращення амплітуди згинання у надп'яtkово-гомільковому суглобі (середній приріст —  $8,3^\circ$ ). Розгинальні рухи збільшилися у всіх обстежених (приріст —  $9,95^\circ$ ). Сила м'язів, що забезпечують згинання, зросла на 1,05 балів ( $p < 0,001$ ), а розгинання — на 0,8 балів. Кореляційний аналіз показав тісний прямий зв'язок між амплітудою рухів і м'язовою силою ( $r = 0,77 - 0,94$ ). За тестом «Встань і йди» середній час виконання скоротився з  $12,8 \pm 1,99$  с до  $9,95 \pm 2,04$  с ( $p < 0,001$ ), що свідчить про достовірне покращення функціональної мобільності та зниження ризику падіння.

**Висновки.** У результаті проведеного курсу реабілітації у 95 % пацієнтів спостерігалось покращення амплітуди згинальних рухів у надп'яtkово-гомільковому суглобі. У більшості з них (40 %) приріст становив  $6 - 10^\circ$ , ще у 25 % — понад  $10^\circ$ , що вказує на суттєве відновлення функціональної рухливості. Лише в одного пацієнта (5 %) показники залишилися без змін; випадків зниження рухливості не виявлено.

Також відзначено покращення амплітуди розгинання у надп'яtkово-гомiлковому суглобі: середній приріст становив  $9,05^\circ$  (приблизно 53,7 % від вихідного рівня). У 75 % пацієнтів спостерігалось збільшення амплітуди більш ніж на  $10^\circ$ , що свідчить про значне покращення функціональної рухливості гомiлково-ступневого комплексу.

Таким чином, позитивна динаміка серед більшості пацієнтів підтверджує, що реалізована програма фізичної терапії сприяла покращенню опори стопи та стабілізації рухів під час ходьби. Отримані результати узгоджуються з концепцією поступового відновлення опорно-рухового апарату після травм нижніх кінцівок, згідно з якою послідовне відновлення мобільності, сили та координації є ключовим критерієм ефективності реабілітаційного втручання.

Така комбінація змін відповідає логіці поетапного відновлення: відновлюється локальна функція суглоба і сила м'язів, що відображаються на інтегрованих параметрах швидкості й упевненості ходьби.

**Ключові слова:** мінно-вибухова травма, реабілітація, надп'яtkово-гомiлковий суглоб, гоніометрія, м'язова сила, функціональна мобільність, тест «Встань і йди».

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