USE OF THERA-TRAINER TIGO IN THE LONG-TERM REHABILITATION PERIOD AFTER THE SPINAL CORD GUNSHOT WOUND INJURIES (CLINICAL CASE STUDY)
VYUŽITIE THERA-TRAINER TIGO V DLHODOBOM REHABILITAČNOM OBDOBÍ PO STRELNOM ZRANENÍ MIECHY (KLINICKÁ PRÍPADOVÁ ŠTÚDIA)

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ABSTRACT
Background: The need for rehabilitation of military personnel after the spinal cord gunshot wound injuries is a topical issue of our time.
Objectives: To find out the possibility of improving the functional state of the patient in the long-term rehabilitation period for spinal cord gunshot wound by implementing a specially developed program of physical therapy with the involvement of the THERA-Trainer Tigo therapeutic device.
Research sample and method: A 26-year-old patient with a fragmentary fracture of Th10-Th11 vertebral bodies (ASIA A) after a gunshot wound in the consolidation stage during a long-term rehabilitation period participated in the study. The level of spasticity was assessed using the MAS scale. To assess the daily activities and independence of the patient, a survey of daily activities was carried out according to the Barthel Index. Regulation of load intensity was conducted using Borg's 10-point scale. The passive range of motion was assessed by the goniometry method. Body weight and length, heart rate (HR), blood pressure (BP), and hand muscle strength were determined according to well-known methods.
Results: A positive effect of the use of the therapeutic program on the passive range of movements in the hip, knee, and ankle joints was observed. Analysis of the results of goniometry indicates a tendency to improve the range of passive movement in the joints of both limbs. A decrease in the spasticity of the hip and knee flexor muscles and the dorsiflexor muscles of the foot was revealed according to the MAS scale, which is manifested in a moderate increase in tone at the end of passive movements. Anthropometric and physiometric indicators did not change, hand dynamometry indicators increased at the end of the study.
Conclusions: The implementation of a specially developed program of physical therapy with the involvement of the THERA-Trainer Tigo therapeutic device improves the functional state of the patient in the long-term rehabilitation period after a gunshot wound to the spinal cord.

Key words: Spinal cord injury. Physical therapy program. Passive mechanotherapy. THERA-Trainer Tigo. Paraplegia.

ABSTRAKT
Východiská: Potreba rehabilitácie vojenského personálu po strelných poraneniach chrbtice a miechy je aktuálnym problémom našej doby.
Ciele: Zistiť možnosť zlepšenia funkčného stavu pacienta v dlhodobom rehabilitačnom období pri poranení miechy pomocou realizácie špeciálne vyvinutého programu fyzikálnej terapie so zapojením terapeutického prístroja THERA-Trainer Tigo.
Výskumná vzorka a metóda: Výskumu sa zúčastnil 26-ročný pacient s fragmentárnou zlomeninou tiel stavcov Th10-Th11 v dôsledku strelného poranenia v štádiu konsolidácie v dlhodobom rehabilitačnom období. Úroveň spasticity bola hodnotená pomocou stupnice MAS. Na posúdenie denných aktivít a samostatnosti pacienta bol vykonaný prieskum denných aktivít podľa Barthelovho indexu. Regulácia intenzity zaťaženia bola vykonaná pomocou Borgovej 10-bodovej stupnice. Pasívny rozsah pohybov bol hodnotený goniometrickou metódou. Telesná hmotnosť, srdcová frekvencia (SF), krvný tlak (KT), sila svalov zápästia boli stanovené podľa známych metód.
Výsledky: Bol preukázaný pozitívny efekt využitia terapeutického programu na pasívnu rozsah pohybov v bedrových, kolenných a členkových kĺboch. Analýza výsledkov goniometrie naznačuje tendenciu zlepšovania pasívnu rozsah pohybov v kĺboch oboch končatín. Podľa stupnice MAS bol zistený pokles spasticity bedrových a kolenných flexorov a dorziflexorových svalov nohy, čo sa prejavuje miernym zvýšením tonusu na konci pasívnych pohybov. Antropometrické a fyziometrické ukazovatele sa nezmenili, ukazovatele zápästnej dynamometrie sa na konci výskumu zvýšili.
Záver: Uplatnenie špeciálne vyvinutého programu fyzikálnej terapie s terapeutickým prístrojom THERA-Trainer Tigo zlepšuje funkčný stav pacienta v dlhodobom rehabilitačnom období po strelnom poranení miechy.

Kľúčové slová: Poranenie miechy. Program fyzioterapie. Pasívna mechanoterapia. THERA-Trainer Tigo. Paraplégia.

INTRODUCTION

The need for rehabilitation has been steadily increasing since the start of the full-scale war in Ukraine. As a result of the negative impact of the factors of combat activity, about 90 percent of servicemen need complex rehabilitation assistance. Gunshot wounds to the spine and spinal cord in the conditions of modern warfare are characterized by many injuries and their severity. The frequency of gunshot wounds to the spine and spinal cord ranges from 0.3 to 3.4 percent. The wounded soldiers with severe and extremely severe combat surgical trauma make up 63.5 percent (Khomenko et al., 2020). Given the explosive and mine-explosive nature of the damage, which is a feature of modern combat, a tendency to its increase is indicated (Dzyak et al., 2015; Rotar, 2018).

In the current difficult time for Ukraine, many of its military personnel receive spinal cord injuries of varying degrees of severity during hostilities. Of course, they are provided with qualified and specialized first aid in military hospitals and specialized medical facilities (Polishchuk et al., 2015). But the subsequent rehabilitation of servicemen with the aim of fully restoring their functions and the opportunity to fully work and live in society is also of great importance. Not only psychological rehabilitation is meant but also physical. The right approach is also important for military rehabilitation (Slynko et al., 2022). It means the choice of optimal methods and technical equipment for the most effective impact in each situation. This determines the speed of rehabilitation measures, the comfortable transfer of procedures, and the corresponding result.

Rehabilitation measures in the acute period of injury are carried out upon transfer from the Neurological resuscitation department to a multidisciplinary neurosurgical or trauma hospital. Rehabilitation in the early and middle periods of trauma should be in specialized rehabilitation centers for patients with dysfunctions of the central nervous system, peripheral nervous system, and musculoskeletal system. Rehabilitation in the late period includes dynamic observation with periodic courses of medical rehabilitation (Somuncu et al., 2022). Most often, rehabilitation continues throughout life. Demobilized and released servicemen can undergo comprehensive rehabilitation in regional hospitals of war veterans at their place of residence and in institutions subordinate to the Ministry of Health of Ukraine. Rehabilitation programs for the comprehensive recovery of military personnel after spinal cord injuries and injuries because of hostilities are aimed at the implementation of rehabilitation support for family members and the development of functional independence of military personnel. In the long-term rehabilitation period, effective rehabilitation is achieved by individual rehabilitation programs (Shestopal et al., 2022).

An important place in the rehabilitation of this category of patients is taken up by physical rehabilitation with the use of mechanotherapy. Mechanotherapy is an important component of physical rehabilitation due to its tonic and trophic (replacement and compensation of the formed defect through regeneration) effects on the human musculoskeletal system, the formation of functional compensations, the reverse favorable development of atrophic and degenerative processes, the normalization of the functional integrity and activity of the body (Mekki et al., 2018).

Rehabilitation after a spinal cord injury and restoration of lost functions are not in the range of simple tasks but are real and scientifically proven.

AIM

To find out the possibility of improving the functional state of a patient with a military spinal cord injury in the long-term rehabilitation period by implementing a specially developed physical therapy program with the involvement of the THERA-Trainer Tigo therapeutic device.

MATERIALS AND METHODS

To determine the feasibility of using the THERA-Trainer Tigo therapeutic device in the physical rehabilitation of military personnel, several studies were conducted. In particular: the survey of daily activities was carried out according to the Barthel Index (BI), which is designed to assess the household activity and independence of the patient; the modified Ashworth scale of muscle spasticity (MAS) by Bohannon and Smith, which made it possible to establish a change in resistance during passive movement of the patient. Spasticity was assessed on a five-point scale that subjectively assesses muscle tone. Before the assessment of spasticity on the MAS scale, training was conducted with the patient. The thigh and knee extensor muscles and the foot flexor muscles were evaluated in the initial position of lying on the back, in a neutral position. A physical therapist passively moved the patient's segments through a full range of motion at the speed of stretching and assessed the degree of tone (Akpinar et al., 2017). The range of passive movement was determined in degrees on the goniometer scale, as the difference between the maximum possible extension and flexion in the joint. The range of movements in the hip, knee, and ankle joints was studied (Yezhova et al., 2021). Regulation of load intensity was carried out using Borg's10-point scale (Kaniuka et al., 2015). Body weight and length, heart rate (HR), blood pressure (BP), and hand muscle strength were determined according to well-known methods.

The obtained experimental data were compared in terms of dynamics during the implementation of the physical therapy program using the methods of descriptive statistics.

RESULTS

The study involved a 26-year-old patient with a fragmentary fracture of the bodies of Th10-Th11 vertebrae of ASIA A in the stage of consolidation in the long-term rehabilitation period (4 years have passed since the bullet wound of the abdominal-vertebral-spinal cord). He visited the clinic intending to reduce his progressive disability and maintain and improve his general physical condition.

The BI made it possible to assess the patient's ability to function independently and to study his mobility in everyday activities. It was found that the patient does not need help in eating, taking a bath (namely, fully wiping the body with a sponge), hygienic procedures, dressing, moving from bed to a wheelchair and back, or driving a wheelchair. The total result corresponds to 75 points and indicates a minimal limitation in functioning in everyday life.

The assessment of the level of spasticity according to the MAS scale revealed a significant increase in the tone of the flexor muscles of the hip, knee, and dorsiflexion of the foot, which makes it difficult for the physiotherapist to perform passive movements, which corresponds to the 4th degree of spasticity (4 points). Measurements of the passive range of movements with a goniometer in the hip, knee, and ankle joints indicate its limitation in both limbs (table 1). Anthropometric indicators indicate that the patient had a moderately pronounced deficit in body weight (47 kg at a height of 169 cm), cardiovascular system indicators were close to normal: heart rate 82 bpm, blood pressure 120/80 mmHg, normal indicators of wrist dynamometry – 58 kg. During the clarification of complaints, the patient reported that he sometimes feels moderate pain, which can limit self-care and sometimes interferes with sleep, stiffness in the joints, especially during the morning hours, pain and stiffness in the joints of the spine, increased spasticity when trying to move from the wheelchair, a decrease in skin turgor and a decrease in its temperature in the lower extremities, deterioration of the psycho-emotional state and irritability.

The goals of physical rehabilitation in the long-term rehabilitation period of a patient with paraplegia were to reduce progressive disability, regulate muscle tone, improve emotional state, improve stabilization, strengthen the muscle corset, and maintain weight. Achieving the goal was ensured by individually selected therapeutic exercises and properly planned physical activity.

The duration of the program was calculated for one month, 5 times a week (20 sessions, the duration of one session is 60 minutes). The program consisted of moderate strength and aerobic physical exercises, passive mechanotherapy with the involvement of the THERA-Trainer Tigo therapeutic device, and relaxation and stretching exercises. THERA-Trainer Tigo therapeutic device received as part of the Erasmus+ project "Innovative rehabilitation education –implementation of new master's programs in Ukraine" REHAB. The structure of the program is described in table 2. Dosing the volume and intensity of physical activity was carried out by the number of repetitions/sets, changing the pace of performance, methods of performing physical exercises, and rational alternation of time of exercise and rest.

The structure of the session included: at the beginning therapeutic exercises for the trunk and upper limbs, passive exercises for the lower limbs, in the main part passive mechanotherapy with the involvement of the therapeutic apparatus THERA-Trainer Tigo, in the final part breathing exercises for relaxation. During the performance of passive exercises, ideomotor training was used, during which the patient was recommended to mentally "speak" the corresponding actions.

During the first week, therapeutic exercises were performed every other day: 1) on the back/abdominal muscles and 2) on the muscles of the shoulder girdle and upper limbs, between which there was a rest from breathing exercises. The patient performed 4 – 6 exercises.

For the muscles of the trunk, mainly strength-directing exercises were used, such as holding and

Table 1 Passive Range of Movements in Lower Limb Joints Before Rehabilitation Intervention

Joint	Hip			Knee			Ankle		
	Norm	Left	Right	Norm	Left	Right	Norm	Left	Right
Range of Movements (in degrees)	120	53	40	135	43	57	70	32	41

Table 2 Contents of the physical therapy program involving the THERA-Trainer Tigo therapeutic device for spinal cord gunshot wound

The structure of the physical therapy program		Load characteristics			
A week of sessions		First	Second	Third	Fourth
Therapeutic exercises/ breathing exercises	back/abdominal muscles	Day: 1, 3, 5 Exercises: 4-6 Repetition: 6-8 Sets: 1	Day: 2, 4 Exercises: 4-6 Repetition: 6-10 Sets:1-2	Day: 1, 3, 5 Exercises: 4-6 Repetition: 6-10 Sets:2-3	Day: 2, 4 Exercises: 4-6 Repetition: 6-10 Sets:3
	muscles of the shoulder girdle and upper limbs	Day: 2, 4 Exercises: 4-6 Repetition: 6-8 Sets:1	Day: 1, 3, 5 Exercises: 4-6 Repetition: 6-10 Sets:1-2	Day: 2, 4 Exercises: 4-6 Repetition: 6-10 Sets:2-3	Day: 1, 3, 5 Exercises: 4-6 Repetition: 6-10 Sets:3
	means: physiotherapeutic and sports equipment	Without equipment, dumbbells	Without equipment, dumbbells, tape expander	Without equipment, dumbbells, expanders, balls	Without equipment, dumbbells, expanders, balls, medicine balls
	passive exercises for the lower limbs	Day: 1-5 Repetition: 4-6	Day: 1-5 Repetition: 4-6	Day: 1-5 Repetition: 4-6	Day: 1-5 Repetition: 4-6
Passive mechanotherapy with the involvement of THERA-Trainer Tigo therapeutic device/relaxation exercises and stretching exercises		Days: 1-5 Duration: 15 min Speed: 10-16 rpm Direction: forward	Day: 1-5 Duration: 15-20 min Speed: 16-20 rpm Direction: back and forth	Day: 1-5 Duration: 20-30 min Speed: 20-30 rpm Direction: back and forth	Day: 1-5 Duration: 30 min Speed: 25-35 rpm Direction: back and forth

lifting the upper part of the trunk in the position of lying on the back and the side. During relaxation – diaphragmatic breathing exercises.

For the muscles of the upper limbs, mainly therapeutic exercises were used, which significantly improved the indicators of muscle strength. They also consisted of 4 – 6 exercises. These were exercises without an object and/or with dumbbells weighing 1 kg in a lying position: bending-extension, abduction-adduction, and rotational movements. Diaphragmatic breathing was performed between exercises. For the lower limbs, passive exercises were used in all groups of joints.

Passive mechanotherapy with the involvement of the THERA-Trainer Tigo therapeutic device was performed for 15 minutes at a speed of 10 – 16 rpm in the forward direction. After mechanotherapy, the patient did breathe exercises, relaxation, and stretching exercises. Such exercises help reduce spasticity and restore the indicators of the cardiorespiratory system to the initial level.

In subsequent weeks, the number of sets of therapeutic exercises increased according to the patient's capabilities. The duration of the exercises gradually increased. Exercises with a larger amount of therapeutic and sports equipment were used: expanders of different stiffness, medicine balls, and dumbbells weighing 2 kg or more. The duration and speed of passive mechanotherapy on the THERA-Trainer Tigo device were increased. Passive movement in two directions was used: forward and backward. It should be noted that it was more difficult for the patient to perform the passive forward movement, therefore THERA-Trainer Tigo was programmed with fewer forward than backward rotations, due to greater spasticity of the flexor muscles. The following control methods were used:

- express control - heart rate and blood pressure control, well-being survey at each session;
- current control - the first, second, and third decade of the month - measurement of the passive range of movements at the beginning and end of the session;
- phased control - at the beginning and end of the program, anamnesis collection, BI index, MAS scale, range of movements in the hip, knee, and ankle joints, anthropometric indicators, and physiometric indicators.

A feature of the physical therapy program for a patient with paraplegia was its gradualness, regulated by feedback. The increase in load was carried out under the condition of a close to normotonic response to physical exertion, which was characterized by an increase in the heart rate by 40 –50 percent of resting values, an increase in systolic blood pressure by 10 – 20 percent, constant diastolic blood pressure or its decrease by 5 –10 percent and

recovery of these indicators after exercise within 5 minutes.

The therapeutic program had a positive effect on the passive range of motion in the hip, knee, and ankle joints (Fig. 1 – 3). The results of goniometry indicate a tendency to improve the range of passive movement in the joints of both limbs. The positive feedback about the result of the rehabilitation of both the physical therapist and the patient should be noted. Thus, at the first session, the physical therapist had difficulty placing the lower limbs on the pedals of the exercise machine due to significant muscle spasticity, the movement of the exercise machine stopped due to spasms 2 – 3 times during 15 minutes of work. During the following classes, the range of passive movements gradually increased, and the work of the exercise machine was not blocked by a spasm. Blood flow to the limbs increased, and spasticity decreased. The patient could already place the lower limbs on the THERA-Trainer Tigo platform without the participation of a physical therapist. The positive subjective feedback of the patient regarding the sense of body during the day should be highlighted: a decrease in spasticity was noted in the limbs, which improved daily activities.

The obtained data show that from the beginning of the lesson to its end, the passive range of movements increased unevenly, progress was for hip joints from 3º to 28º (see Fig. 1), for knee joints from 14º to 25º (Fig. 2), for ankle joints from 3º to 11º (Fig. 3). The greatest increase in range of movements was in the knee joints, which is related to the training effect of THERA-Trainer Tigo.

A survey of a patient with paraplegia one month after the training shows that pain and stiffness in the joints have slightly decreased, both during the day and during the morning hours (awakening), sleep and the level of self-care have improved, pain and stiffness in the spine joints have decreased, and also spasticity when trying to move from the wheelchair, an increase in skin turgor in the lower limbs was noted, the psycho-emotional state improved and irritability decreased. As of BI, the result remained at 75 points. The level of spasticity according to the MAS scale revealed a decrease in the spasticity of the hip and knee flexor muscles and the dorsiflexor muscles of the foot from 4 to 3 points, which is manifested in a moderate increase in tone at the end of passive movements. Anthropometric and physiometric indicators did not change, indicators of hand dynamometry increased by 6.9 percent (62 kg).

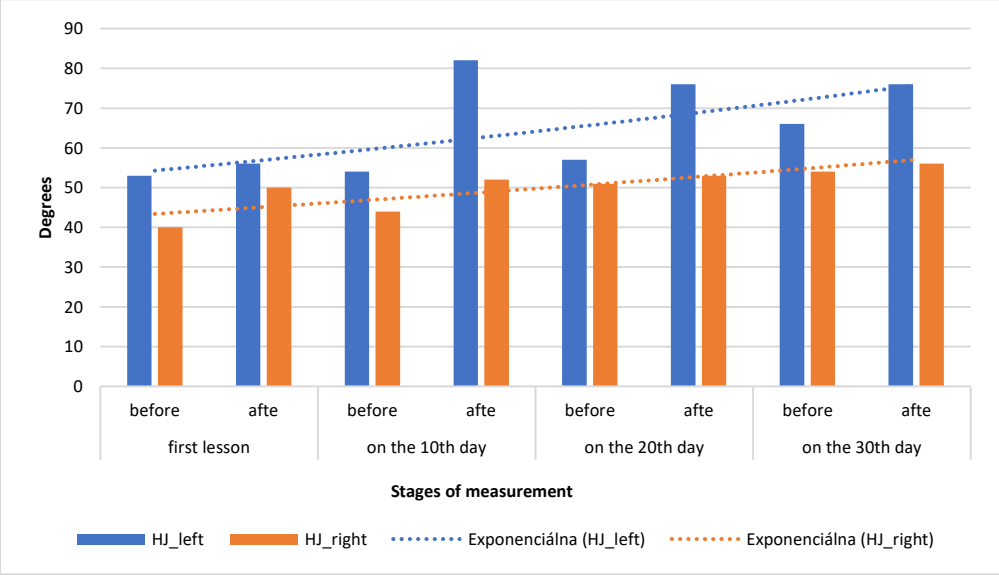

Figure 1 Change in the passive range of movements in the hip joints under the influence of the physical therapy program with the involvement of the THERA-Trainer Tigo therapeutic device (in degrees)
Legend: HJ_left - the left hip joint; HJ_right - the right hip joint.

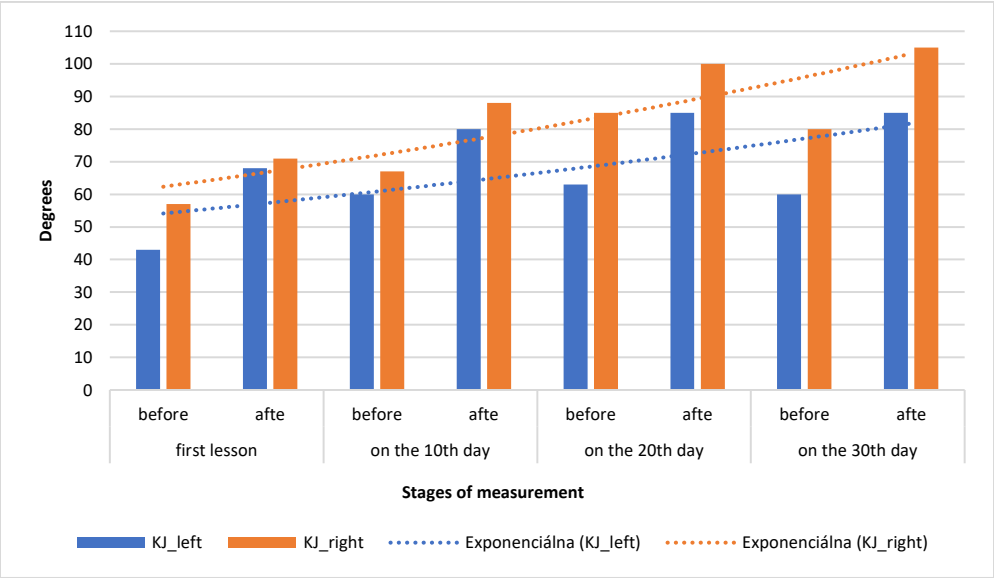

Figure 2 Changes in the passive range of movements in the knee joints under the influence of the physical therapy program involving the THERA-Trainer Tigo therapeutic device (in degrees)
Legend: KJ_left - the left knee joint; KJ_right - the right knee joint.

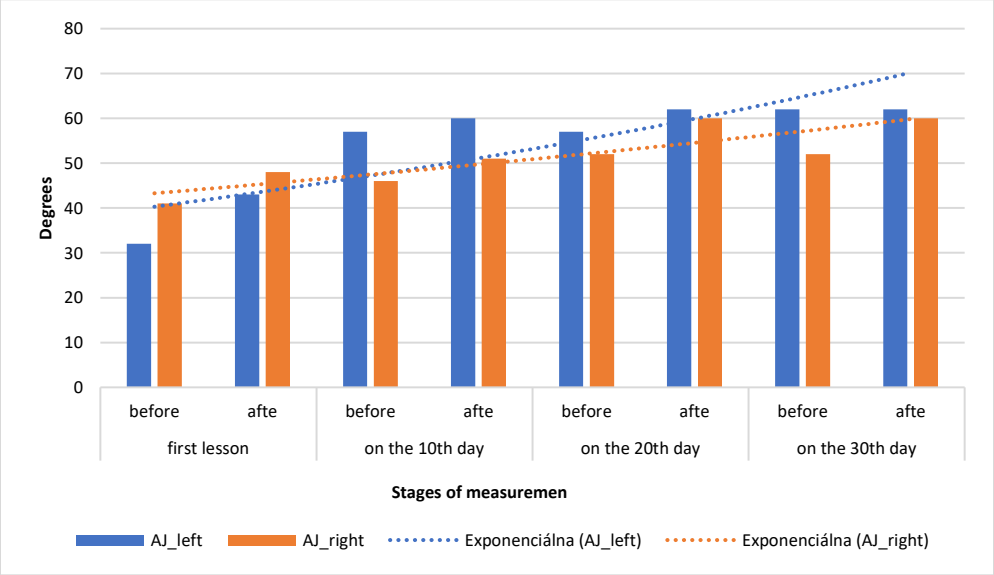

Figure 3 Changes in the passive range of movements in the ankle joints under the influence of the physical therapy program with the involvement of the THERA-Trainer Tigo therapeutic device (in degrees)
Legend: AJ_left - the left ankle joint; AJ_right - the right ankle joint.

DISCUSSION

Discussing the principles and means of physical therapy for paraplegia, it should be emphasized that researchers use various means of physical therapy and their combination. Rehabilitation strategies are quite diverse, including therapeutic exercises for strength, range of motion and stretching, functional and epidural electrical stimulation (FES, EES) of the spinal cord, occupational therapy, acupuncture, and exoskeleton (Rodríguez-Mendoza et al., 2020; Peev et al., 2020; Eisdorfer et al., 2020), online technologies in the home environment, robotic mechanotherapy (Morone et al., 2021; Mekki et al., 2018). THERA-Trainer Tigo takes an active place

among the means of recovery for patients after a stroke, with multiple sclerosis, Parkinson's disease, or craniocerebral injuries, and is successfully used after a joint replacement or other orthopedic diseases (Thera-trainer, 2020*).*

Damage to the spinal column is manifested by a difficult symptom complex of motor, sensory, and trophic disorders. The degree and nature of violations depend on the location of the lesion (Rotar, 2018). Paraplegia occurs when motor and/or sensory function is impaired or lost in the thoracic, lumbar, or sacral segments of the spinal cord secondary to damage to nerve elements in the spinal canal. In paraplegia, the functioning of the arms is preserved, but the trunk, legs, and pelvic organs are affected depending on the level of injury. Considering the patient's state of health and the course of restorative processes in the body, rehabilitation care for such persons consists of three periods: acute, post-acute, and long-term rehabilitation (Somuncu et al., 2022).

The obtained research results confirm the positive impact of the physical therapy program involving the THERA-Trainer Tigo therapeutic device on the functional state of the patient in the long-term rehabilitation period for spinal cord injury and the reduction of progressive disability.

CONCLUSIONS

After using the physical therapy program involving the THERA-Trainer Tigo therapeutic device, the patient with paraplegia improved the indicators of passive range of motion in the hip, knee, and ankle joints, decreased muscle tone, which makes it difficult to perform passive movements, and strengthened the muscles of the upper limbs and trunk while improving the psycho-emotional state.

Therefore, the implementation of a specially developed program of physical therapy with the involvement of the THERA-Trainer Tigo therapeutic device improves the functional state of the patient in the long-term rehabilitation period after a spinal cord injury and indicates the applicability of THERA-Trainer Tigo.

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