COMPLEX KINESITHERAPY PROGRAM FOR POLYFRAGMENT FRACTURE OF THE HUMERUS AND PERIPHERAL NERVE INJURY

Krasimira Zlatkova[1], Yuliyan Zlatkov[1], Miglena Simonska[2], Radostina Kostova[2]

[1]*Department of Kinesitherapy, South-West University "Neofit Rilski", Blagoevgrad*
[2]*Department of Logopedics, South-West University "Neofit Rilski", Blagoevgrad*

KEYWORDS

humerus fracture, neurological injury, kinesitherapy program, neurorehabilitation, virtual reality

ABSTRACT:

Introduction: Humerus fractures are common injuries of the musculoskeletal system. In most cases, no complications are registered and recovery is faster. In some cases, complications such as luxation, vascular and neurological damage are observed. The treatment of these cases requires the participation of a multidisciplinary team and the application of a comprehensive physiotherapy program, including a variety of specialized tools.

Objectives: The aim is to present a comprehensive kinesitherapy program for humerus fracture and peripheral nerve damage and to monitor the effect of its application.

Methods: We present a case of a 56-year-old man with a polyfragmentary fracture of the humerus and damage to the n. radialis and n. ulnaris. We assessed the state of research before and after the end of the follow-up period with goniometry, centimetry, manual muscle testing, grips, 9 Hole Peg Test and the tests included in the X-cogni device. The complex program includes pendulum exercises, exercises to improve the range of motion, manual lymph drainage and training on the X-cogni neurocognitive rehabilitation device.

Results: We report an improvement in the results of the measured indicators at the end of the one-month follow-up period. The range of motion improves, the swelling decreases, and the dexterity in the injured limb improves. The patient begins to use his injured hand in performing some activities of daily living. However, the subject is not fully recovered, which necessitates the continuation of kinesitherapy with other means in order to achieve a full recovery.

Conclusions: The complex application of kinesitherapy procedures in combination with modern therapeutic methods such as the impact of virtual reality, lead to better results. The variety of testing and training tasks and the quick feedback make them preferred for use by therapists and patients.

1. Introduction

Fractures of the proximal humerus are the seventh most common musculoskeletal fracture and the third most common upper extremity fracture. Their incidence is 4-10% of all fractures. There is an increased risk of these fractures in the elderly female population (Iglesias-Rodríguez et al., 2021).

Fractures of the humeral shaft occur as a result of high-energy or low-energy trauma. High-energy traumas include motor vehicle accidents, sports injuries, and work-related accidents. Low-energy traumas include falls and reaching for a support with an outstretched arm. The incidence of this type of fracture varies from 1 to 5% of all fractures. The population between the third and seventh decades of life is prone to high-energy trauma. Low-energy traumas are the cause of fractures of the humeral shaft in the older population (Bounds et al., 2024).

Vascular injuries are a common problem in humeral fractures combined with dislocation. Complications may include hematoma, hypotension, low hemoglobin, nerve trunk/brachial plexus injury. These vascular injuries occur in 90% of cases in patients over 50 years of age. Pandey et al. (2023) suggest that this is due to the reduced elasticity of the blood vessel walls that develops with age and the accumulation of atherosclerotic plaques (Pandey et al., 2023). In diaphyseal fractures of the humerus, it is necessary to assess the patency of the radial and ulnar nerves, since high-velocity fractures of the humeral shaft also cause injuries to the brachial artery (Gallusser et al., 2021). Damage to the n. ulnaris affects the flexor muscle group of the wrist and fingers, while damage to the n. radialis affects the grasping function of the hand (Popova et al., 2017).

In fractures of the middle and lower third of the humeral shaft, there is a risk of damage to the radial nerve of 1% to 5%. The damage may be associated with sensory changes or motor changes, affecting the extensors of the wrist and fingers (Popov, Dimitrova, 2007).

Asadzadeh et al. (2021) share that rehabilitation for many diseases and injuries is a long and difficult process. The use of new methods based on virtual reality improves the duration and intensity of exercise application. The positive impact of virtual reality consists of managing pain, increasing range of motion and muscle strength, improving functional ability and motivation (Asadzadeh et al., 2021).

Parashkevova and Deleva (2009) share that early application of kinesitherapy in fractures of the proximal end of the humerus promotes faster recovery of the affected limb and return to daily activities (Parashkevova, Deleva, 2009).

2. Objectives

The purpose of the publication is to present a complex kinesitherapy program, including specialized kinesitherapy and the application of exercises on a multisensory device based on virtual reality and biofeedback in a patient with a polyfragmentary fracture of the humerus and peripheral nerve damage.

3. Methods

Case report

In this report, we review the case of a 56-year-old man. The patient reported that he had fallen and was subsequently stepped on by a large hoofed animal in the area of the humerus and thigh. He was diagnosed with fracture colli humeri and fracture humeri dextra (pollyfragments). A metal osteosynthesis was performed with 3 pcs. cerclages and a long titanium nail.

The patient was referred for kinesitherapy 40 days after the complex surgery. For one week, we apply exercises to improve the range of motion in the shoulder, elbow and wrist joints.

Due to the position of the wrist and the lack of active movements in the direction of wrist and finger extension, abduction and adduction of the fingers, flexion with ulnar abduction, we referred the patient to a neurologist. After an EMG, it was found that there was no muscle response to stimulation of the n. radialis et n. ulnaris with suspicion of severe peripheral trunk damage to the n. radialis et n. ulnaris.

Methods of examination

1. Goniometry of the shoulder, elbow and wrist joints. Due to humerus fractures, surgery and immobilization, there is a limited range of motion in the shoulder, elbow and wrist joints. We examined the range of motion with a goniometer. We measured flexion, extension, abduction, internal and external rotations in the shoulder joint; flexion and extension in the elbow joint and wrist joint.

2. Centimetry. We examined the circumferences of the upper limb - arm, forearm, fist and wrist in view of the presence of edema, prolonged immobilization and neurological damage.

3. Manual dynamometry - Due to the hypotrophy of the muscles and the affected nerves of the right upper limb, we assessed the grip strength before and after the applied therapeutic program. The grip of both upper limbs is assessed.

4. Manual muscle testing of the wrist and fingers. The presence of damage to the n. radialis and n. ulnaris causes difficulty in the trophicity of the muscles innervated by them. This leads to weakness and difficulty in performing movements.

5. 9-Hole Peg Test. Assesses dexterity. It was introduced in 1971 by Kellor et al. There are two versions of the apparatus - wooden and plastic board (Feys et al., 2017). The test is easy to administer and is used to assess fine motor skills in various nosologies, including neurological diseases. This test requires the subject to place 9 pegs in 9 holes on the board as quickly as possible (Earhart et al., 2011).

6. Testing the X-cogni device:

- ✓ GoNoGo test - assesses the time for impulse reaction. The goal is to perform an abduction-adduction movement as quickly as possible after a signal;
- ✓ Movement precision test. Drawing a heart shape according to a pre-set pattern;
- ✓ Movement time test - assesses the speed of reaching the target. Using an attachment (cup), the subject reaches the glowing circle, which changes its position, as quickly as possible.

Methodology of kinesitherapy

The monitored period is one month. During this time, 13 procedures of range of motion exercises (three times a week) and 12 procedures of the X-cogni device, manual lymph drainage and exercises for the damaged nerves of the hand were performed.

In view of the operation performed on the patient, the immobilization and the subsequent complications, we applied the following rehabilitation protocol:

1. Codman pendulum exercises. These are the main exercises that begin the rehabilitation program for fractures in the shoulder joint. They include movements in the frontal and sagittal planes and circumduction. They are performed with a flexed body and a relaxed, freely hanging arm. The effect of the exercises is explained by the fact that gravity facilitates swing movements through the moment of inertia. In this way, relaxation of the muscles is achieved, which is achieved through minimal traction of the upper limb from its own weight. The amplitude of movement increases with the inclination of the body (Deleva, Popov, 2014).

2. Exercises to improve the range of motion in the shoulder joint, elbow joint and wrist joint. The exercises are performed from the supine position without pain or with minimal pain. We apply continuous passive movements, stretching and active-assisted movements.

3. Manual lymph drainage according to the Vodder method. Due to the significant edema observed throughout the upper right limb, we apply manual lymph drainage.

4. Exercises to restore the functioning of the damaged nerves of the upper limb. At the beginning, we applied passive exercises and those with the elimination of gravity (starting position 2 according to manual muscle testing). We also train the grips.

5. Training on the X-cogni device (Technomex). This is a multisensory device that is used for upper limb therapy and cognitive skills training. The device has tests for assessing motor and cognitive functions. Numerous games based on virtual reality and instant feedback support the patient's motivation to achieve better results. In view of the limitations observed in the monitored patient, we applied the following training on the device: ambulance, hippo, trajectory tracking in a circle and robots. The duration of the training is 12 minutes. The exercises are applied to both upper limbs, with each game being applied for 90 s. Based on the patient's condition, we selected games that include trajectory tracking or movement in order to improve the range of motion and activate muscle contraction in view of prolonged immobilization and peripheral nerve damage.

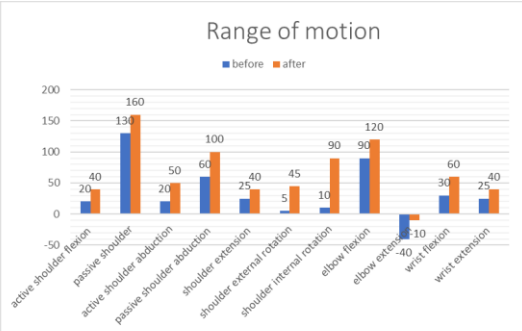
- ✓ Ambulance - This game involves moving an ambulance between cars, and the goal is to avoid a collision with cars and to move the ambulance as quickly as possible. The goal of this game is to improve the volume of movement in the shoulder joint in the frontal plane and the elbow joint in the sagittal plane; to improve muscle function in the upper limb in order to improve trophism and reduce edema. The first three times we applied 50% speed of movement. Due to confidence in the patient's reaction, we then increased the speed of the ruler to 75%. The game was applied for 90 s per limb.
- ✓ Hippo. In this game, the goal is to protect the hipp from rain and lightning. Bright colors and pleasant sounds distract the thought of pain and direct attention to the game. The game was played with 1 level of difficulty (out of 3 levels). Through this activity, we aim to improve the range of motion and muscle strength, which are seriously affected in the right upper limb due to surgery and immobilization.
- ✓ Tracing the trajectory in a circle. This game requires an attachment (cup). We included it on the fifth day of the complex program, since before that it was not possible to grasp the

attachment and reach the extreme points above and to the left. Through this game, the range of motion in the upper limb, the spherical grip and the precision of movement are trained.

- ✓ Robots. The goal of the game is to move the small robot away from the large ones so that they do not hit it. The device is placed in the lowest horizontal position. In this way, the patient tilts and moves the robot, using movements similar to pendulum ones. The tilt of the body and its own weight relaxes the limb, and this helps to achieve a greater range of motion. Controlled circumduction and spherical (swing) movements are applied.

4. Results

We used a standard goniometer to measure the range of motion. The range of motion in the joints of the upper limb is presented in Figure 1.



Graph 1. Range of motion of the upper limb before and after application of kinesitherapy

The range of motion improves after the applied complex rehabilitation protocol. As can be seen from graph 1, the internal rotation in the shoulder joint reaches its full range of motion.

The assessment of the manual dynamometry of the upper limb shows improvement in both the left and the right (damaged limb). The grip strength of the unaffected limb (left) before the kinesitherapy shows values of 30.2 kg., and after it - 31.2 kg. The values of the manual dynamometry of the affected upper limb are 5.3 kg at the beginning and 9.3 kg at the end.

Long immobilization, peripheral nerve damage and significant edema necessitated measuring the circumferences of the upper limb at different levels. At the beginning of the study, the values of the circumference of the arm were 1 cm different (the right arm has a larger circumference). At the end of the study, the right arm remained the same circumference, while the left arm increased its circumference by 1.5 cm. The increase in the circumference of the left arm is due to performing more activities with it at the expense of the right arm. Maintaining the same circumference of the right arm is interpreted as the edema having decreased, but the hypotrophy of the muscles in this area has deepened. The measured values of the circumference of the elbow joint before the applied kinesitherapy show a difference of 1 cm in favor of the affected arm, which is explained by the presence of edema. At the end of the study, we report a decrease in the swelling in the right elbow joint, with the difference in circumferences between the two joints being 0.5 cm in favor of the right. The measured value of the forearm at the beginning of the study shows that the left forearm is 1 cm larger than the right. At the end of the study, the difference between the two arms deepens to 3 cm. Due to the neurological damage and limited movements, the drainage of the damaged right limb is difficult. Despite the application of manual lymph drainage, its effect did not last, due to the antigravity position of the hand, the presence of vascular damage (colder little finger) and the lack of active contraction of the forearm muscles. If there was no edema of the right upper limb, we assume that the difference in circumferences would be greater. When measuring the wrist circumference, it was observed that it was 1 cm larger on the left hand at the beginning of the study. At the end of the study, the values were similar (difference of 0.2 cm). This confirms the significance of the applied manual lymph drainage.

The damage to the n. radialis and n. ulnaris necessitated the application of manual muscle testing in order to monitor the condition of the muscles innervated by these nerves. The results of the performed manual muscle testing are presented in Table 1.

Table 1. Results of the performed manual muscle testing for the muscles innervated by the n. radialis and n. ulnaris.

n. radialis		
Muscle	Degree of MMT	
	At the beginning	At the end
m. extensor carpi ulnaris	2-	2+
mm. extensor carpi radialis longus et brevis	2-	5-
m. extensor digitorum manus m. extensor indicis proprius m. extensor digiti minimi	1	4-
m. abductor pollicis longus	2-	3+
m. extensor pollicis brevis	2-	4-
m. extensor pollicis longus	2	4-
n. ulnaris		
m. flexor carpi ulnaris	3	4+
Mm. lumbricales m. interossei dorsalis mm. interossei palmares	4	5
Mm. interossei palmares	1	3-
mm. interossei dorsalis m. abductor digiti minimi	1	4
m. adductor pollicis	3	4
m. opponeus digiti minimi	1	2
m. flexor pollicis brevis	4	5

From the presented data of the conducted manual muscle testing, we can summarize that the condition of the muscles innervated by n. radialis and n. ulnaris is improving. Despite the better values at the end of the study period, we cannot report on functional recovery of the right upper limb. Values of manual muscle tes with grades 2 and 3 prove the weakness of the muscles and the need for additional therapeutic procedures.

When examining the grips before the kinesitherapy, we found difficulties in the spherical grip (the V finger does not participate in the grip), the tip grip of the V finger, impossible three-point and fist grip. After the kinesitherapy, we report improvement. The spherical and three-point grip are performed without difficulties. The fist grip is performed without the full participation of the V finger.

We assessed the precision in the functions of the fingers of the upper limb with the 9 Hole Peg Test. Due to the severely restricted movements and weakness of the muscles of the right upper limb, we performed the test once for each hand, and also without removing the pegs from the holes. The values of the unaffected hand before the physiotherapy were 16:19 s., and after it - 17:01. The normal average values for this age of the patient for the left hand are 21 s (Mathiowetz et al., 1985). Taking into account the fact that the patient performed the test only by threading the pegs, and that this takes more time, we believe that the examined person has normal precision indicators according to the test. The affected hand has severe difficulty in performing the test. At the beginning of the study, the values are 1:38:50 min, and at the end of the study - 44:63 s. It is also visible from the results that fine movements are severely impaired. Despite the improvement, the precision of the right hand is severely limited.

Testing with the X-cogni device

After the GoNoGo test with the X-cogni device, we also report an improvement in the healthy limb after the end of the study. At the beginning, the impulse reaction time was 1256 ms, and at the end it was 966 ms. Due to the lack of movement and the impossibility of establishing a contact surface between the right upper limb and the device, there are no results at the beginning of the study period. The final results report an impulse reaction time of Go of 1086 ms.

The results of the left upper limb time testing show a slight delay in the direction up to the left 1100 ms (at the beginning) and 1124 ms (at the end). The movement up to the right improves from 1316 ms (at the beginning) to 1109 ms (at the end). The time to perform the movement down to the right at the beginning is 2450 ms, and at the end - 1200 ms. In the movement down to the left, the speed reached was 3833 (at the beginning) and 2216 (at the end). Due to the impossibility of gripping the attachment (cup), the first measurements of the right upper limb were made on the third day after the start of intensive therapy. The time for movement up to the left at the beginning was 1474 ms, and at the end - 1407 ms. Improvement was also reported in the movement up to the right - 1488 ms (at the beginning) and 1432 (at the end). We report a deterioration in the result of this test in the movement down to the left from 1433 to 2650 ms. In the time for movement down to the right, we report a minimal improvement - at the beginning of testing it was 1502 ms, and at the end of the study - 1491 ms.

The precision testing using the X-cogni device reports improved values (%) at the end of the study period. The average accuracy rate with the left hand at the beginning is 82%, varying from 68% to 100% depending on the points reached. At the end of the study, the values range from 93% to 100%, with the average value being 98%. When examining the accuracy of the right hand, we report an improvement at the end of the follow-up period, but we do not report 100% accuracy at any of the points reached. At the beginning, the lowest overlap rate is 43%, and the highest is 90%. The average accuracy rate is 75%. At the end of the reporting period, the average rate improves to 92%, varying in the different overlap points from 83% to 99%.

The implementation of the training with the X-cogni device allows for recording in the database and reporting the achieved results. This allows for a real assessment of the applied kinesitherapy. During the “Ambulance” training, we applied a speed of 50% for the first two days, but since the achieved functionality of the movements and the achieved points are preserved and there is no progress, we had to increase the speed to 75%. The functionality of movement before the training in the left hand is 97%, and in the right -100%. This is normal considering that the right hand is dominant. At the end of the study, the functionality of movement is 100% in both hands. The achieved points from the training for the left hand are 78 at the beginning and 86 at the end of the study. An improvement is also reported in the right hand. At the beginning of the monitored period, the points reached were 76, and at the end - 88.

We started applying precision training on the fifth day of the study, due to a limited range of motion in the right shoulder joint, i.e. 8 precision training sessions were performed. During this time, we achieved an improvement in the precision of movement in the left hand from 94% to 97%, and the total number of points improved from 84 to 87 points. During the training for the right (affected) hand, the functionality improved from 97% to 98%, and the points reached - from 87 to 88 points.

The "Hippo" training did not show a change in precision (98%) in both hands during the first and last training. The points reached on the left hand are maintained throughout all training sessions - 346. For the right hand, during the first procedure, the maximum number of points is 340, and during the last "Hippo" training session - 346, i.e. the points are equalized with the unaffected hand.

The “Robot” training in both hands shows the same values of the points reached at the beginning and at the end of the study period 368 (at the beginning) and 449 (at the end). The functionality of the movement in this game in the left hand improves at the end (97%). In the first procedure it was 85%. The functionality of the affected dominant hand is 87% (in the first procedure), and in the last 96% (in the last).

5. Discussion

The long period of immobilization and the complications that occurred after it hinder the patient's recovery. The inclusion of complex means of kinesitherapy (manual lymph drainage, exercises to improve the range of motion and muscle strength, as well as those on a multisensory device) improves the subject's condition.

The most obvious are the improvements in the range of motion. According to Ong et al. (2024), the full range of motion is not necessary for performing activities of daily living. For older patients with fractures in the proximal end of the humerus, it is more important to lead an independent life than to restore the full range of motion in the shoulder joint. According to the authors, with advancing age, the range of motion in the shoulder joint decreases without affecting the functional ability of the affected and without any apparent reason (Ong et al., 2024). Our patient is of working age, so we set ourselves the task of restoring the full range of motion in the shoulder and elbow joints. The affected upper limb is dominant (right). If the ability to perform active movements is not restored, this will affect the emotional state of the patient, as well as his social and economic life.

Despite the improvement in grip strength, measured by manual dynamometry, the right upper limb has significantly lower values than the healthy left upper limb. The complexity of the surgical intervention and the damage to the n. radialis and n. ulnaris slow down the kinesitherapy course and recovery of the affected limb. The impaired trophic function of the forearm muscles responsible for grasping is dictated by damage to the nerves of the upper limb.

The application of manual lymph drainage led to a reduction in edema in the right upper limb. Neurological damage disrupts the trophic function of the forearm muscles. As a result, a smaller circumference was measured on the right forearm compared to the left.

Better values from the MMT performed at the end of the study cannot be interpreted as meaning that the patient can perform all activities of daily living. After improving the range of motion, we can concentrate on strengthening the muscles.

We attribute the improvement of dexterity, measured with the 9-hole peg test, mostly to the exercises we apply on the multisensory device X-cogni. Thanks to the voiced and well-animated games and the feedback that the patient receives, better motivation is achieved to achieve better results on his part.

Despite the good results that we achieve through the application of the complex physiotherapy program in the studied patient, we cannot report that he has recovered after the one-month course of treatment. Getting used to the selected neurorehabilitation training and some of the exercises that we apply required changing the means that we apply and the training of the multisensory apparatus. The data will be published at a later stage, since the study is not yet completed.

Despite the good results that we achieve through the application of the complex kinesitherapy program in the studied patient, we cannot report that he has recovered after the one-month course of treatment. Getting used to the selected neurorehabilitation training and some of the exercises that we apply required changing the means that we apply and the training of the multisensory device. The data will be published at a later stage, since the study is not yet completed.

The complexity of the operation and the complications caused by it, the late inclusion of kinesitherapy and significant edema slow down the recovery process. The presented data have proven the positive impact of the state of research. The complex application of kinesitherapy procedures in combination with modern therapeutic methods such as the impact of virtual reality, lead to better results. In recent years, an increase in the application of virtual reality and biofeedback in kinesitherapy procedures has been reported. The variety of testing and training tasks and the quick feedback make them preferred for use by therapists and patients. Engagement in the implementation of the therapy diverts the patient's attention from the pain and motivates him to achieve better results.

Acknowledgements

This publication was made possible thanks to project RP-A2/24 "Cognitive neurorehabilitation in persons with neurological damage" with Leader: Assoc. prof. Miglena Simonska, PhD.

Refrences

1. Asadzadeh A, Samad-Soltani T, Salahzadeh Z, Rezaei-Hachesu P. Effectiveness of virtual reality-based exercise therapy in rehabilitation: A scoping review. Informatics in Medicine Unlocked, 2021, 100562.
2. Bounds EJ, Frane N, Jajou L, et al. Humeral Shaft Fractures. [Updated 2023 Dec 13]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448074/
3. Deleva R, Popov, N. Systematic review of kinesitherapy after fractures of the proximal humerus, Proceedings of the Union of Scientists of Ruse, Medicine and Ecology, 4; 2014:115-121 (in Bulgarian)
4. Earhart GM, Cavanaugh JT, Ellis T, Ford MP, Foreman KB, Dibble L. The 9-hole PEG test of upper extremity function: average values, test-retest reliability, and factors contributing to performance in people with Parkinson disease. J Neurol Phys Ther. 2011 Dec;35(4):157-63. doi: 10.1097/NPT.0b013e318235da08. PMID: 22020457.
5. Feys P, Lamers I, Francis G, Benedict R, Phillips G, LaRocca N, Hudson LD, Rudick R; Multiple Sclerosis Outcome Assessments Consortium. The Nine-Hole Peg Test as a manual dexterity performance measure for multiple sclerosis. Mult Scler. 2017 Apr;23(5):711-720. doi: 10.1177/1352458517690824. Epub 2017 Feb 16. PMID: 28206826; PMCID: PMC5405844.
6. Gallusser N, Barimani B, Vauclair F. Humeral shaft fractures. EFORT Open Rev. 2021 Jan 4;6(1):24-34. doi: 10.1302/2058-5241.6.200033. PMID: 33532084; PMCID: PMC7845564.
7. Iglesias-Rodríguez, S., Domínguez-Prado, D.M., García-Reza, A. et al. Epidemiology of proximal humerus fractures. J Orthop Surg Res 16, 402 (2021). https://doi.org/10.1186/s13018-021-02551-x
8. Mathiowetz V, Weber K, Kashman N, Volland G. Adult Norms for the Nine Hole Peg Test of Finger Dexterity. The Occupational Therapy Journal of Research. 1985;5(1):24-38. doi:10.1177/153944928500500102
9. Ong PW, Lim CJ, Pereira MJ, Kwek EBK, Tan BY. Achieving satisfactory functional outcomes in conservatively treated proximal humerus fractures: relationship between shoulder range of motion and patient-reported clinical outcome scores. JSES Int. 2024 Feb 23;8(3):440-445. doi: 10.1016/j.jseint.2024.02.003. PMID: 38707550; PMCID: PMC11064704.
10. Pandey R, Raval P, Manibanakar N, Nanjayan S, McDonald C, Singh H. Proximal humerus fractures: A review of current practice. J Clin Orthop Trauma. 2023 Aug 10;43:102233. doi: 10.1016/j.jcot.2023.102233. PMID: 37636006; PMCID: PMC10457443.
11. Parashkevova P, Deleva R. Kinesitherapy for fractures in the proximal part of the humerus. Scientific Papers of the University of Ruse, 2009, 48(8.1): 133-135 (in Bulgarian)
12. Popov N, Dimitrova E. Kinesitherapy for orthopedic diseases and injuries of the upper limb, NSA-PRESS, 2007, p. 104. (in Bulgarian)
13. Popova D, Filipova M, Megova T. Kinesitherapy for common neurological diseases, Part One, University Publishing House of SWU "Niofit Rilski", Blagoevgrad, 2017, ISBN 978-954-00-0104-3, p.49