

Effectiveness of physical rehabilitation methods after knee arthroscopy for sports injuries

ANTON METALNIKOV¹, ASYLBEK ESHIEV², ANTON VOROZHEIKIN³, VALERY SUSHCHENKO⁴, KRISTIYAN GERASIMOV⁵, MARINA SHIROKOVA⁶, MAXIM GURYANOV⁷, DENIS LOGINOV⁸, ASSEL MEIRAMOVA⁹, IRINA IZBASSAROVA¹⁰, LYAZZAT DYUSSENOVA¹¹, NATALYA BALASHKEVICH¹², PAVEL TYUPA¹³

¹Altai State Medical University, Barnaul, RUSSIA

²Osh State University, Osh, KYRGYZSTAN

^{3,4}Peter the Great St. Petersburg Polytechnic University, St. Petersburg, RUSSIA

⁵Faculty of Public Health, Medical University-Sofia, Sofia, BULGARIA

⁶Altai State University, Barnaul, RUSSIA

⁷Privolzhsky Research Medical University, Nizhny Novgorod, RUSSIA

⁸Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, RUSSIA

^{9,10}Astana Medical University, NCJSC, Astana, KAZAKHSTAN

¹¹Kazakh National Medical University named after S.D. Asfendiyarov, NCJSC, Almaty, KAZAKHSTAN

¹²Semey Medical University, NCJSC, Semey, KAZAKHSTAN

¹³Immanuel Kant Baltic Federal University, Kaliningrad, RUSSIA

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Abstract:

Physical rehabilitation following after surgery is essential for the effective recovery of athletes who have sustained injuries. **Purpose:** The aim of this study is to develop and evaluate the effectiveness of a physical rehabilitation technique for men in the late postoperative period after knee arthroscopy. **Materials and methods:** The study involved 20 men aged 25–30 years in the late postoperative period after minimally invasive knee arthroscopy. The control group (CG) underwent physical rehabilitation using the traditional method, while the experimental group (EG) received a technique we developed. This technique incorporated the DST-8000 exercise machine, neuromuscular exercises with an elastic band and balance pad, walking on a flat surface and treadmill, as well as special and breathing exercises. Physical performance was assessed using the 12-min Cooper treadmill test, and joint range of motion, support ability, dynamic and static muscle strength of the lower limb, postural status, and coordination were measured. The relationship between quality of life and the outcomes of physical rehabilitation after knee arthroscopy was evaluated using the SF-36 questionnaire (Short Form Health Survey). **Results:** Upon completion of the individualized physical rehabilitation program for patients after knee arthroscopy, positive improvements were observed in both groups. The EG demonstrated greater functional capabilities of the joint and neuromuscular apparatus of the lower limb compared to the CG. Physical rehabilitation enhanced the quality of life in both groups, with the most significant improvements in the physical and mental components of quality of life noted in the EG. **Conclusions:** The high effectiveness of restoring the functional capabilities of the joint and neuromuscular apparatus of the lower limb, along with an improvement in quality of life following the use of the developed physical rehabilitation method, supports its recommendation for implementation in therapeutic physical culture practice.

Keywords: musculoskeletal system, arthroscopy, therapeutic physical culture, physical training, quality of life

Introduction

The musculoskeletal system is one of the body's key morphofunctional systems, enabling movement in space and the performance of various motor activities. Physical education and sports activities are recognized for their considerable role in the development and improvement of this functional system (Thaler et al., 2021). However, contemporary researchers have observed a global increase in the prevalence of musculoskeletal disorders (Lim & Al-Dadah, 2022; Kaki, 2024), particularly affecting the knee joint in younger individuals (Baranova, 2018; Tripathy et al., 2022). According to the authors, this increase is attributed to factors such as the growing prevalence of obesity, sedentary lifestyles, lack of sports participation, and vitamin D deficiency (VDD). Furthermore, injuries to the knee joint from various causes are known to disrupt its normal functioning (Nazari et al., 2020). Notably, lower limb injuries of varying origins account for approximately 13.1% of all injuries (Smelov et al., 2021). Among the working-age adult population, dysfunctions of the knee joint rank third in terms of frequency among musculoskeletal injuries.

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Corresponding Author: ANTON METALNIKOV, E-mail: ametalnikov@yandex.ru

Sports participation can also contribute to the development of musculoskeletal diseases and injuries (Mardiana et al., 2021; Morgans et al., 2023; Hayashi et al., 2023). Achkasov et al. (2021) reported that knee joint disorders were highly prevalent among athletes (17.9%), commonly seen in individuals involved in figure skating, speed skating, gymnastics, and volleyball. Meniscus injuries are the most frequent type of knee joint injury (Mai et al., 2024). If left untreated, knee injuries can lead to pathological conditions in the joint structures, requiring medical intervention. Prolonged neglect of these conditions can result in the development of osteoarthritis.

The knee joint, comparable to other lower extremity joints, plays a crucial role in supporting the skeletal system. It bears a substantial proportion of shock loads, which increases the risk of injury during daily activities, occupational tasks, and physical education or sports participation. Restoring the functionality of the knee joint after an injury is important because its impairment severely reduces an individual's motor abilities and can lead to serious complications (Xiao & Sang, 2023). Simple actions become challenging, resulting in an overall decline in physical activity. This can subsequently contribute to physical inactivity and adversely affect vital systems such as the cardiovascular and respiratory systems. Ultimately, these factors considerably compromise an individual's quality of life.

In case of diseases and injuries of the knee joint, conservative and surgical directions of human health improvement are used (Rotini et al., 2023; Grant et al., 2024; Haugaard et al., 2024). One of the innovative methods of surgical treatment of diseases and injuries of the knee and other joints is arthroscopy (Deng et al., 2020; Yoo et al., 2024; Mai, et al., 2024). It is the most common and frequently prescribed method of surgical treatment, which implies a minimally invasive surgical intervention used to diagnose and treat affected tissues and individual parts of the joint. This method has a significant advantage over arthrotomy, a method in which the joint is completely opened.

In order to accelerate the process of joint function recovery after arthroscopy, it is recommended to start physical rehabilitation of the patient starting from the second or third day (Bandak et al., 2021; Gryaznykh, et al., 2021; Cui et al., 2023; Bondarenko et al., 2024). The rehabilitation process is necessary in cases of total knee arthroplasty, when postoperative anomalies develop that can negatively affect a person's daily activities (Oku et al., 2024). Based on extensive research data, it is known that physical exercises for patients are non-pharmacological interventions in knee arthroscopy, which are unanimously recommended as a first-line treatment. The effect of physical exercises is enhanced when supplemented with complexes of knee physiotherapy procedures (Klupiński et al., 2017). Physiotherapy procedures can now be performed using telecommunication techniques (Horton et al., 2021), which lead to similar positive results and are cost-effective compared to in-person physiotherapy.

The use of physical rehabilitation in patients after knee surgery can improve the effectiveness of the overall health program. It allows a person to return to his professional and sports activities in a shorter time and improve the quality of his usual life. It is important to reduce the economic burden on the healthcare system when treating such patients (Baranova, 2018). The high burden is due to the increase in the number of patients with diseases, injuries and complications of the knee joint, especially among young people and middle-aged people. This dictates the need to search for new effective means and methods for rapid rehabilitation of patients after minimally invasive interventions on the knee joint. Therefore, the development and testing of innovative rehabilitation techniques for patients after arthroscopy is an urgent and timely task for scientists and specialists in the field of therapeutic physical culture.

Purpose: The purpose of this study is to develop and evaluate the effectiveness of a physical rehabilitation technique for men in the late postoperative period after knee arthroscopy.

Materials and methods

This research project was performed over the period from September 2022 to June 2023 at the Barnaul City Hospital (Siberian Federal District, Russia). Two groups were formed for the study: a control group (CG, n = 10) and an experimental group (EG, n = 10). The participants were male individuals aged 25–30 years (28.4 ± 1.4 years) who had undergone knee arthroscopy and were in the late postoperative period, typically involving rehabilitation for 3–4 weeks and continuing up to 2–2.5 months after surgery. The focus of rehabilitation during this period is on restoring normal gait, developing dynamic and static strength endurance of the lower limb muscles, and enhancing the overall physical capacity of the body. In addition to the abovementioned rehabilitation objectives, the project also aimed to enhance proprioception and address any residual limitations in joint movement. Prior to their participation in the research project, all participants provided written consent. The goals and objectives of the experiment were thoroughly explained to each individual, ensuring that they aligned with the principles outlined in the Helsinki Declaration of 2008.

Patients in the CG underwent physical rehabilitation following a widely recognized method developed by S.N. Popov (2005). This protocol consisted of 10 rehabilitation sessions administered in a hospital setting and 4 independent sessions performed at home, with each session lasting 90 min. The patients performed a series of physical exercises designed to enhance the mobility, range of motion, and flexibility of the knee joint, as well as

to improve the strength and endurance of the thigh muscles. The exercises also aimed to alleviate pain, prevent contractures and muscle spasms, and stimulate blood and lymph circulation.

In contrast, patients in the EG participated in daily exercise sessions lasting 80–90 min, following an individualized approach based on the developed methodology. Each patient underwent 10 supervised sessions in a hospital setting, followed by 4 independent sessions at home. The methodology incorporated various exercise modalities, including walking exercises and training on the DST-8000 dynamic ladder simulator (manufactured by DPE Medical, Israel). Neuromuscular exercises utilizing rubber bands and balance cushions were also employed, along with walking exercises on a flat surface and on a treadmill. Additionally, specialized exercises with and without equipment were included in the program.

To enhance the proprioceptive function of the knee joint, specific exercises were incorporated on balance pads, which create an unstable surface for performing exercises. Furthermore, to improve the capacity for static and dynamic control of the knee joint position and strengthen the ligamentous apparatus of the affected area, specialized neuromuscular exercises utilizing fitness bands were employed. These exercises are designed to improve movement quality and place emphasis on controlling movements in all three biomechanical planes.

The preparatory phase of the exercise session occupied approximately 32–33 min (35%–36%) of the total session duration. The ratio of general strengthening exercises to breathing exercises was maintained at 3:1. During the first half of the preparatory phase, 25 min were dedicated to training on the Kinetic Spectra mechanical rehabilitation simulator (manufactured by Kinetec, France). This component focused on the passive development of the knee joint, engaging muscle groups in a top-down sequence. Each exercise involved no more than 50% of the muscle groups. The pace of execution was slow to moderate, and the exercises were performed from a seated position.

The main portion of the session, lasting 45 min (50% of the total time), comprised specialized exercises, general developmental exercises, and breathing exercises, with a ratio of 3:1:1, respectively. The pace of execution for these exercises was maintained at a slow to moderate tempo.

During the first week, the main component of the session commenced with 5 specialized exercises performed from a sitting and lying position. Each exercise was performed for 45 s, with a 15-s rest interval between exercises. The number of repetitions for each exercise ranged from 10 to 12. Subsequently, in the main part of the session, neuromuscular exercises were performed from standing and sitting positions, transitioning into a lunge position with an emphasis on the healthy knee. The execution time for this component was 10 min, and the pace of execution was slow. All specialized exercises were alternated with general developmental and breathing exercises. Breathing exercises were performed after the completion of general developmental exercises. Each general developmental exercise was performed for 30 s, followed by a 15-s rest period. Subsequently, a breathing exercise was performed for 30 s. Following this sequence, 6 specialized exercises were performed on the DST 8000 ladder. The time allocated for exercises on the ladder was 12 min. Each exercise was performed in two sets of 10–12 repetitions. Both sets were performed at a slow pace for 40 s, with a 20-s rest interval between sets. To conclude the main component of the session during the first week, walking exercises were incorporated to facilitate gait normalization and adaptation to axial load. The exercise duration was 18 min, the number of exercises was 6, and the pace was slow.

During the second week, the main part of the session commenced with specialized exercises of moderate intensity, performed both with and without equipment. Each exercise was performed for approximately 8 min (alternating between 45 s of active work and 15 s of rest). The total number of exercises was eight, and the pace of execution was moderate. These exercises were performed from supine, seated on the floor, and seated on chair positions. In the main component, the ratio of specialized exercises to general developmental exercises and breathing exercises was maintained at 3:1:1, respectively. The set of general developmental exercises was performed with moderate intensity, alternating between 30 s of active work and 15 s of rest. During the main part of the session, breathing exercises were incorporated, alternating with specialized exercises. Each breathing exercise was performed for 30 s. Additionally, four exercises were performed on balance pads at a slow tempo for 10 min. Each of these exercises was performed in 3 sets of 10–12 repetitions. The starting position for these exercises was standing, either with or without support against a wall or handrail. Subsequently, for 8 min, four exercises were performed on the simulator ladder at a moderate tempo. Each exercise performed on the simulator ladder was performed in two sets, with each set consisting of 15 repetitions. At the end of the main part during the second week, 14-min exercises on a treadmill were incorporated. Each exercise was repeated twice, with each repetition lasting for 1 min (45 s of exercise followed by 15 s of rest). The speed of the treadmill varied from 0.5 to 3.5 km/h.

The concluding phase of the session lasted for 13 min (15%) and was characterized by a slow pace of execution. Exercises were performed from supine, prone, lateral, seated, and standing positions. The primary objective of these exercises was to promote muscle relaxation and facilitate the overall restoration of functional indices in the cardiovascular and respiratory systems. The ratio of breathing exercises to relaxation exercises was maintained at 2:3.

A standardized goniometric test was used to assess the range of motion in the joint and evaluate the efficacy of the interventions implemented in the groups.

Furthermore, to assess coordination and balance capabilities, the single-leg squat test (Crossley et al., 2011) was utilized. Performance was graded on a scale of "good," "satisfactory," and "poor," corresponding to the number of correctly performed repetitions: 5, 3, and 1, respectively.

Lastly, to assess the extent of recovery in the lower limb's support capacity, a test involving mechanical floor scales was performed. The patient was instructed to place the injured limb, followed by the healthy limb, on the scale and apply maximum force with the entire foot's surface until the threshold of pain was reached. The recorded value, expressed in kilograms, served as an indicator of support capacity.

A static pose-holding test was chosen to evaluate the level of static endurance in the thigh and lower leg muscles. The subject assumes a half-squat position, with their back pressed against a wall and their gaze directed forward while extending their arms forward. The angle of flexion at the knee joint is maintained at a minimum of 45°. The duration of pose maintenance is recorded from the moment it is adopted until the end of holding. The lower limit of the norm for this test is 30 s.

To determine the level of overall physical performance, a modified version of the 12-min Cooper test was performed on a treadmill. The task for the subject was to walk as far as possible in a 12-min timeframe. The subject could adjust their walking speed as needed. After 12 min, the distance covered by the patient during the allotted time was recorded. The lower limit of the norm for men aged 25–30 years in this test is 2.1 km.

The relationship between an individual's quality of life and the outcomes of physical rehabilitation after knee joint surgery during the late postoperative period was investigated using the internationally recognized SF-36 questionnaire (Short Form Health Survey). This questionnaire comprises 36 questions categorized into 8 scales that assess both physical and psychological health components (Ware et al., 1998). The indicator values for each scale range from 0 to 100 points, with 100 representing optimal health.

Statistical analysis was performed using Statistica 10.1 and MS Excel 2016 software to determine the arithmetic mean ($\bar{X}$), standard deviation (σ), and standard error of the mean (m). The reliability of differences in the arithmetic mean values of the examined characteristics was assessed using Student's *t*-test. A 95% significance level was adopted for determining reliability.

Results

Table 1 presents the results of the comparative analysis performed to evaluate the efficacy of the proposed physical rehabilitation method for post-knee arthroscopy patients in comparison to the conventional approach. At the beginning of the research project, no significant differences were observed in the values of functional indicators and lower limb strength capabilities between patients in the CG and EG ($p > 0.05$). This suggests that the groups were homogeneous and suitable for further investigation.

Table 1. Threshold values of functional indicators for knee joint and lower limb strength abilities in control and experimental groups ($\bar{X} \pm m$)

No	Tests	Groups	Beginning of the experiment	End of the experiment	Physiological norm
1.	Physical performance, km	CG	0.98 ± 0.15	1.2 ± 0.25	2.1 km
		EG	1.1 ± 0.22	$1.8 \pm 0.14^*$	
2.	Knee flexion, angular degree	CG	47.6 ± 8.83	$116.2 \pm 2.9^*$	130 angular degrees
		EG	48.3 ± 10.49	$130.3 \pm 2.71^*$	
3.	Postural status and balance, number of times	CG	1.5 ± 0.53	2.4 ± 0.57	5 times
		EG	1.4 ± 0.52	$5.0 \pm 0.48^*$	
4.	Weight-bearing capacity, kg	CG	29.4 ± 3.53	$68.9 \pm 3.18^*$	76.0 kg
		EG	30.2 ± 6.14	$76.7 \pm 2.36^*$	
5.	Strength of the biceps femoris, semitendinosus, semimembranosus muscles, points	CG	2.1 ± 0.42	3.5 ± 0.92	5 points
		EG	2.2 ± 0.42	$4.4 \pm 0.69^*$	
6.	Static endurance of the thigh and calf muscles, s	CG	13.7 ± 1.63	$26.7 \pm 1.7^*$	30 s
		EG	13.5 ± 1.58	$32.3 \pm 1.49^*$	

Note. * Significant differences in values at the end of the experiment compared to the beginning, $p < 0.05$

At the end of the research project, an increase in the values of all functional indicators and lower limb muscle strength capabilities was observed in patients belonging to both groups when compared to the baseline measurements. In the CG, significant improvements ($p < 0.05$) were noted in three tests, while all tests in the EG group demonstrated significant advancements. Notably, four tests performed on EG patients yielded values that reached normal levels, a result not achieved by any test in the CG group. At the project's end, the EG group exhibited a greater increase in functional test indicator values compared to the CG group, as shown in Figure 1.

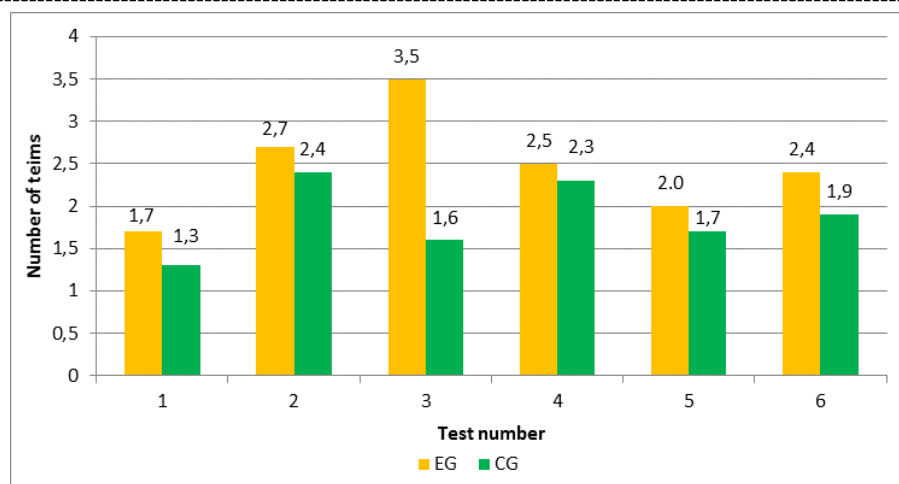


Fig. 1. Improvement in functional test scores in patients by the end of the observation period compared to the start of the research project

The most significant improvements in scores were observed in the EG group, particularly in functional test No. 3 ("postural status and balance"), test No. 2 ("knee flexion"), and test No. 4 ("support ability"). In contrast, the CG group exhibited a substantially smaller increase in functional test scores.

Rehabilitation measures for patients following knee arthroscopy not only improved functional scores in both experimental groups but also positively influenced their quality of life (Table 2).

Table 2. Quality of life scores for patients in both groups before and after rehabilitation measures (M ± m)

No	SF-36 questionnaire scales	CG (n = 10)		EG (n = 10)	
		Before rehabilitation	After rehabilitation	Before rehabilitation	After rehabilitation
Physical component					
1.	Physical activity, PF	55.2 ± 2.4	68.5 ± 2.7*	53.5 ± 2.6	84.8 ± 4.2*
2.	Role activity, RP	57.6 ± 1.7	65.2 ± 1.8*	61.2 ± 1.8	73.4 ± 3.3*
3.	Physical pain, BP	42.2 ± 1.1	70.2 ± 2.2*	44.5 ± 1.6	82.5 ± 3.2*
4.	General health, GH	61.1 ± 1.7	76.1 ± 3.5*	60.5 ± 1.4	79.5 ± 3.7*
Psychological component					
5.	Mental health, MH	62.2 ± 2.1	68.4 ± 2.7*	59.8 ± 1.9	82.4 ± 4.3*
6.	Emotional status, RE	81.3 ± 3.0	83.3 ± 3.2	77.3 ± 2.8	86.7 ± 4.6*
7.	Social activity, SF	66.1 ± 1.9	73.2 ± 2.8*	68.4 ± 2.3	77.3 ± 3.5*
8.	Life activity, VT	70.5 ± 3.2	76.4 ± 3.4	67.5 ± 2.5	84.5 ± 4.4*

Note: * Significant difference compared to the beginning of the experiment, $p < 0.05$

At the beginning of the experiment, the quality of life indicator values in patients from both groups were comparable, with no significant differences observed in either the physical or psychological components ($p > 0.05$). Both the CG and EG groups exhibited a significant spread of the intensity of physical pain (42.2 ± 1.1 and 44.5 ± 1.6 points, respectively), primarily attributed to the knee joint condition. Consequently, the physical activity of the subjects was restricted, not exceeding 55.2 ± 2.4 points in CG and 53.5 ± 2.6 points in EG ($p > 0.05$). Both groups demonstrated low levels of mental and overall health, marginally exceeding 60 points. This contributed to a decline in social and life activity among the patients, reflected in the relatively low values of their respective indicators.

Upon completion of the physical rehabilitation program, all patients exhibited an improvement in quality of life indicator values compared to baseline measurements. The CG group demonstrated a significant increase in indicator values across 6 out of 8 scales of the SF-36 questionnaire ($p < 0.05$). However, superior results were observed in the EG group, where a significant increase in indicator values was recorded across all scales of the SF-36 questionnaire ($p < 0.05$). Notably, the magnitude of improvement in quality of life indicators among EG patients surpassed that of the CG group compared to baseline values, as illustrated in Figure 2.

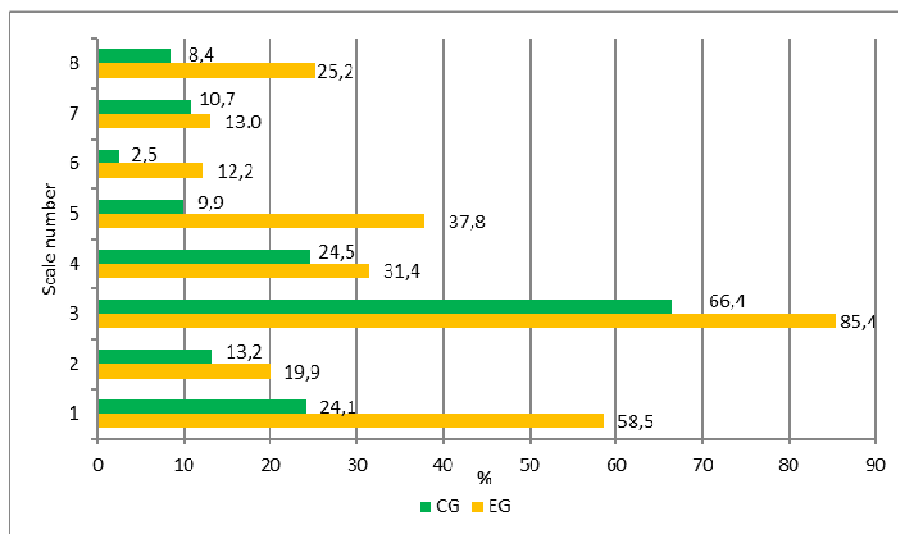


Fig 2. Improvement in quality of life indicators in patients in both groups at the end of the experiment

The most significant enhancements in quality of life indicator values were observed in EG patients in scale No. 3 ("intensity of physical pain," 85.4%), scale No. 1 ("physical activity," 58.5%), and scale No. 5 ("mental health," 37.8%). In contrast, the CG group demonstrated a considerably smaller increase in quality of life indicator values across all scales compared to the EG group. In the CG, the most substantial improvements were seen in scale No. 3 ("intensity of physical pain," 66.4%) and scale No. 4 ("general health," 24.5%).

The obtained results of the conducted research project indicate the effectiveness of the rehabilitation method developed by us for young patients in the late postoperative period after knee arthroscopy compared to the traditional method. This is evidenced by higher results of restoration of the functional capabilities of the articular and neuromuscular apparatus of the lower limb and an improvement in the level of quality of life.

Dicussion

Scientists and medical specialists have registered an increase in the number of cases of musculoskeletal disorders (Lim, & Al-Dadah, 2022; Kaki, 2024) and, first of all, the knee joint in young people (Baranova, 2018; Tripathy et al., 2022). The occurrence of knee joint disorders is associated with the development of diseases that are specific to the human musculoskeletal system or injury at home or at work (Nazari et al., 2020). The causes of diseases or injuries of the knee joint can be physical education and sports activities (Achkasov et al., 2021; Romanova, et al., 2021).

Currently, methods associated with the use of minimally invasive surgical interventions are becoming widespread for the treatment of diseases of the musculoskeletal system. One of them is knee arthroscopy (Deng et al., 2020; Yoo et al., 2024; Mai, et al., 2024), which is used to diagnose or treat the joint. Despite the minimally invasive nature of this surgical intervention, physical rehabilitation is required after its implementation to speed up the patient's return to normal life and prevent the occurrence of a number of serious complications. According to the authors' observations, physical rehabilitation begins on the second day after surgery (Bandak et al., 2021; Cui et al., 2023; Bondarenko et al., 2024). We agree with the opinion of these researchers that physical rehabilitation is especially important in the late stages after surgery, which is carried out in the period from 3-4 weeks and lasts up to 2-2.5 months.

In the conducted research project, we proposed a method for physical rehabilitation of patients in the late stages after knee arthroscopy. The proposed method differs from the traditional approach to physical rehabilitation, which was proposed by S.N. Popov (2005). The peculiarity of the proposed method is that the main part of the therapeutic physical culture session included neuromuscular exercises, which were performed with rubber bands and on balance cushions. The method used exercises on the DST 8000 ladder simulator, special exercises with and without equipment, walking exercises on a flat surface and on a treadmill, as well as general developmental physical activity in combination with breathing exercises. This contributed to the effective restoration of the functional capabilities of the articular and neuromuscular apparatus in patients. This is evidenced by the results of a comparative analysis of the two tested methods. At the end of the research project, an increase in the values of all functional indicators was established in patients of both experimental groups compared to the beginning of the experiment. In both experimental groups, an increase in physical performance, knee flexion angle, support ability, strength of the biceps femora's, semitendinosus, semimembranosus muscles, static endurance of the thigh and lower leg muscles, and an improvement in postural status and balance were registered. However, the proposed method of rehabilitation measures turned out to be

more effective. The values of the indicators in the subjects of the control group increased reliably significantly only in three tests and in all tests in patients in the experimental group. At the same time, the values of the indicators reached the physiological level in four tests. In men in the control group, such a result was not achieved in any test. At the end of the project, the increase in the values of the indicators in all functional tests in patients where the method we proposed was used was significantly greater than in men in the control group.

Our studies of the patients' quality of life indicated significant problems in their life activities at the beginning of the research project. This is consistent with the opinion of Oku et al. (2024) on the development of negative postoperative anomalies in patients with musculoskeletal diseases that impair their usual life, which necessitates the organization of physical rehabilitation. In the process of studying the quality of life of young men, we established the presence of significant physical pain in them, which is caused by a knee joint disease. This limits their physical and life activity, social activity and reduces the level of general and mental health. The use of physical rehabilitation in patients improved their quality of life in both experimental groups at the end of the experiment. However, the quality of life indicators increased more in the group of patients where the experimental technique proposed by us was used. They had a significantly reduced intensity of physical pain, which allowed them to fully perform physical, life and social activities.

The experiment has prospects for further scientific research. Of scientific and practical interest is the remote comparative assessment of the effectiveness of the proposed method 6, 12, 24 months after the completion of rehabilitation measures. The study of this issue will answer the question of whether there was a remote alignment of the values of the performance indicators when comparing two methods of physical rehabilitation of young men after knee arthroscopy.

Conclusions

The comparative analysis of the proposed physical rehabilitation method for males aged 25–30 years in the late postoperative period after knee arthroscopy revealed its superior efficacy compared to conventional therapeutic physical culture approaches. The experimental rehabilitation protocol incorporates specialized exercises performed with and without equipment. It includes neuromuscular exercises utilizing rubber bands and balance pads, physical activity on the DST 8000 ladder simulator, walking exercises on a flat surface and on a treadmill, and a combination of general developmental exercises integrated with breathing exercises. Upon completion of the rehabilitation program, patients in the EG who underwent the proposed technique exhibited a higher level of physical performance, improved gait patterns, elimination of residual joint movement limitations, enhanced lower limb muscle strength indicators, and superior support ability compared to the CG.

Physical rehabilitation interventions after knee arthroscopy resulted in quality of life improvements in both groups. Notably, the EG demonstrated a significantly greater enhancement in the physical and mental components of quality of life compared to the CG. The reduction in physical pain experienced by patients in the EG led to an increase in their physical activity levels, as well as improvements in their vitality, social interactions, general health, and mental well-being.

The proposed physical rehabilitation technique, which effectively restores the functional capabilities of the lower limb's articular and neuromuscular systems and enhances quality of life, is highly recommended for implementation in the practice of therapeutic physical culture.

Conflicts of interest. The authors declare no conflict of interest.

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