



**NATIONAL SPORTS ACADEMY
„ VASSIL LEVSKI“**

Department of Theory and Methods of Kinesiotherapy

**ROLE OF PROPRIOCEPTIVE TRAINING IN
REHABILITATION FOLLOWING ANTERIOR CRUCIATE
LIGAMENT RECONSTRUCTION**

ABSTRACT

of dissertation submitted for
conferral of the PhD educational and scientific degree,

NORA IVANOVA TANEVA – GEORGIEVA

Supervisor:

Prof. Ruska Paskaleva, PhD

Formal reviewers:

Prof. Nikolay Popov, DSc

Assoc Prof. Daniela Popova, PhD

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LIST OF ABBREVIATIONS

VAS	-	Visual analogue scale
EG	-	Experimental group
CG	-	Control group
ROM	-	Range of motion
KT	-	Kinesiotherapy
MMT	-	Manual muscle testing
PIR	-	Post isometric relaxation
ACL	-	Anterior cruciate ligament

INTRODUCTION

The stifle joint is an intermediate locomotor element of the lower extremity kinetic chain, which determines its numerous functional features. The stifle joint is the most significant articulation of the locomotor apparatus. The traumatic injuries in the region of the stifle lead to functional, locomotor disturbances, restriction of everyday, professional and sport activities. The rupture of the anterior cruciate ligament (ACL) is among the most common injuries of the locomotor apparatus. It requires a prolonged treatment and is a prerequisite for a number of complications. This is the reason for its particular social importance and requires constant updating of kinesiotherapeutic algorithms used in the treatment of patients.

There are several inconsistencies related to the combination of kinesiotherapeutic means for recovery after traumatic ACL injuries, especially with regard to open and closed kinetic chain exercises due to the risk from repeated injury of healing tissues. Yet, there is not a full consent on efficient rehabilitations programmes for recovery after ACL rupture. Some sources support the early weight-bearing, whereas others affirmed that this should be done at a later stage of recovery.

There are also disagreements on the effects of proprioceptive training during recovery from ACL reconstruction. This confirms the necessity of isolated studies on the efficiency of neuromuscular and proprioceptive training on healing structures.

The present dissertation discusses and analyses the role and efficiency of proprioceptive training in patients after ACL reconstruction surgery. Data from functional investigations performed to evaluate the post-operative effect of applied kinesiotherapeutic methods in patients with ACL surgery are analysed. Conclusions about the efficiency of the proposed KT protocol are made on the basis of the results from the statistical analysis.

WORKING HYPOTHESIS

The literature overview allowed concluding that there is no uniform rehabilitation protocol for recovery following ACL reconstruction. This statement support the hypothesis that the development of a updated kinesiotherapeutic algorithm with enhanced proprioceptive training would speed up the overcoming of restricted locomotion and the return of patients to previous level of physical activity for a shorter time period in comparison to standardised protocols through ensuring protection of healing structures.

Aim of studies.

The aim of the present dissertation was to investigate the role of proprioceptive training in kinesiotherapy of patients after ACL reconstruction and evaluation of its efficiency.

Tasks of studies.

1. Investigation of modern evidence-based concepts of KT models aimed at treatment of soft tissue traumatic injuries at both national and international scale.
2. Development and application of questionnaires as supplement to functional tests.
3. Development and promotion of a updated kinesiotherapeutic protocol with emphasis on proprioceptive training for enhanced overcoming of restricted locomotion and the return of patients to their previous level of physical activity.
4. Analysis and comparison of data from studies and measurements in different stages of recovery with between-group comparisons. Summarising the results on efficacy of recovery protocols.
5. Development of innovative platform for in-home KT targeted to therapists and patients with traumatic soft tissue injuries of the stifle.

STUDY ORGANISATION AND STUDY COHORT SELECTION

The research study was conducted in Kinesi-3 Rehabilitation Centre, Stara Zagora, from December 2017 to February 2021. Each patient was consulted by a specialist in orthopaedics and traumatology for diagnosing a soft tissue stifle injury.

Patients with traumatic soft tissue stifle injuries comprised **the study cohort**.

Subject of the study was the development and implementation of a KT protocol in patients with ACL reconstruction surgery with emphasis on proprioceptive training.

Inclusion criteria for the study cohort:

The following criteria were applied for inclusions of patients in the study cohort:

- Age up to 45 years;
- History of traumatic injury in the stifle joint region;
- Diagnosis of soft tissue stifle injury;
- Orthopaedic treatment of the injury;
- Possibility for performing a long-term recovery with regard to its monitoring;
- Lack of complications after treatment of the soft tissue injury and/or trauma of adjacent segments of lower extremities.

Exclusion criteria for the study cohort:

- Age over 45 years;
- Recent surgery of other segments;
- Neurological and psychic diseases;
- Chronic respiratory and cardiovascular diseases reflecting on the patient response to physical load;
- Obesity as primary cause of restricted locomotor capability.

In order to obtain consistent results, a **representative sample** of all patients diagnosed with ACL rupture was selected (n=35). All 35 participants were treated by arthroscopic surgery and **patellar tendon reconstruction**. The admission of patients in the rehabilitation centre was after the immediate post-operative period (post-operative days 1-5) and KT procedures started from the maximum protection stage (post-operative days 8-10).

Participants in the study were divided into two principal groups according to the applied KT recovery protocol – **control group** (CG) of 18 patients and

experimental group (EG) of 17 patients. The standard KT protocol used for ACL rupture was applied in the CG, whereas the EG was submitted to the experimental protocol with enhanced proprioceptive training.

The CG comprised 77.80% (n=14) men and 22.20% (n=4) women. The sex ratio in the EG was 64.70% (n=11) men and 35.30% (n=6) women ($\chi^2=0.232$; $P=0.6303$). Regarding age, the groups were also uniform without statistically significant differences ($P=0.2343$). The mean age of patients from the CG was 32.5 years vs 29 years in the EG. There were no relevant differences with regard to body weight ($P=0.0854$), which was one of inclusion criteria. The median weight for the CG was 80.5 kg and for the EG: 70 kg. The groups were also with similar height ($P=0.0958$): 182.5 cm for CG and 172 cm for EG.

The social status of the study cohort and some risk factors (smoking, drinking etc.) were studied.

Information about the lifestyle of included patients was obtained in some main directions: nutrition, level of locomotor activity before the injury, history of previous traumatic injuries of lower extremities. According to the level of locomotor activity before the trauma ($\chi^2=3.042$; $P=0.3852$), the patients belonged to the following groups: with active lifestyle, practicing either amateur or professional sports activities, not engaged in sports but affirming to live an active lifestyle and living a sedentary lifestyle. The distribution of these groups is illustrated on Fig 1.

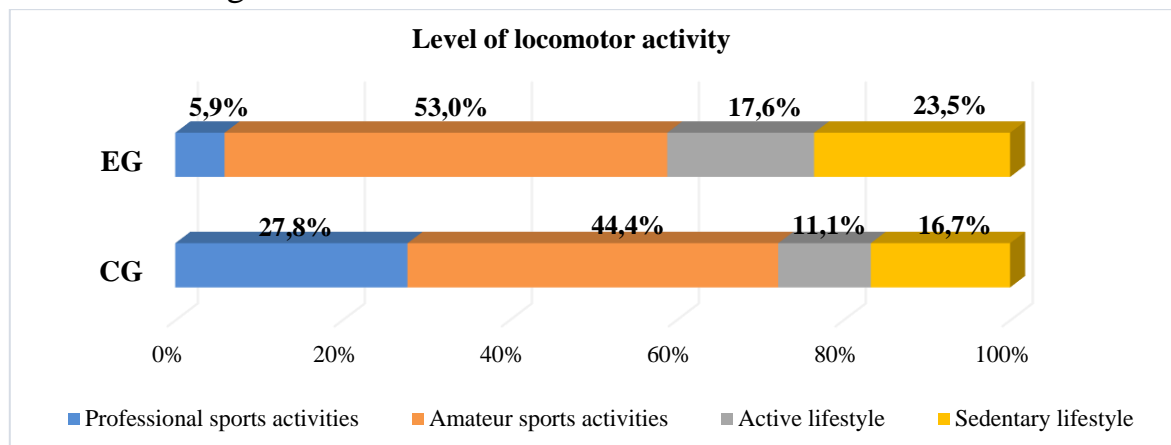


Fig. 1. Distribution of study cohort according to locomotor activity level.

The results about CG patients engaged in sports showed that half of them exercised regularly - 50% (n=9), those that exercised rarely were 27.8% (n=5), and 22.2% (n=4) did not exercise at all. In the EG, the proportion of those exercising regularly was 47% (n=8), those that exercised rarely were 35.4% (n=6) whereas 17.6% (n=3) did not exercise at all. There were no significant between-

group differences ($\chi^2=0.264$; $P=0.8762$). The distribution of patients according to their engagement in sports activities is shown on Fig 2.

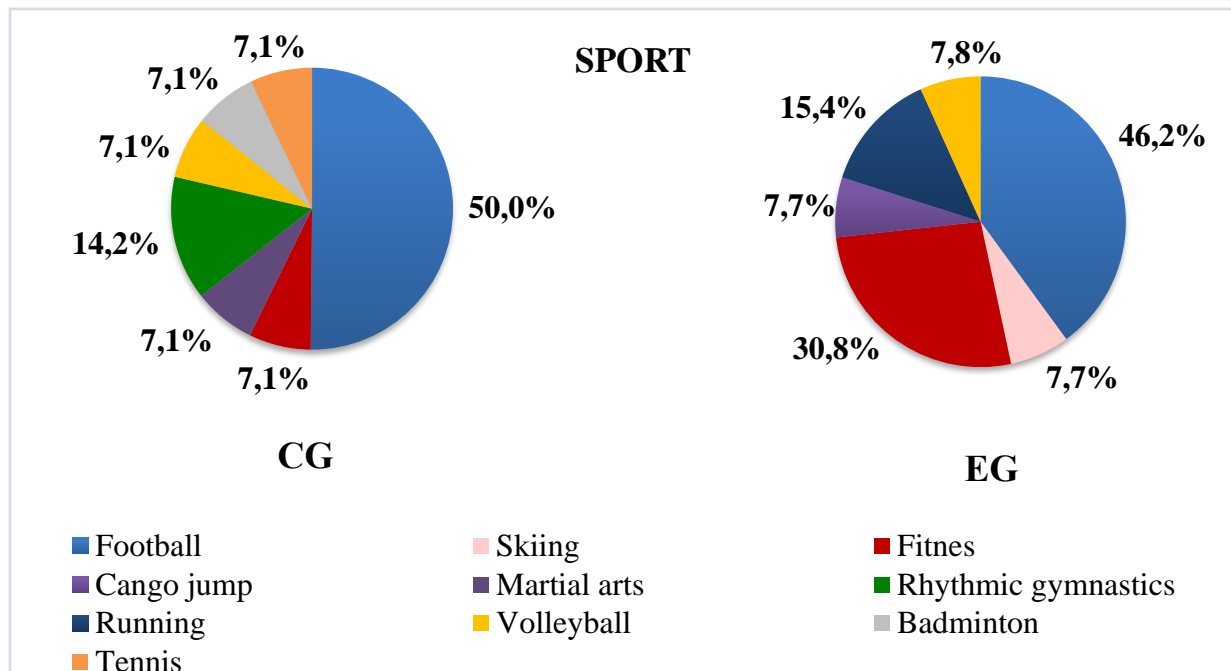


Fig. 2. Distribution of study cohort according to practiced sport.

RESEARCH METHODS

Statistical methods and analyses

The analysis of research data was conducted using statistical tests for detection of significant differences between control and experimental groups:

1. *Kolmogorov-Smirnov test*;
2. *Descriptive statistical analysis*;
3. *Analysis of between-group differences* – non-parametric test of *Kruskal-Wallis*, test of *Friedman*;
4. *Pearson's chi-square test (χ^2 test)*.

Methods of functional tests and assessment

1. Disease history;
2. Questionnaire survey of patients;
3. Visual analogue scale (VAS);
4. Inspection and palpation;
5. Anthropometric measurements and studies;
6. Goniometry of lower extremities;
7. Manual muscle testing (MMT);
8. Study of active, passive and accessory movements;

9. Tests for increased tone and/or spasticity;

10. Gait investigation and analysis.

Functional tests for evaluation of rehabilitation potential of every patient and monitoring of effect from applied KT protocols were performed three times. First measurements were done before the rehabilitation procedures for evaluation of initial status and acquaintance with locomotor potential of patients. During the moderate protection phase, functional tests were repeated for monitoring of the response of participants to applied KT means and adjustments were made if necessary. The third functional measurement was performed during the last rehabilitation course for final registration of achieved results.

KINESIOTHERAPY PROTOCOL IN STUDIED GROUPS

Kinesiotherapeutic activities in both groups were conducted three times per week, and their duration and dose depended on individual locomotor potential of patient and the post-operative period. The recovery period for each patient with ACL reconstruction was followed from post-operative week 8-10 to full recovery of limb function. The aim and tasks of applied therapy were set in line with traumatic injury mechanism, age, general condition, locomotor capabilities and co-morbidities. Individual approach to each patient was used in which loading was in compliance with existing joint instability.

The main **goal of kinesiotherapy** in both groups was the functional recovery of the lower extremity and return to pre-trauma level of locomotor activity.

KT tasks for the two groups may be summarised as follows:

1. Elimination of swelling and pain;
2. Achievement of normal range of motion, muscle force and balance;
3. Recovery of normal walking stereotype;
4. Gradual return to everyday locomotor activity;
5. Return to the pretraumatic locomotion level with minimum risk from relapse of injury;
6. Overcoming psychological barriers to return to sports activities and fear of injury relapse

The patients from the **control group** were submitted to the standardised KT programme. During the **maximum protection phase**, applied means comprised oedema massage, cryotherapy, TENS, positioning therapy, mobilisation of the patella, post-isometric relaxation (PIR), passive, active and assisted exercises, isometric contractions, training in walking with aids, open and closed kinetic chain exercises, aerobic training. During the **moderate protection phase**, KT

means were selective massage, positioning therapy, joint mobilisation techniques, closed kinetic chain exercises, exercises against resistance, stretching, training in walking without aids. The standard approach during the **minimum protection phase** included stretching, exercises against substantial resistance, plyometric exercises, exercises for speed and agility, and specific sports activities.

In the **experimental group**, a new protocol with focus on proprioceptive training was applied. The KT means were selected in line with the individual patient's recovery period.

Kinesiotherapy in the maximum protection phase (post-operative weeks 2-4).

The typical clinical manifestations during this phase included pain, restricted stifle joint movements, swelling, post-operative haemarthrosis, reduced thigh muscle strength. The patients walked with the aid of crutches and a protective splint. The duration of KT procedures for both groups was 45 minutes. The ROM of knee flexion by the 8th post-operative day was 90° and by the 10th day after surgery: 100°.

The KT goal during this period was to stimulate recovery processes and to protect the autograft.

KT tasks:

1. Pain and swelling control and reduction;
2. Gradual weight-bearing with the limb;
3. Prevention of complications e.g. muscle inhibition etc.;
4. Training of the patient of proper walking with aids;
5. Training of the patient to perform in-home KT.

The KT means, applied during this phase are presented in Table 1.

The KT programme comprised carefully selected exercises depending on functional diagnostics' results. The dose of each exercise depended on individual potential of the patient and muscle strength evaluation.

Table 1. Kinesiotherapeutic means applied in the control and experimental groups of patients following ACL reconstruction in the maximum protection phase.

MAXIMUM PROTECTION PHASE (post-operative weeks 2-4)		
Control group (n=18)		Experimental group (n=17)
Kinesiotherapeutic means:		
2nd post-operative week	• Oedema massage	• Oedema massage
	• Cryotherapy	• Cryotherapy
	• TENS	• TENS
	• Positioning therapy	• Positioning therapy
	• Grade 1 and 2 mobilisation of the patella	• Grade 1 and 2 mobilisation of the patella
	• PIR for shortened muscles	• PIR for shortened muscles
	• Passive ROM exercises	• Passive ROM exercises
	• Active exercises for adjacent joints	• Active exercises for adjacent joints
	• Assisted exercises for the lower extremity	• Assisted exercises for the lower extremity
	• Isometric contractions for thigh muscles	• Isometric contractions for thigh muscles
	• Training in walking without aids	• Training in walking without aids
3rd post-operative week	• Electrostimulation of weak muscles	• Electrostimulation of weak muscles
	• Gradual weight-bearing with the limb	• Gradual weight-bearing with the limb
	• Half squats in a closed kinetic chain	• Half squats in a closed kinetic chain
	• Exercises for lower leg muscles	• Exercises for lower leg muscles
	• Exercises against resistance	• Exercises against resistance
	• Extension in an open kinetic chain	• Extension in an open kinetic chain
	• Aerobic exercise bike workout	• Aerobic exercise bike workout
		• Proprioceptive training

Kinesiotherapy in the moderate protection phase (post-operative weeks 4-10).

During that period, equilibrium and coordination troubles, rapid fatigue and residual locomotor deficiency were still present. The measurements and tests were repeated for monitoring of body response to applied means. The orthosis was removed, the active ROM was increased. The swelling and pain were reduced whereas the thigh muscle strength was improved.

The KT goal during this phase was to achieve a good locomotor control during walking.

KT tasks:

1. Restoration of the full range of motion without pain;
2. Increase of muscle strength;
3. Achievement of dynamic control on stifle joint;
4. Training in walking without aids.

Table 2. Kinesiotherapeutic means applied in the control and experimental groups of patients following ACL reconstruction in the moderate protection phase.

MODERATE PROTECTION PHASE (post-operative weeks 4-10)	
Control group (n=18)	Experimental group (n=17)
Kinesiotherapeutic means:	
• Selective massage	• Selective massage
• Positioning therapy	• Positioning therapy
• Joint mobilisation techniques	• Joint mobilisation techniques
• Exercises in a closed kinetic chain	• Exercises in a closed kinetic chain
• Exercises against resistance	• Exercises against resistance
• Stretching	• Stretching
• Endurance exercises	• Endurance exercises
• Exercises against elastic resistance	• Exercises against elastic resistance
• Training in walking without aids	• Training in walking without aids
	• Proprioceptive training

Kinesiotherapy in the minimum protection phase
(post-operative weeks 11-24).

During this phase, the pain and swelling were completely eliminated, the active ROM was restored and the muscle strength – increased. Difficulties were noticed while performing some locomotor activities at a quick pace or during some specific movements.

The KT goal was complete recovery and preparation for return to the previous level of locomotor activities, including sports activities.

KT tasks:

1. Restoration of muscle strength and endurance;
2. Restoration of dynamic proprioception;
3. Achievement of neuromuscular control and dynamic stability.

Table 3. Kinesiotherapeutic means applied in the control and experimental groups of patients following ACL reconstruction in the minimum protection phase.

MINIMUM PROTECTION PHASE (post-operative weeks 11-24)	
Control group (n=18)	Experimental group (n=17)
Kinesiotherapeutic means:	
• Stretching	• Stretching
• Joint mobilisation techniques	• Joint mobilisation techniques
• Exercises against substantial resistance	• Exercises against substantial resistance
• High load exercises in a closed kinetic chain	• High load exercises in a closed kinetic chain
• Plyometric exercises	• Plyometric exercises
• Different walking modes	• Different walking modes
• Exercises for speed and agility	• Exercises for speed and agility
• Specific sports activities	• Specific sports activities
	• Proprioceptive training on unstable support

Methodical instructions, which were set and followed during the KT sessions of both groups included:

1. Use of various initial positions without forced increase of ROM of the affected joint until tolerable pain.
2. To follow the principle of gradual increase of load in line with the individual condition and recovery course of the patient.
3. Joint mobilisation techniques were included in the moderate protection phase, as in the maximum protection phase they are contraindicated because of the graft (Kraev, T., N. Popov, 2009).
4. The systematic performance of courses both in the rehabilitation centre and at home was monitored.
5. The load was increased by higher number of repetitions of each of exercises and weight-bearing increase.
6. For exercises with elastic bands, complexity of locomotor activities and load was achieved by increase of the resistance.

STUDY RESULTS AND ANALYSES

Results from the questionnaire survey for evaluation of locomotor deficiency during everyday life activities.

Before the start of the kinesiotherapy, the subjective condition of the study cohort following the surgical intervention was examined by a questionnaire survey. The questions were directed at determining the general level of locomotor capabilities, walking, the current condition and difficulties in everyday activities. The detailed results by groups are presented in Table 4.

Table 4. Distribution of patients from the study cohort according to their locomotor capabilities and limited activities.

Parameter	CG (n=18)	EG (n=17)	Total (n=35)	P	χ^2
Reduced locomotor activity				0.1303	4.076
• Entirely reduced	52.2% (n=10)	23.5% (n=4)	40.0% (n=14)		
• Partly reduced	39.2% (n=7)	58.9% (n=10)	48.6% (n=17)		
• Not reduced	5.6% (n=1)	17.6% (n=3)	11.4% (n=4)		
Walking				0.8695	0.027
• Independently	50.0% (n=9)	51.9% (n=9)	51.4% (n=18)		
• With an aid	50.0% (n=9)	47.1% (n=8)	48.6% (n=17)		
Difficulties in everyday activities				0.4686	1.516
• In all activities	28.0% (n=5)	17.6% (n=3)	22.9% (n=8)		
• Only in some activities	66.4% (n=12)	68.4% (n=11)	65.7% (n=23)		
• No difficulties	5.6% (n=1)	17.6% (n=3)	11.4% (n=4)		
Subjective evaluation of health status				0.1138	4.346
• Excellent	-	5.9% (n=1)	2.9% (n=1)		
• Satisfactory	44.4% (n=8)	70.6% (n=12)	57.1% (n=20)		
• Unsatisfactory	65.6% (n=10)	23.5% (n=4)	40.0% (n=14)		

Difficulties in performing all daily life activities were experienced by 28.0% (n=5) of CG patients and 17.6% (n=3) of EG patients. The highest rates were registered only with respect to some activities - in 66.4% (n=12) of CG and 68.4% (n=11) of EG. No difficulties were encountered by one CG patient (5.6%) and three EG patients (17.6%) ($\chi^2=1.516$; $P=0.4686$).

The results from questionnaire survey showed that almost all patients from both groups experienced difficulties in squatting, and climbing or descending stairs. Difficulties in walking was less frequently reported: in 62.5% (n=10) of EG and 47.1% (n=8) of CG patients. The distribution of patients from both groups with regard to change of initial position from standing into sitting was almost equal – 56.3% (n=9) for the EG and 58.8% (n=10) for the CG ($\chi^2=12.181$; $P=0.5918$).

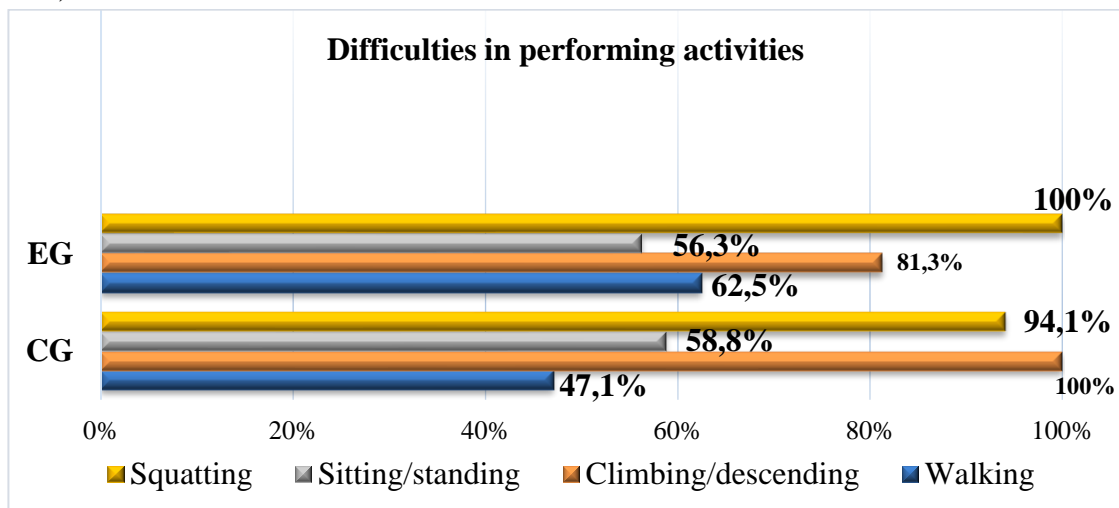


Fig. 3. Difficulties in performing everyday activities by groups.

The analysis of results demonstrates that the most common difficulties in daily activities were squatting, climbing and descending stairs. Difficulties in walking and during change of initial position from standing into sitting and vice versa were less common. The results from the survey showed that the locomotor activity in 88.6% (n=31) of respondents was entirely or partly reduced. This indicated poorer quality of life and substantial difficulties while performing daily living activities and selfcare. The unsatisfactory health condition has a negative impact on the psycho-emotional status and increased hypokinesia of patients following ACL reconstruction.

Results from pain evaluation and dynamics.

Characteristics of pain.

A detailed investigation of pain was performed according to all important characteristics – presence, intensity, localisation, character, time of onset. The

entire study cohort experienced pain before the beginning of the rehabilitation sessions ($\chi^2=0.707$; $P=0.4003$). In the CG, 38.90% ($n=7$) noted that pain was not constant, but appeared only while performing specific movements or under the influence of external factors. Patient with constant pain from this group were 61.10% ($n=11$). In the EG, 41.10% ($n=7$) of respondents were with constant pain and 58.90% ($n=10$): with occasional pain.

With regard to pain localisation, only 2.9% ($n=1$) indicated that pain was diffuse and changes its localisation. The other 97.1% ($n=34$) responded that pain was felt at a specific site in the stifle joint region – caudally to the patella ($\chi^2=0.001$; $P=0.9769$).

An important feature of pain is its character. Before the start of KT procedures, the majority of patients from both group have evaluated the pain as bearable – 58.9% ($n=10$) in the EG and 66.7% ($n=12$) in the CG. The share of patients with mild pain in the EG was 23.5% ($n=4$) vs 16.7% ($n=3$) in the CG. Intense, unbearable pain was present in 17.6% ($n=3$) of EG patients and 22.2% ($n=4$) of CG patients ($\chi^2=1.163$; $P=0.7619$).

The analysis of the results demonstrated that pain is an inevitable part of the postoperative clinical picture after ACL reconstruction surgery. It is a major limiting factor for the stifle range of motion and a cause of hypokinesia of the lower extremity. The pain was defined by the patients as mostly bearable, localised caudally to the patella. The highest proportion of study cohort was that of patients whose pain was intermittent and appeared after loading the limb.

Pain intensity and dynamics

Pain intensity was investigated three times through a visual analogue scale (VAS). During the first evaluation, patients, with pain score of 6 were the most numerous in the CG; in the EG, the highest number had a pain score of 7 ($P=0.2165$) (Fig. 4).

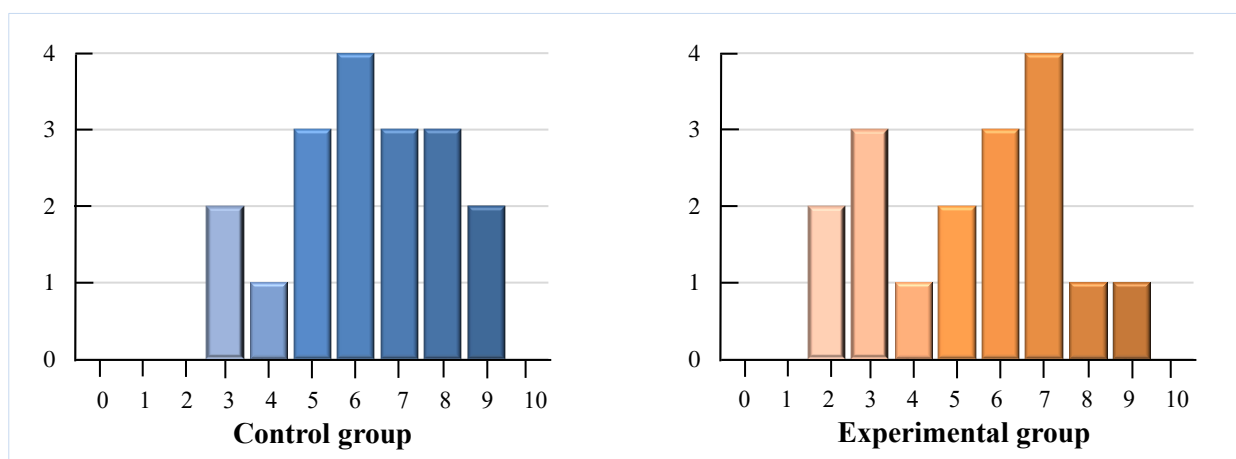


Fig. 4. Distribution of patients from both groups according to VAS scores of pain intensity – first measurement.

By the end of the recovery period, the last pain intensity evaluation showed reduction of pain in both groups with median values 1, range 0-3 ($P=0.4318$). Although minimal, EG patients showed lower pain scores at the end of recovery (Fig. 5).

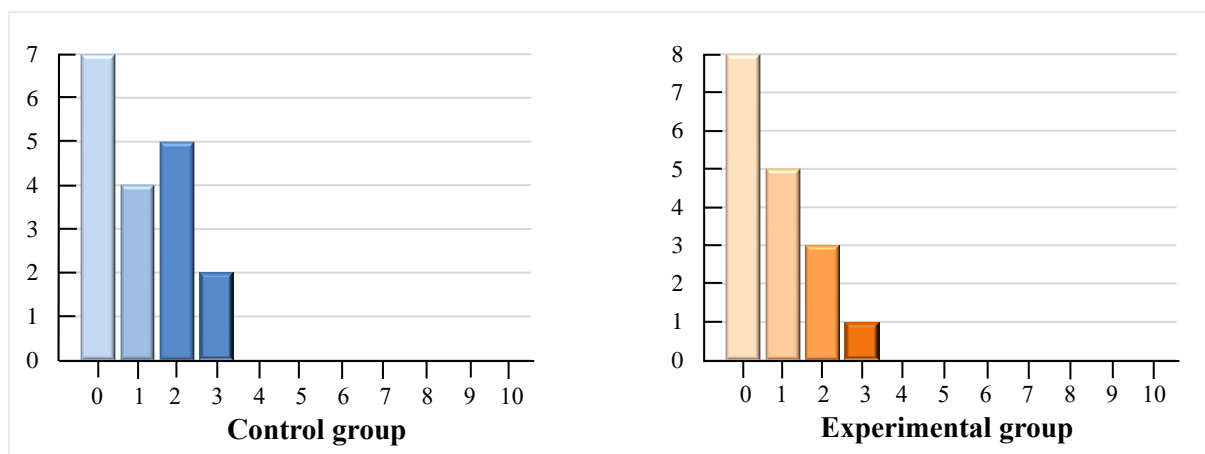


Fig. 5. Distribution of patients from both groups according to VAS pain intensity scores – third measurement.

The plot of pain intensity vs measurement day (Fig. 6) showed once again better results in the EG. Lower scores were registered in a larger part of the cohort. The comparison of time necessary for reduction of pain in the two groups demonstrated that scores in the EG decreased more rapidly than in the CG.

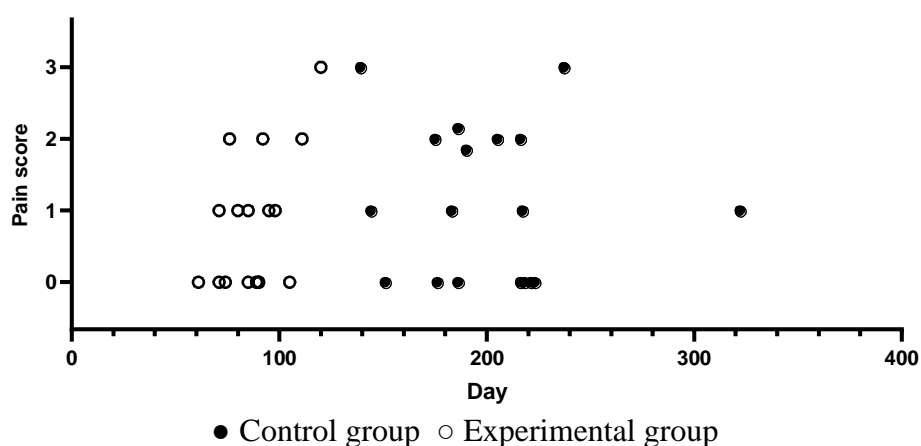


Fig. 6. Pain dynamics at the end of the recovery period.

The reduction of pain was achieved for a significantly shorter period of time in the experimental group compared to the control group. The results allowed affirming that the tested protocol resulted in shortening of the period

for attenuation of pain, which would have an effect on other parameters, e.g. ROM, muscle strength, daily life activities etc.

There was a statistically significant difference ($P=0.0309$) between the subjective evaluation of pain in patients with history of previous traumatic injuries (median score 6.5; range 3-9) and those without previous injuries (median 5; range 2-8). The patients with previous traumatic stifle injuries indicated a higher pain intensity (Fig. 7).

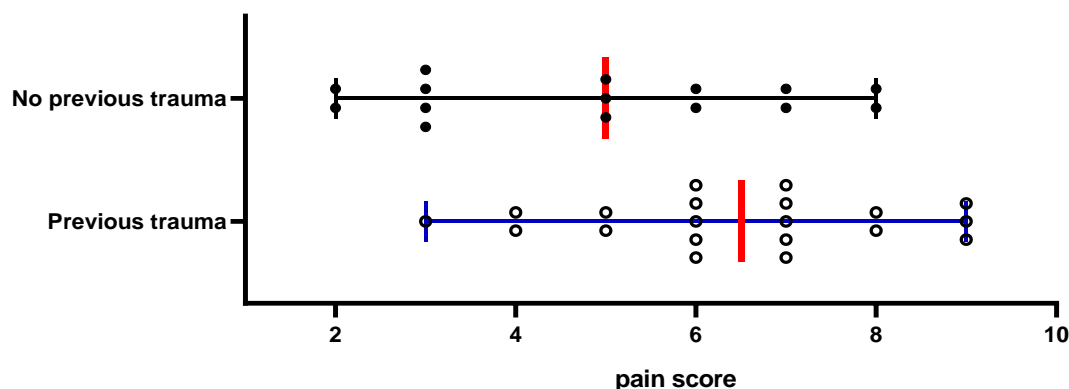


Fig. 7. Relationship between pain intensity and history of previous traumatic injuries.

The higher the pain scores of patients, the less satisfactory was the indicated health status ($P=0.019777$). In our opinion, this may be a prerequisite for lack of motivation for active participation in the recovery process and performing kinesiotherapy at home.

Results from anthropometric measurements of lower extremities.

The measurement of stifle joint circumference determined the presence of oedema – one of primary factors for impaired arthrokinematics and muscle hypertrophy. Fig. 8 presents a scatter plot of the relationship between variables.

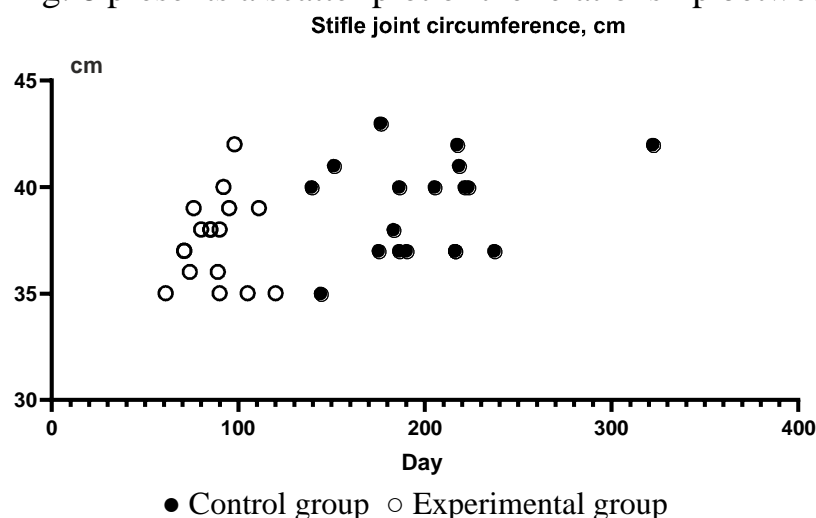


Fig. 8. Dynamics of stifle circumference at the end of the recovery period.

Reduction of periarticular swelling was observed in both groups, but it occurred considerably more rapidly in the EG compared to the CG patients.

The results indicated that the applied kinesiotherapeutic protocol in experimental group patients was more efficient in the complete reduction of stifle joint oedema following ACL reconstruction as early as the moderate protection phase. It may be also concluded that although the difference was small, the experimental protocol allowed a more rapid elimination of congestive events and swelling of lower extremities.

Results from goniometric measurements of lower extremities.

Goniometry was performed according to the standard SFTR techniques for measuring the active ROM of lower leg joints. The between-group comparison of stifle joint goniometry demonstrated statistically significant differences between the first and last measurement. The results are listed in Table 5.

Table 5. Stifle joint goniometry in patients after ACL reconstruction.

	First measurement		Second measurement		Third measurement	
Group	CG	EG	CG	EG	CG	EG
Stifle joint extension (°)						
Operated	5 (0-15)	5 (0-15)	5*** (0-15)	5** (0-10)	0*** (0-5)	0*** (0-5)
Healthy	0 (0-0)	0 (0-0)	0 (0-10)	0 (0-0)	0 (0-0)	0 (0-0)
P	P<0.0001	P=0.0002	P=0.0005	P=0.0010	-	-
Stifle joint flexion (°)						
Operated	90 (70-115)	95 (60-115)	100*** (70-115)	100*** (75-125)	120*** (100-125)	120*** (115-125)
Healthy	125 (115-125)	125 (110-125)	125 (120-125)	125 (115-125)	125 (120-125)	125 (115-125)
P	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P=0.0010	P=0.0413
*P<0.05; **P<0.01; ***P<0.001 vs first measurement.						

Results from the goniometric measurements of lower extremities

Fig. 9 illustrates a scatter plot of degrees of stifle joint flexion in relation to the day of last procedure. A tendency towards improved ROM of the joint in both groups was present, yet in the control group recovery took a longer time.

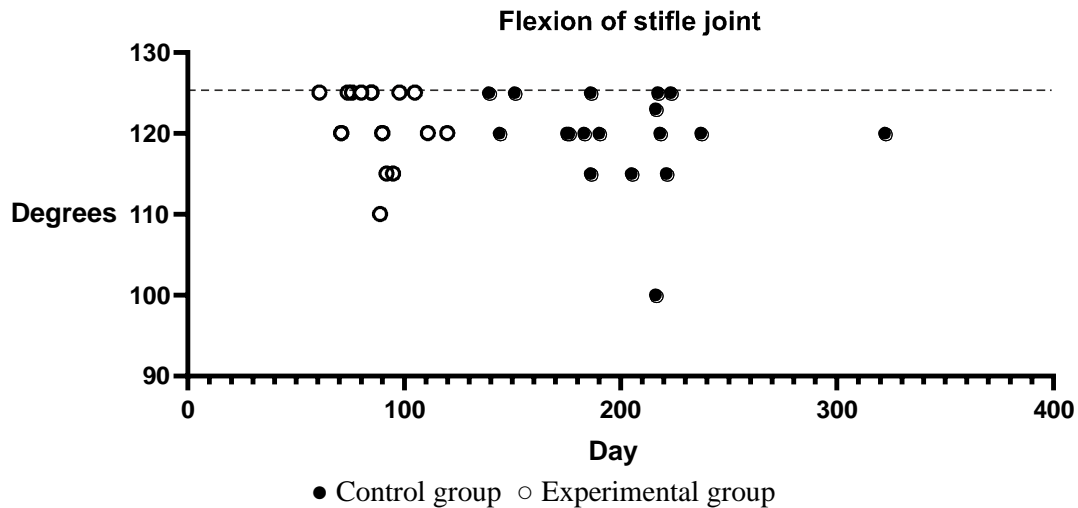


Fig. 9. Dynamics of stifle joint flexion at the end of the recovery period.

Patients treated with the experimental KT protocol demonstrated better results compared to those receiving the standard KT with respect to the time needed for achievement of normal stifle ROM.

Results from MMT of stifle flexors and extensors.

Before the KT, the MMT in both groups demonstrated decreased muscle strength of **stifle flexors** with median values of 1.75 for the CG and 2 for the EG ($P < 0.0001$). Increase in muscle strength occurred at the time of the second measurement, when MMT of CG was 2.75, and that of EG: 3. At the end of recovery period, a residual deficiency was yet present in the CG with median MMT value 4, which however did not compromise the normal movements of the lower limb. The muscle strength of EG patients was normal and equal to that of the contralateral limb. For most of measurements, the level of significance was lower than $P = 0.005$.

The median of initial muscle strength of **stifle extensors** in both groups was 2 ($P < 0.0001$). With application of the KT protocols, the strength increased to a median score of 3, succeeding in overcoming gravitational forces ($P < 0.0001$). By the end of recovery, normal muscle strength was attained in the two groups ($P = 0.0132$).

The time necessary for restoration of muscle strength of stifle joint flexors and extensors in both groups was monitored and compared. The results (Fig. 10) showed a superiority of the experimental protocol with enhanced proprioceptive training. In the EG patients, muscle strength was recovered significantly more rapidly. According to the change in MMT scores, similar results were obtained for muscle strength recovery of muscles involved in stifle extension.

Day

400

300

200

100

0

3 4 5

MMT

Flexors

Day

400

300

200

100

0

3 4 5

MMT

Extensors

● Control group ○ Experimental group

The analysis of results confirmed that the experimental KT protocol was more efficient for restoration of muscle strength to full symmetry with the contralateral limb. The recovery of stifle joint extensors was equally influenced in both groups and normal muscle strength was attained at the end of the therapy. Regarding the period necessary to overcome muscle weakness however, the protocol applied in the EG was once again superior.

The number of KT sessions (procedures) necessary for the complete recovery of the lower extremity after ACL rupture was investigated.

22

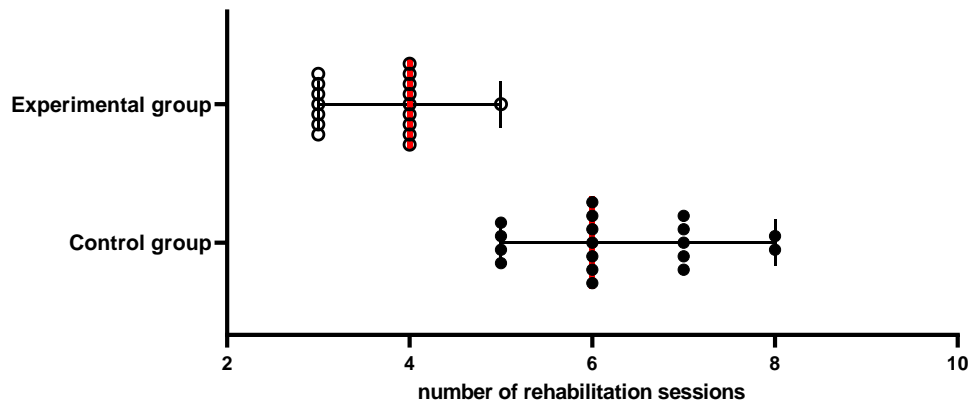


Fig. 11. Number of necessary rehabilitation sessions in both groups.

The analysis of results on the necessary number of KT sessions confirmed the supremacy of the experimental protocol and proved its high efficiency for reduction of the recovery time and return to the previous level of locomotor activity.

The association between the expectations of patients for recovery and the number of rehabilitation sessions was also investigated. A statistically significant differences ($P=0.022974$) was found out between median number of sessions in patients expecting complete recovery (4) and those expecting partial recovery with residual restrictions (6). The results are presented on Fig. 12.

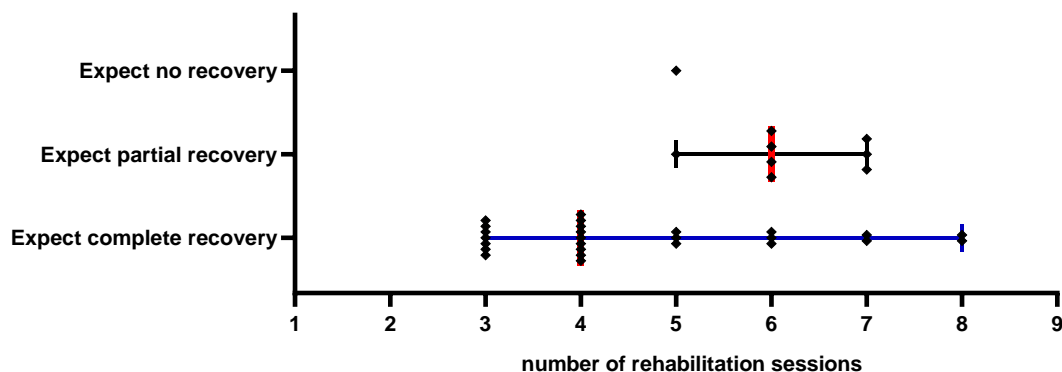


Fig. 12. Relationship between the number of necessary rehabilitation sessions and recovery expectations of the study cohort.

Presented data allowed affirming that the expectations and attitude of patients were directly associated with the time of recovery after ACL reconstruction. The number of rehabilitation sessions in patients with positive attitude about the recovery outcome was lower.

The obtained results and our current clinical experience with the recovery of patients following ACL reconstruction confirmed our expectations that the experimental KT protocol would contribute to reduction of the recovery period and would give more satisfactory results compared to the established kinesiotherapeutic methods. More satisfactory results were found out for anthropometric features, pain intensity, stifle joint mobility and muscle strength. This determines the patients' good psycho-emotional tone and their motivation for active participation in the recovery both in the medical facility and at home.

CONCLUSIONS

The detailed analysis of data from performed measurements and studies allowed concluding that:

1. The obtained results are not significantly different from the existing data in the Bulgarian and foreign literature. This gives reason to believe that they can be compared and weighed against other scientific studies on the subject.
2. The applied kinesiotherapeutic methodology with enhanced proprioceptive training resulted in accelerated recovery of muscle function, joint stability and improvement of the quality of life.
3. Proprioceptive exercises improve the effect of the integral kinesiotherapeutic protocol with respect to pain and oedema reduction.
4. Proprioceptive training allows for more rapid return to the level of motor activity prior to the trauma and significant shortening of the recovery period.
5. The in-home application of kinesiotherapeutic activities additionally strengthens and enhances the effect of KT procedures and recovery shortening.

RECOMMENDATIONS

On the basis of obtained results, the following recommendations to specialists working with patients after ACL traumatic injuries may be made:

1. Early inclusion of kinesiotherapeutic activities, ensuring as complete as possible recovery of the stifle joint complex.
2. Application of kinesiotherapy programmes to realisation of complete functional recovery.
3. Inclusion of proprioceptive exercises as element of the kinesiotherapeutic complex in order to accelerate the recovery.
4. Training of patients to perform in-home kinesiotherapy in order to prevent complications.

GENERAL CONCLUSION

The proprioceptive training plays a key role for accelerated functional recovery of the lower extremity. The methodology is successful and effective, particularly in terms of recovery time and number of treatment sessions. The results about the dynamics of the recovery are a unambiguous proof of the need for proprioceptive training in patients with ACL reconstruction due to the positive influence on the entire locomotor apparatus and improvement of the quality of life of patients. The proprioceptive training contributes to shorter recovery period and helps the more rapid return to sports activities. The general physical condition and psycho-emotional health is improved.

CONTRIBUTIONS

Theoretical scientific contributions:

1. Scientific theories and results from contemporary national and international studies investigating the recovery from traumatic soft tissue injury of the knee, after operative treatment were systematised.
2. The clear positive therapeutic effect of proprioceptive training for overcoming muscle imbalance, limited range of motion and functional deficiency was proven.
3. The effect of proprioceptive training on the required recovery time and the number of rehabilitation sessions was studied and proven.
4. The theoretical basis of kinesiotherapy was broadened by development of updated programmes for recovery after ACL reconstruction and studies on the beneficial effects of proprioceptive exercises.

Practical scientific contributions:

1. Questionnaires and functional test cards for collection of comprehensive information about the initial condition of patients and the results from the performed KT procedures were developed.
2. An effective kinesiotherapeutic algorithm with significant participation of proprioceptive training for patients after ACL reconstruction was developed.
3. It was proven that the applied model contributes to a more rapid and more satisfactory recovery of the stifle joint complex. Amateur and professional sports activities are successfully resumed over a shorter period of time.
4. A project for an innovative online platform supporting both the in-home kinesiotherapy of patients with traumatic soft tissue knee damage, as well as for control on the recovery process by therapists was developed.

PUBLICATIONS ASSOCIATED WITH THE DISSERTATION

- 1. Taneva-Georgieva, N.** Influence of pain on the recovery process after soft tissue injury in the knee joint. Knowledge, 2023, Vol. 61.4, p. 713-720.
- 2. Taneva-Georgieva, N., R. Paskaleva.** Subjective evaluation as stimulating factor of the recovery process. Varna Medical Forum, 2023, vol. 12, p. 92-95.
- 3. Taneva-Georgieva, N., R. Paskaleva.** Application on innovative technologies in kinesitherapy in recovery of traumatic injuries of the knee joint. Knowledge, 2022 Vol. 55.4, p. 687-691.