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The effect of eccentric loading on pain syndrome and range of motion in individuals with knee joint dysfunction

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Abstract. Currently, there is an increasing number of patients presenting with complaints of pain and limited mobility of the knee joint. The search for effective methods of restoring function in the early stages of osteoarthritis is becoming increasingly relevant. The aim of this study was to identify a possible relationship between pain intensity and eccentric contraction parameters in individuals with knee joint dysfunction. An experiment was conducted at a medical centre to study the eccentric mode of muscle contraction in knee osteoarthritis. During the rehabilitation sessions, emphasis was placed on the eccentric phase of quadriceps femoris muscle contraction. Myograph readings and pain levels assessed via a visual analog scale (VAS) were evaluated before and after the experiment. The mean amplitude of eccentric quadriceps contraction increased more than twofold: for instance, in the vastus lateralis muscle, it rose from 98.7 μV to 298.4 μV. Upon completion of the exercise course, full knee joint extension was recorded in six out of nine participants. All subjects demonstrated a reduction in pain syndrome intensity, with pain disappearing completely in two individuals. The study results showed that the eccentric mode of muscle contraction contributes to a reduction in pain levels and an increase in electromyographic activity indicators. This regimen facilitates the development of muscle strength and neuromuscular control during movement, as well as a reduction in mechanical load on the articular cartilage. The data obtained indicate that eccentric exercises for the quadriceps femoris muscle in the early stages of knee osteoarthritis can be effective, as they simultaneously address the cause (muscle weakness) and the consequence (pain, range of motion deficit). The results can be utilised in the development of individualised rehabilitation programs for patients with early-stage knee osteoarthritis

Keywords: gonarthrosis; electromyography; musculoskeletal system; negative phase; knee pain

INTRODUCTION

The number of complaints regarding pain and restricted mobility of the knee joint, as well as the dysfunctions themselves, is steadily growing among the population. The relevance of this study is driven by the need for an in-depth understanding of the complex interrelations between the subjective and objective manifestations of knee joint dysfunction and the potential for influencing them through eccentric loading. Of particular importance is the identification of the mechanisms through which such loads affect the musculoligamentous apparatus and joint biomechanics. The insufficient study of these processes limits the effectiveness of existing rehabilitation approaches and necessitates further research. The results obtained may contribute to the optimisation of recovery and prevention programs for knee joint dysfunction.

F. Sharif *et al.* [1] conducted a systematic review examining the effects of eccentric and isometric loading

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and dry needling on patellar tendinopathy. The findings of this review indicate that dry needling and eccentric exercises are more effective for the long-term reduction of pain and improvement of knee joint function, whereas isometric exercises are more beneficial for short-term pain relief, especially during sports activities. C.Y. Zeng *et al.* [2] noted that therapeutic physical exercise, as an adjunctive physiotherapy method, helps prevent cartilage degeneration, suppress inflammation, and reduce the loss of subchondral bone and metaphyseal trabecular bone. There is growing evidence that therapeutic physical exercise reduces pain, stiffness, dysfunction, and muscle weakness in knee osteoarthritis. The modalities of such physical exercise are diverse: aerobic exercises, strength training, neuromuscular exercises, balance training, proprioceptive training, aquatic exercises, and traditional exercises.

R. Gérard *et al.* [3] investigated the effects of an eccentric strength training program for the hamstring muscles, performed by healthy adults for a minimum of 4 weeks, on muscle structure and eccentric strength. Randomised controlled trials comparing isolated eccentric strength training of the biceps femoris muscle to other programs were reviewed. The review findings revealed that in healthy adults, the eccentric strength training program led to structural changes in the long head of the biceps femoris and increased eccentric hamstring strength.

In a randomised controlled trial, D. Karabay *et al.* [4] studied the effects of eccentric versus concentric exercise regimens on subacromial pain syndrome. The results of this study showed that the eccentric regimen increased abduction strength to a greater extent than the concentric regimen but had no effect on pain levels. S.A. Harper & B.J. Thompson [5] noted that eccentric exercise possesses several promising properties for such an approach, as it effectively induces overload during contractions, which can lead to significant neuromuscular adaptations. When used within a minimal-load resistance training paradigm, eccentric exercise may represent a particularly promising approach for older adults, enabling effective increases in muscle mass, strength, and functional performance. One approach that may lead to improved neuromuscular function and overall health is the enhancement of exercise tolerance, which will promote more active participation of older adults in training.

In a randomised controlled trial, E. Hanci *et al.* [6] assessed the effect of a 4-week eccentric training program for the peroneal muscles in patients with chronic ankle instability. The study did not directly investigate the effect on range of motion; however, the increases in strength and dynamic range control were key outcomes. The results demonstrated that training with eccentric exercises can positively influence neurophysiological parameters in patients with joint instability, suggesting improvements in functional stability and control throughout the full range of motion. The duration of these neurophysiological adaptations remains unclear.

The application of this mode of muscle contraction and its comparison with others for the rehabilitation of tendinopathies has been described in several scientific papers. D.J. Jayaseelan *et al.* [7] investigated the effects on patellar and Achilles tendinopathy. For Achilles tendinopathy, eccentric exercises have demonstrated effectiveness, and the "Alfredson protocol" focuses primarily on exercises in this mode. For athletes, an emphasis on eccentric exercises allows for the enhancement of athletic performance by increasing explosive strength and speed-strength qualities, as noted by O. Younes-Egana *et al.* [8]. Most studies on this topic are short-term; the long-term effects, as well as the impact on injury prevention, have not been studied. There is also an opinion that for elite athletes, an emphasis on a specific mode of muscle contraction provides only a marginal advantage. The effect on pain was investigated in a study by S. Holden *et al.* [9]. Patients with knee pain were asked to perform a single session of quadriceps femoris exercises, both isometric and eccentric. Pain was assessed using the VAS scale. The study results showed that isometric exercises significantly reduced pain syndrome, whereas eccentric exercises did not lead to a significant change.

Despite the importance of each component (pain, range of motion, muscle function), the interrelation between the subjective perception of pain, the objective limitation of mobility, and the neurophysiological parameters of eccentric contraction in knee joint dysfunction has not been sufficiently comprehensively studied. This study aimed to determine the relationship between pain intensity and eccentric contraction parameters in individuals with knee joint dysfunction. The research objectives were as follows:

- to determine the subjective perception of pain in the subjects;
- to conduct a spectral analysis of the data recorded by the electromyograph;
- to evaluate the relationship between subjective indicators and the electromyogram of the quadriceps femoris muscle in the eccentric mode.

MATERIALS AND METHODS

To address the set objectives, the following methods were employed: a visual analog scale (VAS) was used to quantitatively assess pain intensity; surface electromyography (sEMG) was utilised to determine the electrical potential of the quadriceps femoris muscle (vastus medialis, vastus lateralis, and rectus femoris). The study employed an eight-channel Russian-manufactured electromyograph, model KBK BP-08-4. The interpretation of the obtained results was performed using the EMGAnalyzer software. A Root Mean Square (RMS) transformation was applied to the EMG

signals with a 1,000 ms window (empirically selected to smooth the signal without losing significant changes). The RMS unit of measurement is microvolts (μV). The choice of RMS is justified by the fact that this parameter is the standard for assessing EMG signal amplitude during isometric and isotonic contractions, reflecting the aggregate activity of motor units. Figure 1 illustrates the schematic diagram of electrode placement on the muscles during the study. Electrodes (disposable, Ag/AgCl, inter-electrode distance 20 mm) were placed parallel to the muscle fibre direction on the bellies of the respective muscles, in accordance with the SENIAM recommendations: for the vastus medialis – 2 cm medial to the upper edge of the patella at a 50° angle; for the vastus lateralis – 3 cm lateral and superior to the patella; for the rectus femoris – at the midpoint between the anterior superior iliac spine and the upper pole of the patella. The reference electrode was fixed on the lateral epicondyle of the femur. The study was conducted at the "Ariadna" Medical Centre, located at 19 Shmitovskiy Proezd, Moscow, Russia. The experimental period lasted from June 1, 2025, to July 31, 2025.

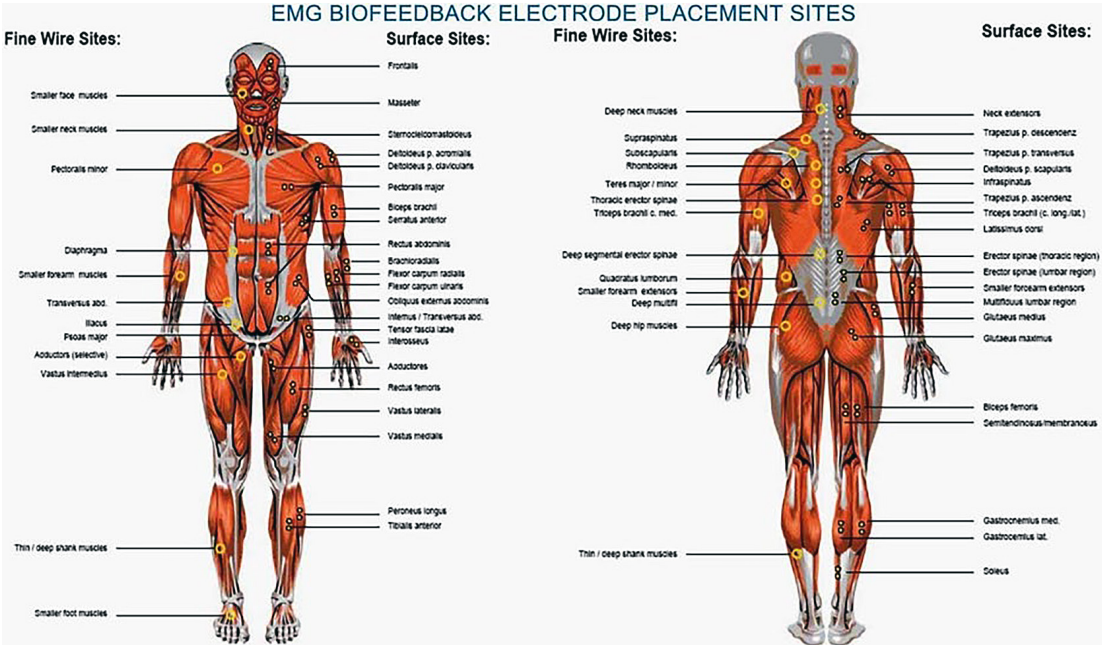

Figure 1. Electrode placement scheme on the muscles

Source: authors' development

The sample comprised 9 individuals aged 44-60 years, 7 women and 2 men. All subjects had knee joint dysfunction and were diagnosed by a physician with grade 1-2 gonarthrosis. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki [10] and was approved by the local ethics committee of the "Ariadna" Medical Centre. Study Protocol No. 2, dated June 06, 2025. All participants were informed in advance about the objectives, potential risks, and conditions of participation and signed voluntary informed consent. The subjects' personal data were processed confidentially and used exclusively for scientific purposes.

The study design involved pre- and post-testing in a single group (before-after). A control group was not included due to the pilot nature of the work; the intervention effect was evaluated by comparison with each participant's baseline level. Subjects were asked to perform a knee extension exercise in eccentric mode: 12 repetitions, 4 sets, with a 2-minute rest interval. The effort was exerted with maximal possible force, but without pronounced pain (not exceeding 4 points on the VAS). Baseline testing was conducted prior to the start of the experiment (before 12:00 PM to control for circadian rhythms). The eccentric phase was provided by manual resistance applied by the instructor.

To standardise the load and ensure reproducibility of conditions:

1. all sessions were conducted by the same instructor, who had undergone preliminary training;

2. manual resistance was applied distally (at the ankle joint) with the thigh in a fixed position;

3. the resistance magnitude was regulated subjectively using the Borg Rating of Perceived Exertion scale (6-20) with a target value of 15-17 ("hard"), also taking into account the VAS (≤4 points);

4. to minimise variability, each set was performed through an identical range of motion (from full extension to 90° of flexion), with control maintained by a goniometer;

5. during the course, as pain diminished, manual resistance was increased while maintaining pain control (also up to 4 points on the VAS).

Prior to each session, all subjects underwent a 15-minute massage of the anterior thigh and quadriceps stretching using the post-isometric relaxation method (1 set, 5 repetitions). After a treatment course of 12 sessions (every other day), post-testing was performed following the same protocol as the baseline. To control for confounding factors: analgesic intake was excluded 24 hours before each testing session (confirmed by verbal inquiry); all testing was conducted at the same time of day (morning) under identical environmental conditions. Student's t-test was used to compare pre- and post-intervention indicators.

RESULTS

The development and progression of gonarthrosis are driven by a complex of interrelated factors. Among the main causes are physical inactivity, leading to weakening of the muscular corset and deterioration of cartilage trophism, as well as obesity, which mechanically increases the load on joint surfaces and contributes to chronic inflammation of adipose tissue. E.K. Ermolenko & T.G. Grichanova [11] write that impaired gait biomechanics can negatively affect the entire body. However, the key link closing the vicious circle is pain syndrome. Pain is the primary subjective symptom that directly limits daily activity, reduces working capacity, and impairs the quality of life of patients. In response to pain, restricted mobility emerges – an objective sign of dysfunction. This manifests as altered walking biomechanics (reduced knee flexion angle during the swing phase), a pathological pattern of ascending and descending stairs (compensatory straightening of the leg and shifting the load to the healthy limb), and redistribution of muscle activity [6].

In this context, the eccentric mode of muscle contraction becomes particularly significant. Unlike concentric (muscle shortening under load) or isometric (no change in length), the eccentric mode is characterised by the lengthening of an actively tensed muscle. It is precisely this mode that provides two effects critically important for the knee joint. First, eccentric work of the quadriceps femoris is necessary for stabilising the knee during the stance phase of gait, especially when descending stairs, where the muscle, while lengthening, controls joint flexion and prevents excessive flexion. Second, U. Proske *et al.* [12] and J. Douglas & D. Morgan [13] wrote that this mode serves as a physiological shock absorber: the muscle dampens impact loads arising at heel strike, thereby protecting the articular cartilage from excessive compression and micro-damage.

In a systematic review, S. Hody *et al.* [14] demonstrated that eccentric exercises lead to a more pronounced increase in strength and muscle mass compared to concentric exercises, even with a lower training volume. The authors attribute this phenomenon to delayed onset muscle soreness (DOMS). DOMS arises from micro-damage to myofibrils and the basal membrane, triggering a local inflammatory response and subsequent supercompensation of structural proteins. It is important to emphasise that DOMS is not a harmful side effect but the primary driver of unique neuromuscular adaptations: the number of satellite cells increases, the synthesis of contractile proteins (actin and myosin) is enhanced, and muscle architecture (pennation angle and fascicle length) improves. However, for this effect to be realised, proper load dosing and training periodisation are necessary, otherwise DOMS transitions into pathological overstrain. J.M. Foley *et al.* [15] indicate that eccentric exercises induce greater hypertrophy than isometric or concentric contractions and require less metabolic energy and cardiovascular load, making them particularly suitable for older adults and individuals with chronic conditions.

With regard to the population, S. Hody *et al.* [14] specifically note the efficacy of eccentric programs in individuals with sarcopenia (age-related muscle loss). It was found that such training effectively counteracts fatty muscle degeneration – a process in which myocytes are replaced by adipocytes, leading to functional weakness and reduced metabolic activity. In patients with gonarthrosis, who frequently exhibit quadriceps sarcopenia, the eccentric regimen may serve as a pathogenetically grounded method for restoring muscle balance and reducing pain by improving joint stability.

The results presented below are aimed at quantifying the changes in bioelectrical activity of the quadriceps muscle and pain syndrome following a course of eccentric exercises combined with massage and stretching in patients with grade I-II gonarthrosis. Figure 2 demonstrates the mean electromyographic amplitude of eccentric quadriceps femoris contraction: the rectus femoris increased its values from 87.1 μV to 163.2 μV, the vastus lateralis from 98.7 μV at baseline to 298.4 μV at the end, and the vastus medialis from 59.3 μV before to 220.7 μV after the experiment.

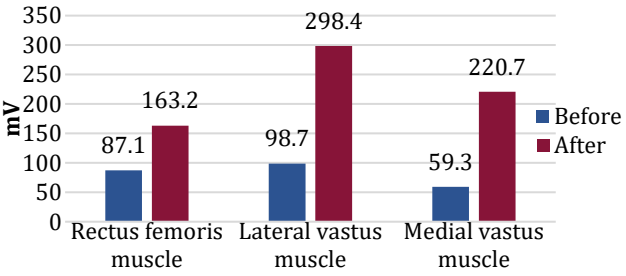

Figure 2. Mean amplitude of eccentric quadriceps contraction

Source: developed by the authors

EMG results for the quadriceps femoris muscle show that the increase in mean EMG amplitude for each head has important functional significance. The increase in EMG amplitude of the rectus femoris indicates its active participation in knee joint extension,

which is important for performing movements requiring strength and power, such as jumping and sprinting. The growth in vastus lateralis activity testifies to its role in stabilising the knee joint during dynamic loads, which is critical for injury prevention and ensuring proper movement mechanics. Similarly, the increase in EMG amplitude of the vastus medialis points to its involvement in knee stabilisation, especially during eccentric movements such as downhill walking or landing after a jump. The increased activity of the vastus medialis can be linked to its function in supporting overall knee joint stability and load distribution among the other heads.

The pronounced increase in the activity of the vastus lateralis and vastus medialis muscles can be explained by the need for improved knee joint stabilisation during eccentric exercise performance. These muscles help control knee movement and prevent lateral displacement, which is critically important for injury prevention. During eccentric exercises, the load on the four heads can be redistributed, leading to an increase in the activity of the vastus lateralis and vastus medialis. This is important for the proper distribution of force and preventing overload of other muscles. Furthermore, the increase in the activity of these muscles may result from adaptation to eccentric work regimes, allowing the muscles to better cope with loads and increase their strength.

The presented results demonstrate an increase in the mean EMG amplitude of all three heads of the quadriceps femoris muscle following a course of eccentric exercises. The most pronounced increase was recorded for the vastus lateralis (from 98.7 to 298.4 μV) and vastus medialis (from 59.3 to 220.7 μV) muscles, which aligns with the literature data on the activation of these muscles during loads requiring knee movement control. However, it should be emphasised that the observed increase in EMG amplitude is an empirical fact, whereas its interpretation in terms of "improved stabilisation", "load redistribution", or "adaptation" represents a hypothetical explanation. It cannot be ruled out that the increase in electrical activity is partially due to a reduction in pain syndrome (allowing subjects to generate greater effort without pain inhibition), individual differences in exercise technique, or variability in subjectively perceived resistance. Further research, including, in particular, the analysis of kinematic movement parameters and the assessment of joint torque, is required to confirm the hypothesis of functional reorganisation of muscle coordination and improved dynamic joint stabilisation.

Analysis of the EMG results for the maximum amplitude of the quadriceps femoris muscle (Fig. 3) demonstrates differences in the average EMG amplitude change for each head. The rectus femoris muscle showed the smallest increase, from 213.6 μV to 263.8 μV, indicating its stable but minor activity in eccentric conditions. In contrast, the vastus lateralis muscle demonstrated significant amplitude growth, increasing from 239.1 μV to 497.1 μV. This points to its important role in ensuring knee joint stability and adaptation to eccentric loads, which may be critical for injury prevention and movement mechanics optimisation. The vastus medialis muscle also exhibited a notable increase, raising its values from 150.5 μV to 371.5 μV. This confirms its active participation in controlling and stabilising the knee joint during eccentric exercise performance. The difference in activity between the muscle heads can be explained by their specific functions in ensuring knee stability. The vastus lateralis and vastus medialis muscles, as key stabilisers, are activated in response to eccentric loads, enabling them to distribute force more effectively and reduce injury risk. The rectus femoris, although active, does not demonstrate the same level of adaptation, which may indicate a more limited role in this context. Overall, the increase in the activity of the vastus medialis and vastus lateralis muscles reflects their ability to adapt to eccentric work regimes, contributing to the improvement of their functional characteristics and overall strength.

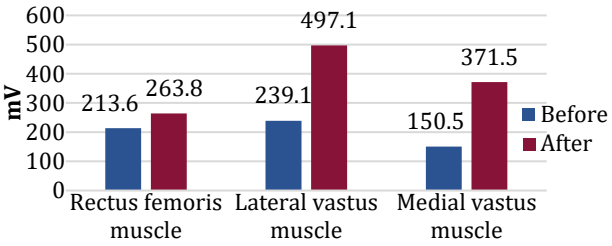

Figure 3. Maximum amplitude of eccentric quadriceps contraction

Source: developed by the authors

Analysis of the electromyography results for the maximum amplitude of the quadriceps femoris muscle (Fig. 3) demonstrates an increase in the mean EMG amplitude for all three heads following the course of eccentric exercises: rectus femoris – from 213.6 to 263.8 μV, vastus lateralis – from 239.1 to 497.1 μV, vastus medialis – from 150.5 to 371.5 μV. The largest increase was registered for the vastus lateralis and vastus medialis muscles. It should be emphasised that the presented data reflect only the change in muscle electrical activity under the conditions of the study and do not allow for a definitive causal relationship to be established with improved knee stabilisation, load redistribution, or reduced injury risk. Assertions about the specific functional role of individual heads, as well as adaptation to the eccentric work regime, are hypothetical in nature and require further confirmation in studies with a control group and assessment of dynamics over time. The obtained EMG amplitude values could have been influenced by methodological factors: variability in exercise performance, the

subjective nature of external resistance, the baseline level of pain, and individual electrode placement characteristics. Thus, the identified increase in EMG activity should be considered an objective empirical fact, whereas its interpretation in terms of functional reorganisation of muscle coordination remains a hypothesis requiring further investigation. Figure 4 presents the results of pain levels according to the VAS scale. Pain syndrome decreased in all participants by the end of the experiment.

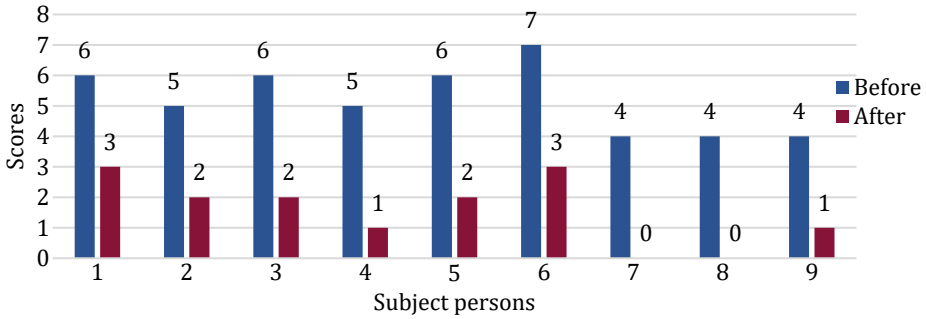

Figure 4. Results of the VAS pain assessment

Source: developed by the authors

Before the intervention, the mean indicator value was 5.22 with a standard deviation of 1.09, and the median was 5.0. After the intervention, the mean decreased to 1.56 with a standard deviation of 1.13, and the median was 2.0. The paired Student's t-test results showed that the mean difference reached -3.67, which corresponds to a 3.67-point reduction. The standard error of the difference was 0.17, and the p-value was less than 0.001, indicating the statistical significance of the obtained changes. The effect size was expressed as an absolute reduction of 3.67 points (95% CI: 3.28-4.05) and a relative decrease of 70.2% from the baseline mean level. Quantitative analysis confirms the observed dynamics. The mean pain level before the intervention was 5.22 ± 1.09 points (M ± SD), with a median of 5.0 points. After completing the eccentric loading course, the mean decreased to 1.56 ± 1.13 points, with a median of 2.0 points. The variability indicators (standard deviations) remained comparable, indicating the preservation of individual differences in response to the load with an overall positive trend.

To verify the statistical significance of the changes, a paired Student's t-test was applied. The analysis revealed a highly significant reduction in pain level: $t(8) = 21.76$, $p < 0.001$. The absolute reduction in the mean VAS score was 3.67 units (95% confidence interval: 3.28-4.05), which corresponds to a relative decrease in pain syndrome severity of 70.2% compared to the baseline level. The reduction in pain syndrome following eccentric exercises may be associated with improved movement control, a reduction in the inflammatory component, and adaptation of muscle-tendon structures. The experimental results show heterogeneity in pain reduction among the participants, which may be due to differences in baseline pain levels. The obtained data are consistent with the known rehabilitative effects of eccentric loading in gonarthrosis. Studies show that eccentric exercises can lead to a significant reduction in pain syndrome and improvement in the functional state of joints. In particular, they help strengthen the muscles supporting the joint and contribute to improving its stability.

Figure 5 presents the change in the flexion angle for each patient before and after the course. Quantitative analysis confirms the visually observed increase in mobility. Before the intervention, the mean flexion range was 109.3° (median 106°, standard deviation 10.45°), indicating moderate variability in baseline values. After the course, the mean flexion angle increased to 129.3° (median 130°, SD 6.25°), while the spread of results decreased, indicating a more homogeneous response to therapy. The absolute gain averaged 20.0° (ranging from 10° to 27° among the subjects), and the relative increase was 18.3% of the baseline level. The paired t-test for dependent samples revealed a highly significant difference between pre- and post-intervention indicators ($t = 10.87$, $df = 8$, $p < 0.001$). Thus, the course of eccentric exercises combined with massage and stretching leads to a statistically significant improvement in the flexion function of the knee joint in patients with grade I–II gonarthrosis. Figure 6 presents the results of knee joint extension. The extension deficit (limitation of full leg straightening) was assessed in degrees. Its reduction reflects the restoration of normal biomechanics. Before the sessions, the mean deficit was 9.78° (median 10°, SD 4.06°), with two patients reaching 14-16°. After the course, the mean value decreased to 1.33° (median 0°, SD 2.06°), with the deficit being completely eliminated (0°) in six out of nine participants, and reduced to 3-5° in the remaining ones. The absolute reduction in deficit averaged 8.44°, corresponding to a relative improvement of 86.3% from the baseline value. Paired comparison using the Wilcoxon test (due to non-normal distribution after

the intervention) also confirmed the significance of the changes (Z = -2.67, p = 0.008; for the t-test: t = 9.24, p < 0.001). These data indicate a pronounced clinically significant effect of the intervention aimed at restoring the full range of extension, which is a key factor for normal gait and standing stability.

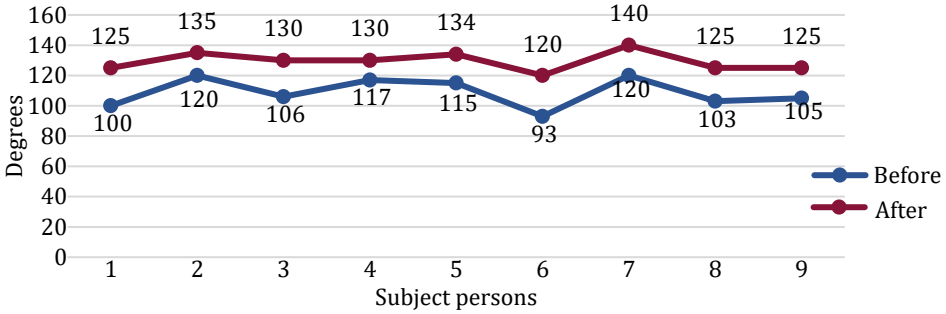

Figure 5. Knee joint flexion range of motion

Source: developed by the authors

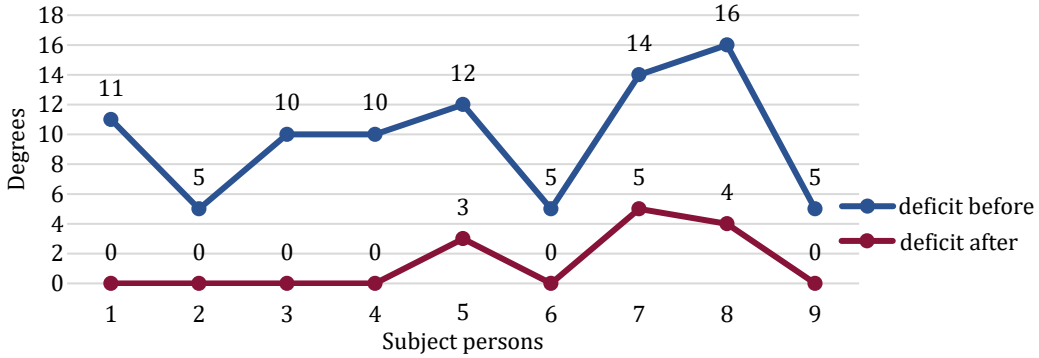

Figure 6. Knee joint extension range of motion

Source: developed by the authors

The conducted study represents an initial stage aimed at evaluating the efficacy of a short-term course of eccentric exercises for the quadriceps femoris muscle in patients with grade 1-2 gonarthrosis (n = 9). The study employs standard tools for rehabilitation research: subjective assessment of pain using VAS, objective goniometry, and surface electromyography for the analysis of muscle activation. The obtained results demonstrate positive dynamics across all three parameters: a significant reduction in pain syndrome, an increase in the range of motion (both flexion and extension in the knee joint), and a rise in EMG amplitude, particularly in the vastus medialis and vastus lateralis muscles. Based on this study, it is possible to suggest the method's efficacy, explaining it through neuromuscular, morphofunctional, and biomechanical components.

DISCUSSION

The scientific research by E. Hanci *et al.* [6] on the ankle joint is methodologically similar. Their studies also employ methods consistent with the modern approach to evidence-based rehabilitation, which requires a combined assessment of subjective (pain, function) and objective (biomechanical, neurophysiological) parameters. This involves the use of the VAS, goniometry, and EMG triad. P.R. Camargo *et al.* [16], in their work on shoulder impingement, use methods distinct from the present study. That study employed ultrasound examination and a multitude of orthopaedic tests. The work also differs in its larger sample size and longer study duration (6 weeks, with sessions every other day). Ultrasound examination can reveal tendon integrity, degenerative changes, muscle fiber thickness, micro-damage, and the like. In similar studies, this method can be of high value.

S. Holden *et al.* [9] investigated the effect of isometric exercises on knee joint pain. The study results showed that knee pain in the subjects decreased significantly. These findings may suggest that a well-designed training regimen can reduce pain syndrome regardless of the mode of muscle contraction. It is also worth noting that the study examined the effect of the isometric regimen on patellar tendinopathy; based on this, one can assume that a particular mode of muscle contraction may be more effective for different diagnoses. The focus on joint pathology (gonarthrosis) and the application of eccentric training to improve its function directly relates to the work of D. Stasinopoulos *et al.* [17], who studied tendinopathies. A common feature is the

aim to prove that controlled eccentric loading, contrary to the potential risk of increasing pain, leads to its reduction and improvement of objective indicators.

Similar results in the interpretation of EMG data are found in the work of P. Correia *et al.* [18], concerning the possible consequences of insufficient eccentric hamstring strength. The results regarding the greatest increase in the activation of the vastus medialis and vastus lateralis muscles, which are key dynamic stabilisers of the knee joint, coincide with the findings of P. Correia *et al.*, who identified an activation deficit of specific hamstring muscle heads after injury. This supports the hypothesis that the positive effect of eccentric exercise is largely mediated not merely by an increase in strength, but by the normalisation of the motor unit recruitment pattern and improved joint control.

B.A. Baxter *et al.* [19], in a randomised controlled trial, indicate that one weekly session of submaximal eccentric resistance training over 12 weeks leads to the same improvements in neuromuscular function as the currently recommended twice-weekly training. Considering the significant improvement in neuromuscular function and the previously identified low adherence to current twice-weekly training recommendations, eccentric training may play a key role in developing a minimal-dose strategy to prevent neuromuscular decline. This study has substantial differences, for instance, a larger sample size (n = 36), the inclusion of a control group, and an experimental duration of 12 weeks. The similarities with the present study lie primarily in the investigation of the influence of the eccentric regimen and the assessment of thigh muscles.

The works by E. Hanci *et al.* [6], D. Stasinopoulos *et al.* [17], and the present study share a similar methodology, results, and data interpretations. Their difference lies in the fact that the aforementioned studies are large-scale investigations designed as randomised controlled trials, including a control group performing other exercises or receiving standard therapy. These works also consider larger sample sizes. The present study, as mentioned above, is an initial stage, and judgments regarding the efficacy of the proposed methodology are preliminary. In a study on the impact of isokinetic eccentric exercises on strength, muscle volume, and postural stability, A.D. Kay *et al.* [20] reach similar conclusions that eccentric exercises contribute to the improvement of thigh muscle function. The author also notes an increase in the strength and volume of the knee extensor muscles. The main difference from the present work is the examination of postural stability, on which exercises in the selected mode had no effect, the author notes. It is worth noting that the authors used the ultrasound method. A similar research object can be found in the work of J.P. Gordon *et al.* [21], regarding the eccentric mode of muscle contraction and its effect on functional indicators. Both articles view eccentric exercises as a powerful training stimulus. A similarity is observed in the evaluation of their key role in joint stabilisation and movement biomechanics improvement, which in the present study is directly linked to pain reduction.

CONCLUSIONS

Eccentric training of the quadriceps femoris muscle demonstrates high efficacy in patients with stage I-II knee osteoarthritis, as confirmed by the dynamics of subjective indicators (pain syndrome). The development of strength and control through these exercises contributes to a significant improvement in functional status.

The positive effect is complex in nature. The neuromuscular component is conditioned by an enhanced ability of the CNS to recruit muscle fibres, including the stabilisers of the knee joint – the vastus lateralis (239.1 μV before the intervention, 497.1 μV after) and vastus medialis (150.5 and 371.5 μV, respectively) heads of the quadriceps muscle, which ensures control during the eccentric phase of movements. The morphofunctional component is expressed in an increase in muscle strength, enabling more effective damping of mechanical load and reducing compression of the articular cartilage, which directly correlates with pain reduction and improved quality of life. The biomechanical component is associated with an increased range of motion, optimisation of gait biomechanics, and a reduction of excessive impact on cartilaginous structures.

The application of eccentric exercises for the quadriceps femoris muscle opens up promising directions for further clinical and scientific research. Given the confirmed positive effect in this category of patients, several priority tasks can be identified. First, a significant limitation of the current work is the small sample size (n = 9). To obtain valid and representative data, an expansion of the sample size is required, with consideration for differentiation by age, sex, and pathology stage, which will allow for the clarification of the methodology's efficacy in various subgroups. Second, an evaluation of long-term outcomes is necessary. Determining the duration of the retention of achieved effects after the completion of the training course will allow for the justification of the need for and periodicity of maintenance programs. Third, it is relevant to compare eccentric training with other rehabilitation approaches to determine their relative efficacy and optimal conditions of application.

A promising direction is the development of individualised training programs that take into account the patient's clinical characteristics. Research in this area is necessary to determine the optimal loading parameters (intensity, frequency, volume) for different groups, which will contribute to enhancing the effectiveness of rehabilitation interventions. Further study of eccentric training for knee osteoarthritis requires a comprehensive approach, and the implementation of the outlined

directions will expand rehabilitation possibilities and improve the quality of life for this patient category.

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CONFLICT OF INTEREST

None.

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Тизе муунунун функциясы жабыркаган адамдар арасында ооруга жана кыймыл диапазонуна эксцентрикалык жүктөмдөрдүн таасири

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Аннотация. Учурда тизе муунундагы ооруга жана кыймылдын чектелүүлүгүнө нааразы болгон бейтаптардын саны көбөйүүдө. Остеоартроздун алгачкы стадияларында функцияны калыбына келтирүүнүн натыйжалуу ыкмаларын издөө барган сайын маанилүү болуп баратат. Бул изилдөөнүн максаты – тизе муунунун функциясынын бузулушу бар адамдарда оорунун интенсивдүүлүгү менен эксцентрикалык жыйрылуу параметрлеринин ортосундагы мүмкүн болгон байланышты аныктоо болуп саналат. Медициналык борбордо тизе остеоартрозу менен жабыркагандар арасында булчуңдардын жыйрылуусунун эксцентрикалык режимин изилдөө үчүн эксперимент жүргүзүлдү. Реабилитациялык сессиялар квадрицепстердин жыйрылуусунун эксцентрикалык фазасына багытталган. Миографтын көрсөткүчтөрү жана оорунун деңгээли экспериментке чейин жана андан кийин визуалдык аналогдук шкала колдонулуп бааланган. Квадрицепстин эксцентрикалык жыйрылуусунун орточо амплитудасы эки эседен ашык көбөйгөн: мисалы, vastus lateraliste ал 98,7 мкВдан 298,4 мкВга чейин жогорулаган. Көнүгүүлөрдүн курсун аяктагандан кийин, тогуз катышуучунун алтоосу тизенин толук чоюлушуна жетишкен. Бардык катышуучулар оорунун азайганын билдиришкен, ал эми экөө ооруну толугу менен басаңдаткан. Изилдөөнүн жыйынтыктары эксцентрикалык булчуңдардын жыйрылуусунун ооруну азайтып, электромиографиялык активдүүлүктү жогорулатканын көрсөттү. Бул режим кыймыл учурунда булчуң күчүн жана нерв-булчуң көзөмөлүн өнүктүрүүгө, ошондой эле муун кемирчегине механикалык жүктү азайтууга жардам берет. Жыйынтыктар эксцентрикалык квадрицепс көнүгүүлөрү тизе остеоартроздун алгачкы стадияларында натыйжалуу болушу мүмкүн экенин көрсөтүп турат, анткени алар бир эле учурда себепти (булчуңдун алсыздыгы) жана кесепетин (оору, кыймылдын чектелүү диапазону) чечет. Жыйынтыктар тизе муунунун остеоартрозунун алгачкы стадиялары менен ооруган бейтаптар үчүн жекече реабилитациялык программаларды иштеп чыгуу үчүн колдонулушу мүмкүн

Негизги сөздөр: гонартроз; электромиография; таяныч-кыймыл системасы; негативдүү фаза; тизе муунунун оорусу

Влияние эксцентрических нагрузок на болевой синдром и амплитуду движений у лиц с нарушением функций коленного сустава

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Аннотация. В настоящее время наблюдается увеличение числа пациентов с жалобами на боль и ограничение подвижности коленного сустава. Актуальным становится поиск эффективных методов восстановления функции на начальных стадиях остеоартроза. Целью настоящего исследования явилось выявление возможной взаимосвязи между интенсивностью боли и параметрами эксцентрического сокращения у лиц с нарушением функций коленного сустава. На базе медицинского центра проведён эксперимент, в ходе которого изучался эксцентрический режим мышечного сокращения при остеоартрозе коленного сустава. В реабилитационных сессиях акцент делался на эксцентрическую фазу сокращения четырёхглавой мышцы бедра. До и после эксперимента оценивались показатели миографа, уровень боли по визуально-аналоговой шкале. Средняя амплитуда эксцентрического сокращения четырёхглавой мышцы увеличилась более чем в два раза: например, у латеральной широкой мышцы – с 98,7 мкВ до 298,4 мкВ. После завершения курса занятий у шести из девяти участников зафиксировано полное разгибание в коленном суставе. У всех испытуемых отмечено снижение уровня болевого синдрома, у двух человек боль исчезла полностью. Результаты исследования показали, что эксцентрический режим мышечного сокращения способствует снижению уровня боли и росту показателей электромиографической активности. Данный режим позволяет развивать силу мышц и нейромышечный контроль при движениях, а также снижать механическую нагрузку на суставной хрящ. Полученные данные свидетельствуют, что упражнения в эксцентрическом режиме для четырёхглавой мышцы бедра на начальных стадиях остеоартроза коленного сустава могут быть эффективны, так как воздействуют одновременно на причину (мышечная слабость) и на следствие (боль, дефицит амплитуды движений). Результаты могут быть использованы при разработке индивидуальных реабилитационных программ для пациентов с начальными формами остеоартроза коленного сустава

Ключевые слова: гонартроз; электромиография; опорно-двигательный аппарат; негативная фаза; боль в коленном суставе