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CLINICAL MANAGEMENT AND REHABILITATION STRATEGY FOR WRESTLERS WITH PRE-EXISTING POST-TRAUMATIC GONARTHROSIS IN THE POST-ACUTE REHABILITATION PHASE AFTER RE-INJURY OR SURGICAL INTERVENTION

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ABSTRACT

Introduction. Post-traumatic knee osteoarthritis in combat sports athletes is characterized by an aggressive clinical course due to constant axial and rotational overloads. Traditional rehabilitation approaches often neglect the specificity of the autonomic status and neuromuscular control in the post-acute period, leading to early disability. The study aimed to trace the dynamics of functional and structural changes in wrestlers with PTOA under the influence of the developed "Wrestle-Knee Rehab" clinical management strategy.

Material and methods. A prospective study involved 32 wrestlers aged 22–35 with verified Stage I–II PTOA. The 8-week rehabilitation program was based on the International Classification of Functioning, Disability and Health (ICF) architecture and included four stages: immobilization, early and late post-immobilization, and pre-training. Assessment was performed using high-frequency ultrasonography, goniometry, the Lovett scale, and KOOS and WOMAC questionnaires. Statistical analysis was conducted using Wilcoxon and Spearman criteria ($p<0.05$).

Results. The implementation of the strategy allowed for the elimination of active extension deficit ($p < 0.01$) and restoration of flexion range to 142.3°. Ultrasound monitoring showed regression of synovitis (reduction of effusion from 8.5 mm to<1.5 mm) and an increase in hyaline cartilage thickness from 1.8 mm to 2.2 mm. Muscle strength on the Lovett scale increased from 0.58 to 4.48. The most significant improvement on the KOOS scale was recorded in the “Sport and Recreation” subscale (from 22.4 to 79.8 points), indicating the restoration of the specific motor stereotype.

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Conclusions. It has been proven that the combination of structural damage and proprioceptive deficit necessitates active clinical management specifically during the post-acute period. The implementation of a four-stage rehabilitation program ensured the complete elimination of extension deficit and the attainment of physiological range of motion. A significant increase in muscle strength on the Lovett scale, alongside a decrease in the WOMAC index, confirmed the restoration of neuromuscular control. The most substantial improvement in KOOS scores within the «Sport and Recreation» domain verified the wrestlers' readiness for a safe return to professional sports.

Keywords: post-traumatic gonarthrosis, wrestlers, clinical management, rehabilitation, KOOS score, ultrasonography.

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КЛІНІЧНИЙ МЕНЕДЖМЕНТ ТА СТРАТЕГІЯ РЕАБІЛІТАЦІЇ БОРЦІВ ІЗ НАЯВНИМ ПОСТТРАВМАТИЧНИМ ГОНАРТРОЗОМ У ПІСЛЯГОСТРИЙ ПЕРІОД РЕАБІЛІТАЦІЙНІЙ ФАЗІ ПІСЛЯ РЕТРАВМАТИЗАЦІЇ АБО ХІРУРГІЧНОГО ВТРУЧАННЯ

Вступ. Посттравматичний гонартроз колінного суглоба у представників контактних єдиноборств характеризується агресивним клінічним перебігом через постійні осьові та ротаційні перевантаження. Традиційні підходи до реабілітації часто ігнорують специфіку вегетативного статусу та нейром'язового контролю у післягострому періоді, що призводить до ранньої інвалідизації. Метою дослідження було простежити динаміку функціональних та структурних змін у борців з посттравматичним гонартрозом у післягострому періоді під впливом комплексних реабілітаційних навантажень для оптимізації стратегії клінічного менеджменту.

Матеріали та методи. У дослідженні взяли участь 32 борці віком 22–35 років із верифікованим посттравматичний остеоартрит колінного суглоба I–II стадії, 8-тижнева програма реабілітації базувалася на Міжнародній класифікації функціонування, обмеження життєдіяльності та здоров'я (МКФ) і включала чотири етапи: іммобілізаційний, ранній та пізній постіммобілізаційні, а також передтренувальний. Оцінка проводилася з використанням високочастотної ультрасонографії, гоніометрії, шкали Ловетта, а також опитувальників KOOS та WOMAC. Статистичний аналіз виконано з використанням критеріїв Вілкоксона та Спірмена ($p < 0.05$).

Результати. Впровадження стратегії дозволило повністю усунути дефіцит активного розгинання (<0.01) та відновити амплітуду згинання до 142.3°. Ультразвуковий моніторинг зафіксував регрес синовіту (зменшення випоту з 8.5 мм до<1.5 мм) та збільшення товщини гіалінового хряща з 1.7 мм до 2.4 мм. М'язова сила за шкалою Ловетта зросла з 0.58 до 4.48 балів. Найбільш значуще покращення за шкалою KOOS зафіксовано у субшкалі «Спорт та активний відпочинок» (з 22.4 до 79.8 балів), що свідчить про відновлення специфічного рухового стереотипу.

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Висновки. Доведено, що поєднання структурних пошкоджень та дефіциту пропріорецепції потребує активного клінічного менеджменту саме у післягострому періоді. Впровадження чотириетапної реабілітації забезпечило повне усунення дефіциту розгинання та досягнення фізіологічної амплітуди рухів. Суттєве зростання м'язової сили за шкалою Ловетта паралельно зі зниженням індексу WOMAC підтвердило відновлення нейром'язового контролю. Найбільш значущий приріст показників за шкалою KOOS у домені «Спорт і відпочинок» верифікував готовність борців до безпечного повернення у професійний спорт.

Ключові слова: посттравматичний гонартроз, борці, клінічний менеджмент, реабілітація, шкала KOOS, ультрасонографія.

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INTRODUCTION

The contemporary paradigm of clinical management of post-traumatic gonarthrosis is based on understanding this pathology as a complex degeneration of all joint tissues, which necessitates an immediate transition to an active rehabilitation strategy already in the post-acute period [1, 2]. An important stage in restoring work capacity and physical activity in individuals with musculoskeletal system injuries is the post-acute period, during which intensive rehabilitation is initiated.

In representatives of contact martial arts, particularly wrestlers, post-traumatic gonarthrosis represents a complex degenerative-dystrophic process in which, at the initial stages, new adaptive mechanisms are formed that are necessary for the effective restoration of sport-specific motor skills and quality of life [3, 4]. The high probability of damage to the structures of the knee joint in wrestlers is associated with degenerative-destructive changes under conditions of extreme loads, where the risk of sports injuries, according to the American Research Center (TCRC), ranges from 50% to 85% of cases [3, 5].

It is precisely the post-acute period that focuses on restoring the wrestler's functional capacity at both biological and physical levels. However, the application of an individualized approach requires an in-depth investigation of the accompanying stages of regulation of joint homeostasis and neuromuscular control [6, 7, 8]. Given the complex anatomical structure of the knee joint as a hinge–rotational articulation, forced increases in the active or passive amplitude of physiological movements beyond the normative range of 140–150° in wrestlers lead to critical injuries of the cruciate ligaments and menisci [3, 9].

Another debatable issue is the heterochrony of degenerative changes in the knee joint in the context of gonarthrosis progression. There are physiological explanations for the variability in the clinical course of post-traumatic gonarthrosis, in which the morphofunctional characteristics of damaged cartilage may differ significantly even under identical mechanisms of injury [10]. Most contemporary studies are devoted to chronic stages or the consequences of arthroscopic meniscectomy; however, insufficient attention is paid to integrated clinical management in wrestlers specifically during the post-acute period [5, 8, 9].

Autonomic and neurohumoral factors play a relevant role in shaping normal joint adaptation to rehabilitation loads. Specialists assess hemodynamic and autonomic responses to physical stress as markers of recovery effectiveness [10]. It has been established that excessive pain-related and physical overloads during the post-acute period cause disturbances in compensatory–adaptive mechanisms in wrestlers, which inevitably reduces work capacity and inhibits the regeneration of the treated meniscus or cartilage [11, 12].

Even physiologically acceptable levels of loading after arthroscopic interventions have a direct impact on joint function. Excessive strain may induce fatigue of periarticular tissues, leading to enhanced vagotonic influence and regulatory exhaustion [7, 8].

During degenerative meniscal tears, the multivector nature of loads inherent in wrestling requires rapid mobilization of functional muscle groups, which is possible only under conditions of adequate multidisciplinary rehabilitation support [9, 1].

In clinical practice, post-traumatic gonarthrosis in wrestlers is often accompanied by a typical symptom complex, including pain, restricted mobility, and instability arising from amplitude femoral rotation with a fixed tibia. The effectiveness of early active therapy has been confirmed; however, the methods of its implementation in elite wrestlers differ substantially due to the necessity of restoring a sport-specific dynamic stereotype [3, 13].

The substantiation and validation of contemporary rehabilitation strategies after injuries and surgical interventions during the post-acute period among athletes, particularly wrestlers, aimed at correcting autonomic status and restoring the functional state of the knee joint, currently remain an unresolved issue in physical therapy.

Purpose. To trace the dynamics of functional and structural changes in wrestlers with post-traumatic gonarthrosis during the post-acute period under the influence of comprehensive rehabilitation loads, in order to optimize the clinical management strategy.

MATERIAL AND METHODS

This randomized study was conducted within the framework of the institutional research programs of Sumy State Pedagogical University, Department of Therapy and Rehabilitation – "Theoretical, methodological, and organizational aspects of health, physical therapy, rehabilitation, occupational therapy, and special education" (registration no. 0120U100803) and the Department of Public Health and Medical and Biological Foundations of Physical Culture – "A comprehensive study of functional status, adaptive capacity of the body, and the risk of disease development in different population groups" (registration no. 0120U100799). A prospective clinical study was conducted involving 32 male wrestlers (freestyle wrestling, Greco-Roman wrestling, and sambo) aged 22–35 years. The inclusion criteria were as follows: sports qualification not lower than Candidate for Master of Sports, verified post-traumatic gonarthrosis of Kellgren–Lawrence grades I–II, and being in the post-acute phase of rehabilitation (4–12 weeks after injury or arthroscopic meniscectomy). The study adheres to the principles of the Declaration of Helsinki, and the protocol was approved by the local Bioethics Committee.

Methodology and Rehabilitation Strategy. Clinical management was based on a developed strategy integrating the principles of evidence-based medicine and the framework of the International Classification of Functioning, Disability and Health (ICF) [1, 9]. The physical therapy program was structured into four stages:

1) *Immobilization stage* – isometric contractions of the thigh muscles (quadriceps and hamstrings) were applied without changing the joint angle in order to preserve neuromuscular control and prevent atrophy of the joint's muscular support while minimizing mechanical load on the damaged cartilage;

2) *Early post-immobilization stage* – the primary objective was to restore the physiological range of motion and eliminate contractures. Exercises aimed at unloading the kinematic chains and gentle manual techniques for patellar mobilization were applied. To stimulate intra-articular metabolic processes, active movements without axial loading were introduced, which contributed to stabilization of the joint's autonomic status and reduction of residual edema;

3) *Late post-immobilization stage* – this stage was crucial for wrestlers due to the introduction of proprioceptive training. Exercises were performed on unstable platforms within closed kinetic chains, incorporating elements of the wrestling stance. Special attention was given to eccentric muscle strengthening at a four-second lowering phase, which promoted reinforcement of the tendon-ligament apparatus and prepared the cartilage for loading;

4) Pre-training stage – neuromuscular exercises with elastic resistance were included to correct dynamic valgus during sport-specific movements and simulated grips.

Load intensity was dosed according to the athlete's autonomic status, ensuring a safe transition from therapeutic exercises to full training without risk of relapse. Each stage involved differentiated loading tailored to the dynamics of the athlete's autonomic status.

Assessment Methods According to ICF Domains. To objectively evaluate structural, functional, and socio-professional changes in wrestlers, a comprehensive diagnostic toolkit was employed, systematically organized according to the domains of the International Classification of Functioning, Disability and Health (ICF). (Table 1).

Table 1 – Structure of Clinical and Functional Assessment of Wrestlers According to ICF

ICF Domain / Factor Structure	Research Methods and Indicators	Rehabilitation Period (weeks)
Structure and Function	Ultrasonography, Goniometry, Pain VAS	1, 3, 6, 9, 12
Activity and Participation	WOMAC and KOOS Scales	1, 6, 12
Personal Factors	Structured Interview, Medical/Sports History Collection	1, 12

Notes: ICF - International Classification of Functioning, Disability and Health; VAS - Visual Analog Scale for pain assessment; WOMAC - Western Ontario and McMaster Universities Osteoarthritis Index; KOOS - Knee Injury and Osteoarthritis Outcome Score

Instrumental and Functional Monitoring

Structural Assessment. The evaluation of structural changes in the knee joints of wrestlers during the post-acute rehabilitation period was based on high-frequency sonography (ultrasound examination). Particular attention was given to visualizing areas of chondromalacia and assessing the volume of synovial effusion in joint recesses, which served as a marker of the adequacy of the prescribed rehabilitation loads [10, 13].

Assessment of Body Functions

Goniometry. Active and passive range of motion (ROM) was measured using a goniometer with the participant in the supine position (axis aligned with the projection of the lateral femoral condyle). Full extension was considered the neutral position (0°). A primary goal of clinical management was the elimination of extension deficits-even within 3–5°-which is critical for preventing cartilage degeneration and restoring the biomechanics of the stance phase in wrestlers.

Algometry. Pain intensity was assessed using the Visual Analog Scale (VAS, 0–10 cm). Participants independently marked discomfort on a 100-mm scale at rest, during passive mobilization, and following functional loads. This approach allowed for objective determination of the "safe loading threshold" and helped prevent chronicity of inflammatory processes in athletes aged 22–35 years, who are prone to ignore pain signals in order to return to sport quickly.

Assessment of Activity and Participation

Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Functional status was evaluated using the 24-item questionnaire. The structure included three domains: pain (5 items), stiffness (2 items), and physical function (17 items). Scoring was performed on a 5-point scale (0–4), with a reduction in the total score serving as a criterion for regression of inflammation and restoration of joint functional capacity during rehabilitation.

Knee Injury and Osteoarthritis Outcome Score (KOOS). Knee joint status was assessed using the KOOS questionnaire (42 items), covering five categories: pain, symptoms, activities of daily living, quality of life, and sports/recreational function. The last domain was a priority for wrestlers, as it includes assessment of jumping and rotational loads. Scores were calculated on a 100-point scale, with higher scores indicating better joint status. Assessments were conducted before and after the rehabilitation course to verify the clinical effectiveness of the management strategy.

Personal Factors. Specific Questionnaire. Sports activity history was collected, along with an assessment of treatment expectations and the ability to perform sport-specific motor patterns of wrestlers (e.g., knee falls, rotation with a fixed tibia).

Statistical Analysis. Primary statistical data are presented as the mean ± standard deviation (M±SD). For binary and ordinal variables, both absolute frequencies (n) and relative frequencies (%) were calculated.

The Shapiro–Wilk test was used to assess the normality of data distribution at each stage of rehabilitation. Data conforming to a normal distribution were compared using the paired Student's t-test, whereas data deviating from normality were analyzed with the Wilcoxon signed-rank test for paired samples. To evaluate changes across all four rehabilitation stages, the non-parametric Friedman test was applied. When statistically significant differences were detected, pairwise stage comparisons were performed using Bonferroni correction to prevent Type I error.

Spearman's rank correlation coefficient (rs) was used to assess relationships between ranked or ordinal variables, allowing determination of the strength and direction of monotonic associations between indicators. Statistical significance was set at $p<0.05$. Primary preparation of tables and preliminary calculations was carried out in Microsoft Excel, while the main statistical analysis was performed using STATISTICA 13.0.

RESULTS

In a cohort of elite wrestlers (Candidates for Master of Sport and Masters of Sport) aged 22–35 years, the progression of post-traumatic knee gonarthrosis demonstrates an aggressive disease course. This phenomenon is attributable to the combination of a high-energy primary knee injury and the continued exposure to excessive axial loading during the post-acute phase of recovery. Despite the relatively small sample size, the high degree of group homogeneity with respect to anthropometric parameters and injury mechanisms allowed for the identification of statistically significant correlations between the pattern of joint damage and the rate of articular cartilage degeneration.

The analysis demonstrated that combined injuries of the capsuloligamentous apparatus represent the most critical predictor of early manifestation of post-traumatic knee osteoarthritis (gonarthrosis). In particular, the concomitant rupture of the anterior cruciate ligament and meniscal injury exhibited the highest correlation coefficient with osteoarthritis severity according to the Kellgren–Lawrence classification ($r=0.82$; $p<0.001$). This association is explained by the development of persistent biomechanical instability, which triggers a cytokine cascade and promotes chronic synovial inflammation.

A notable finding is the strong positive correlation between prior meniscectomy and radiographic signs of joint space narrowing ($r=0.79$; $p<0.001$). For wrestlers of

this level, meniscus loss is critical, as it leads to increased contact pressure on the subchondral bone in areas subjected to the highest loads during throwing techniques. The negative correlation between anterior cruciate ligament reconstruction and proprioceptive control (r=−0.52) indicates that surgical restoration of anatomy does not equate to recovery of functional stability, highlighting the need for specific clinical management during the post-acute period to prevent progression of gonarthrosis (Table 2).

Table 2 – Correlation Matrix of Etiological Determinants and Pathogenetic Mechanisms in Post-Traumatic Knee Osteoarthritis Among Elite Wrestlers (n=32)

Age, sample	Injury/Pathogenic Marker	Correlation coefficient	p
Post-acute period			
22–35 years, *n*=32	Posterior cruciate ligament (PCL) injury / Subchondral bone marrow edema	0.48	< 0.05
	Premature return to activity / Synovial hypertrophy	0.64	< 0.01
	Chondral lesion/ Pro-inflammatory IL-6 concentration	0.61	< 0.01
	Partial meniscectomy / Joint space narrowing (JSN)	0.79	< 0.001
Rehabilitation period			
22–35 years, n=32	Reconstruction of the Anterior Cruciate Ligament / Proprioception Deficit	-0.52	< 0.05
	Premature Return to Load / Synovial Hypertrophy	0.64	< 0.01
	Osteochondral Fracture / Early Osteophytosis	0.55	< 0.05
	Combination (Anterior Cruciate Ligament + Meniscus) / Stage of Post-Traumatic Gonarthrosis (according to Kellgren-Lawrence)	0.82	< 0.001

Notes: Correlation spectrum of reliable coefficients

The analysis of the dynamics of knee joint sonographic parameters confirmed the high adaptability and clinical effectiveness of the proposed clinical management program “Wrestle-Knee Rehab.” At the initial stages of rehabilitation − the immobilization and early post-immobilization phases − a statistically significant regression of secondary synovitis manifestations was observed. In particular, the depth of free fluid in the suprapatellar recess significantly decreased from 8.5±1.2 mm to 4.2±0.8 mm (p<0.01), indicating a reduction in exudative activity and showing a significant correlation with the stabilization of the athletes’ autonomic status. These changes created favorable conditions for the timely and safe expansion of the motor regimen.

The transition to the late post-immobilization stage, accompanied by the introduction of dosed eccentric loading, was associated with positive morphological changes in the hyaline cartilage. According to ultrasound chondrometry, the thickness of the cartilage layer in the region of maximal load on the femoral condyles increased significantly from 1.7±0.2 mm to 2.4±0.1 mm (p<0.05). This dynamic may be interpreted as a result of optimized hydration of the cartilage extracellular matrix and activation of chondrocyte synthetic activity under controlled mechanical stimulation.

During the pre-training stage of rehabilitation, primary attention was focused on the functional state of the periarticular tissues and the operated meniscus. Sonographic examination verified increased density and structural organization of the ligamentous apparatus echostructure, as well as stabilization of the meniscal body height at 4.4±0.1mm (p<0.05). A statistically significant increase in the resistance index (RI) in the synovial membrane vessels to 0.80±0.04 (p<0.05) was identified as an important prognostic marker of recovery, indicating complete resolution of the active inflammatory process and functional readiness of the knee joint for high-intensity and extreme sports loads.

The absence of recurrent episodes of increased exudation during exercises performed in closed kinetic chains and proprioceptive training confirmed the safety and high effectiveness of the selected rehabilitation strategy in wrestlers with post-traumatic gonarthrosis (Table 3).

Table 3 – Dynamics of Absolute Sonographic Parameters of the Knee Joint at Different Stages of Rehabilitation (M±SD, n=32)

Parameter (absolute values)	Stage 1 Immobilization	Stage 2 Early post-immobilization	Stage 3 Late post-immobilization	Stage 4 Pre-training
Hyaline cartilage thickness (mm) (femoral condyle region)	1.7±0,2	1.9±0.1	2.1±0.1*	2.4±0.1*
Synovial membrane thickness (mm)	3.6±0.4	2.8±0.3*	2.1±0.2*	1.7±0.2*
Depth of free fluid in the suprapatellar recess (mm)	8.5±1.2	4.2±0.8**	2.1±0.4**	1.3±0.2** (physiological norm)
Resistance Index (RI) (synovial vessels, Doppler)	0.55±0.05	0.63±0.05*	0.75±0.04*	0.80±0.04*
Meniscal body height (mm) (after resection / suture)	4.2±0.2	4.1±0.2	4.2±0.1	4.4±0.1*

*Notes: Significant statistical differences *p<0.05, **p<0.01 (statistically significant difference compared with the previous rehabilitation stage)*

Goniometric assessment revealed a consistent increase in knee joint range of motion across all stages of rehabilitation in wrestlers with post-traumatic gonarthrosis during the post-acute period.

During the immobilization stage, a pronounced deficit in knee extension was observed: active extension measured −7.2±0.8°, and passive extension −4.5±6°. Throughout the early and late post-acute stages, the extension deficit gradually decreased, reaching full extension (0°) for both active and passive movements by the pre-training stage. The difference between the first and fourth stages was statistically significant ($p < 0.01$).

Knee flexion also demonstrated significant positive dynamics. The amplitude of active flexion increased from 92.4±4.5° at the immobilization stage to 142.3±1.5° at the pre-training stage ($p<0.01$). A similar trend was observed for passive flexion, which increased from 105.2±3.8° to 148.6±1.2° ($p<0.01$).

Overall, these findings indicate systematic restoration of both active and passive knee joint mobility throughout the rehabilitation process, with the most pronounced improvements observed in extension, which normalized by the pre-training stage (Table 4).

Table 4 – Goniometric Assessment of Knee Range of Motion in Wrestlers with Post-Traumatic Gonarthrosis During the Post-Acute Rehabilitation Period (M±SD, n=32)

Parameter (°)	Stage 1 Immobilization	Stage 2 Early post-immobilization	Stage 3 Late post-immobilization	Stage 4 Pre-training	p (Stage 1 vs 4)
Active extension deficit	−7.2±0.8	−3.5±0.4	−1.2±0.2	0.0±0.0	<0.01
Passive extension deficit	−4.5±0.6	−1.8±0.3	−0.5±0.1	0.0±0.0	<0.01
Active flexion	92.4±4.5	110.8±3.2	128.5±2.8	142.3±1.5	<0.01
Passive flexion	105.2±3.8	122.4±2.5	136.7±1.9	148.6±1.2	<0.01

Notes: Values are presented as mean±standard deviation (°). Neutral position for extension was defined as 0°. Negative values indicate extension deficit. p-values reflect differences between Stage 1 (Immobilization) and Stage 4 (Pre-Training). Goniometric measurements were performed in the supine position according to a standardized protocol

Analysis of pain dynamics using the Visual Analog Scale (VAS) demonstrated a stepwise reduction in pain intensity in wrestlers with post-traumatic gonarthrosis throughout the rehabilitation process (Figure 1).

At the first rehabilitation stage (immobilization period), the highest level of pain was recorded, with a mean VAS score of 6.8±0.6 cm. At the second stage (early post-acute period), pain intensity significantly decreased to 4.5±0.5 cm ($p<0.01$ compared with Stage 1).

A further reduction in pain was observed at the third rehabilitation stage (late post-acute period), where mean VAS values reached 2.9±0.4 cm, which was statistically

significant compared with the previous stage ($p<0.05$).

At the fourth, pre-training stage, pain intensity was minimal, averaging 1.6±0.3 cm. The difference between the first and fourth stages was statistically significant ($p<0.001$). These findings indicate a sustained positive trend toward pain reduction throughout the entire rehabilitation process.

The dynamics of muscle strength assessed using the Lovett scale demonstrated the most pronounced increase between the second and fourth stages of rehabilitation. At the first stage, the low score (0.58±0.08 points) was attributable to pronounced arthrogenic muscle inhibition caused by pain and joint effusion.

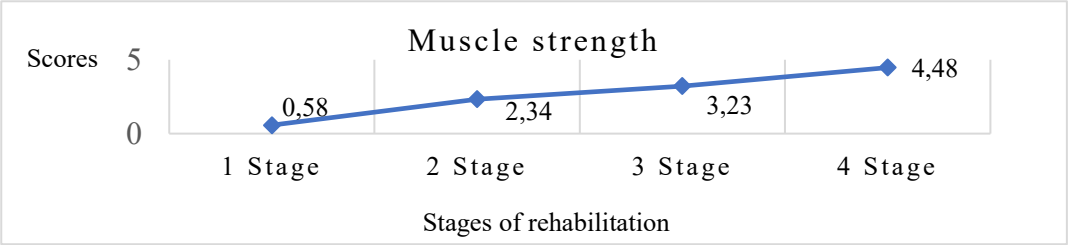

Figure 1. Dynamics of muscle strength (Lovett scale) in wrestlers with post-traumatic gonarthrosis throughout the rehabilitation stages (scores)

At the third stage, a substantial improvement was observed (3.23±0.12 points), coinciding with the introduction of eccentric exercises and proprioceptive training, which enabled patients to effectively overcome gravitational force.

Achievement of a mean value of 4.48±0.10 points at the fourth stage indicates restoration of the muscles' ability to stabilize the joint under significant resistance, which is crucial for preventing valgus deformation during execution of wrestling techniques.

Overall, the positive dynamics observed on the Lovett scale confirm that an emphasis on neuromuscular correction contributed not only to the restoration of muscle mass but also to enhanced functional capacity for eccentric muscle control.

Assessment of activity and participation using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) revealed a statistically significant positive trend in the functional status of wrestlers with post-traumatic gonarthrosis throughout the post-acute rehabilitation period.

At the first stage of rehabilitation (immobilization period), the highest total WOMAC scores were recorded, indicating a substantial negative impact of pain, joint stiffness, and physical function limitations on athletes' daily activities. The mean total WOMAC score was 58.6±4.2.

At the second stage (early post-acute period), a significant reduction in the total WOMAC score was observed, decreasing to 44.3±3.7 ($p<0.01$ compared with Stage 1), which was accompanied by a reduction in pain severity and early restoration of functional capacity.

Further improvement was documented at the third rehabilitation stage (late post-acute period), where the total WOMAC index decreased to 30.8±3.1, representing a statistically significant change compared with the previous stage ($p<0.05$).

At the pre-training stage of rehabilitation (Stage 4), minimal WOMAC values were recorded (18.5±2.4 points). The difference between the first and fourth stages was highly significant ($p<0.001$), indicating a substantial reduction in the negative impact of the degenerative process on activity and participation among wrestlers.

Thus, the dynamics of the WOMAC index reflected a stepwise regression of clinical manifestations of post-traumatic gonarthrosis and served as an integral indicator of the effectiveness of the rehabilitation program.

The dynamics of patients' subjective assessment of knee joint status using the Knee Injury and Osteoarthritis Outcome Score (KOOS) also demonstrated statistically significant improvements across all five domains following completion of the developed clinical management program. Baseline data indicated marked limitations in athletes' functional abilities, particularly in categories associated with high-intensity loading.

The most pronounced positive changes were observed in the "Sport and Recreation" domain, where the mean score increased from 22.4±5.2 to 79.8±3.6. This result is critically important for wrestlers, as this domain evaluates the ability to perform jumping, squatting, and rotational movements under load. The improvement was achieved through the sequential implementation of the third and fourth rehabilitation stages, with an emphasis on proprioceptive training and eccentric strengthening of stabilizing muscles.

Scores in the "Quality of Life" domain increased by 44.8 points, indicating a substantial reduction in psychological discomfort and fear of re-injury. Positive changes in the "Pain" and "Symptoms" domains (reduction in swelling and crepitus) correlated with

sonographic monitoring data (decreased effusion depth) and restoration of range of motion as assessed by goniometry.

Overall, implementation of the "Wrestle-Knee Rehab" strategy not only alleviated pain but also restored sport-specific functional activity in wrestlers, thereby creating conditions for a safe return to specialized mat-based training.

DISCUSSION

The results of our study confirm the complex, multifactorial nature of post-traumatic gonarthrosis, which is consistent with contemporary concepts regarding the global medical and social burden of this pathology [2]. The particularly aggressive course of degenerative changes in young athletes and representatives of contact martial arts [4] necessitates a reconsideration of traditional approaches in favor of early preventive therapy [5, 13]. The correlation identified between combined injuries and the stage of osteoarthritis according to the Kellgren-Lawrence classification is supported by scientific evidence emphasizing sport-specific biomechanical determinants of injury in wrestling [3]. It is important to consider that physiological soft tissue healing [10] and adequate visualization of structural changes [17] are fundamental for predicting recovery timelines and preventing premature disability.

A key component of effective clinical management is the elimination of neuromuscular deficits and adequate pain control. The reduction in pain intensity assessed by the VAS and the improvement in functional indicators observed in our cohort are consistent with evidence supporting the effectiveness of therapeutic exercise in preventing joint degeneration [8] and with modern multidisciplinary rehabilitation strategies [9]. Particular attention should be paid to the phenomenon of central sensitization [11, 12], which-similarly to systemic rheumatologic diseases [15, 16] – may negatively affect treatment outcomes by transforming acute pain into a persistent chronic condition. The use of validated instruments such as the KOOS allows for objective assessment of patient dynamics not only at the level of clinical symptoms but also in the context of sport-specific activity [14].

Restoration of neuromuscular strength to a level of 4 points on the Lovett scale emerged as a critical predictor of a safe transition to functional loading. This finding is consistent with conclusions regarding the direct relationship between knee biomechanical characteristics and pain intensity [7], as well as with the concept of anatomically correct alignment of joint surfaces to ensure stability under axial loading [18]. Positive dynamics in sonographic parameters confirm the feasibility of physical therapy as a method of active correction of joint homeostasis [1]. Optimization of neuromuscular control and proprioception is a necessary condition for restoring the wrestler's motor stereotype and preventing progression of degeneration in both the affected and contralateral joints [6].

CONCLUSIONS

1. It was established that the key predictor of an aggressive course of post-traumatic gonarthrosis in elite-level wrestlers is combined injury to the capsuloligamentous apparatus, particularly the coexistence of anterior cruciate ligament rupture and meniscal damage ($r=0.82$; $p<0.001$). It was demonstrated that anatomical reconstruction of these structures is not equivalent to restoration of functional stability ($r=-0.52$ for proprioceptive control), which substantiates the need for targeted clinical management specifically during the post-acute period.

2. Implementation of the four-stage rehabilitation program demonstrated high clinical effectiveness. Sonographic monitoring confirmed a significant regression of secondary synovitis, evidenced by a reduction in joint effusion from 8.5±1.2 mm to within physiological limits (1.3 mm; $p <0.01$), as well as improvement in hyaline cartilage trophicity, reflected by an increase in cartilage thickness from 1.7±0.2 mm to 2.4±0.1 mm ($p<0.05$). These findings indicate the adequacy of the proposed mechanical stimuli.

3. Application of the strategy allowed for complete elimination of the extension deficit and achievement of a physiological flexion range (148.6±1.2°; $p<0.01$). The dynamics of muscle strength assessed by the Lovett scale (increase from 0.58 to 4.48 points) and the reduction in the WOMAC index (from 58.6 to 18.5 points) indicate restoration of eccentric control and stabilizing muscle capacity, which are essential for a safe return to sport-specific wrestling loads.

4. The most pronounced positive dynamics on the KOOS scale were observed in the "Sport and Recreation" domain (increase from 22.4 to 79.8 points), confirming the athletes' ability to perform rotational movements and squatting without the risk of recurrent effusion. This improvement establishes a foundation for long-term preservation of joint health in professional sport.

PROSPECTS FOR FUTURE RESEARCH

Further research should focus on investigating the long-term outcomes (12–24 months) of the implemented clinical management strategy in order to assess the rate of progression of degenerative changes in wrestlers who have returned

to competitive activity. The introduction of digital methods for movement kinematic analysis and stabilometry appears promising for more precise verification of neuromuscular control under conditions simulating real competitive bouts. In addition, special attention should be given to the investigation of genetic markers associated with susceptibility to early-onset osteoarthritis, which would allow for personalization of rehabilitation prognosis in elite wrestlers.

AUTHOR CONTRIBUTIONS

All authors substantively contributed to the drafting of the initial and revised versions of this paper. They take full responsibility for the integrity of all aspects of the work.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

ETHICAL CONSIDERATIONS

The study adheres to the principles of the Declaration of Helsinki, and the protocol was approved by the local Bioethics Committee.

REFERENCES

1. Kuliński W, Kaczmarczyk M. Gonarthrosis as a clinical and social problem: analysis of physical therapy after knee arthroplasty. Acta Balneologica. 2025;67(2):90-95. https://doi.org/10.36740/ABAL202502102
2. Sharma L. Osteoarthritis of the knee. *New England Journal of Medicine*. 2021;384(1):51-59. https://doi.org/10.1056/NEJMcp1903768
3. Gorbov AM, Pasichna TV. Biomechanical Determinants of Knee Injuries in Combat Sports: Implications for Physical Therapy. *Journal of Physical Education and Sport*. 2024;24(2):412-420. https://doi.org/10.7752/jpes.2024.02052
4. Pape D, Tischer T. Kniearthrose bei jungen Patienten [Osteoarthritis of the knee in young patients]. *Orthopade*. 2021;50(5):132-138. https://doi.org/10.1007/s00132-021-04095-8
5. Whitaker JL, Culvenor AG, Juhl CB, et al. Outcomes associated with early post-traumatic osteoarthritis following knee joint injury in youth sport: a systematic review. *Osteoarthritis and Cartilage Open*. 2021;3(4):100213. https://doi.org/10.1016/j.ocarto.2021.100213
6. Aljehani MS, Christensen JC, Snyder-Mackler L et al. Knee biomechanics and contralateral knee osteoarthritis progression after total knee arthroplasty. *Gait & Posture*. 2022;91:266-275. https://doi.org/10.1016/j.gaitpost.2021.10.020
7. Hutchinson L, Grayson J, Hiller C et al. Relationship between knee biomechanics and pain in people with knee osteoarthritis: A systematic review and meta-analysis. *Arthritis Care & Research (Hoboken)*. 2023;75(6):1351-1361. https://doi.org/10.1002/acr.25001
8. Patterson BE, Crossley KM, Culvenor AG. Is there a role for therapeutic exercise in the prevention of post-traumatic osteoarthritis? *Current Rheumatology Reports*. 2022;24(10):312-321. https://doi.org/10.1007/s11926-022-01085-7
9. Kaur H, Kumar S, Kaur M. Multidisciplinary Rehabilitation Strategies for Sports-Related Knee Injuries: A Clinical Review. *Journal of Clinical Medicine*. 2024;13(5):1245. https://doi.org/10.3390/jcm13051245
10. Litvinova O, Kumetchko M, Pavlov S, Babenko N, Kolisnyk I. Problems of healing soft tissue injuries. East Ukr Med J. 2025;13(1):1-13. https://doi.org/10.21272/eumj.2025;13(1):1-13
11. Bombela V, Neblett R, Stanislavchuk M, Smiianov V, Smiianova O. The effectiveness of rheumatoid arthritis treatment is negatively associated with signs of central sensitization. East Ukr Med J. 2025;13(1):149-158. https://doi.org/10.21272/eumj.2025;13(1):149-158
12. Nijs J., George S.Z., Clauw D.J. Central sensitisation in chronic pain conditions: latest discoveries and their potential for precision medicine. TheLancet. Rheumatology.2021; 3(5): e383–e392. https://doi.org/10.1016/S2665-9913(21)00032-1.
13. Roos EM, Arden NK. Strategies for the prevention of post-traumatic osteoarthritis. *Nature Reviews Rheumatology*. 2023;19(2):92-104. https://doi.org/10.1038/s41584-022-00892-8
14. Collins NJ, Barton CJ, Schache AG, et al. Knee Injury and Osteoarthritis Outcome Score (KOOS): What is the state of the evidence? A systematic review and meta-analysis. *British Journal of Sports Medicine*. 2022;56(14):800-810. https://doi.org/10.1136/bjsports-2021-105001
15. Radu AF, Bungau SG. Management of Rheumatoid Arthritis: An Overview. Cells. 2021;10(11):2857. https://doi.org/10.3390/cells10112857

16. Taylor PC. Joint pain and beyond: the systemic nature of rheumatoid arthritis. The Lancet Rheumatology. 2023;5(6):e351–e360. https://doi.org/10.1016/S2665-9913(23)00091-1
17. Lansdown DA, Southworth TM, Feeley BT. Imaging in the management of post-traumatic osteoarthritis: Current status and future directions. *Journal of Orthopaedic Research*. 2023;41(1):15-26. https://doi.org/10.1002/jor.25368
18. Karasavvidis T, Pagan Moldenhauer CA, Haddad FS et al. Current concepts in alignment in total knee arthroplasty. *Journal of Arthroplasty*. 2023;38(7 Suppl 2):S29-S37. https://doi.org/10.1016/j.arth.2023.01.060

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