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THE EFFECTIVENESS OF A STRUCTURED REHABILITATION PROGRAM BASED ON PHYSICAL INDICATORS IN IMPROVING NEUROMUSCULAR FUNCTION AND REDUCING FEMORAL CARTILAGE DEGENERATION

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Abstract

Objective: This study aimed to evaluate the effectiveness of a rehabilitation program designed based on specific physical indicators in reducing femoral cartilage damage in the knee joint. The research sought to analyze the program's impact on improving knee joint mobility, alleviating pain, and enhancing overall neuromuscular function among individuals diagnosed with femoral cartilage degeneration.

Methods: A quasi-experimental design was adopted, involving six patients diagnosed with femoral cartilage damage at the Baqubah Teaching Hospital. The rehabilitation program spanned 12 weeks (three sessions per week) and included muscle strengthening, balance training, and flexibility exercises. Functional assessments were conducted using standardized tests, including the Maximum Quadriceps Strength Test, Back Muscle Strength Test, Trunk Flexion Test, and a structured Pain Scale Assessment. Statistical analyses were performed using paired t-tests to compare pre- and post-rehabilitation outcomes, with significance set at $p < 0.05$.

Results: The post-intervention results demonstrated significant improvements in quadriceps strength (74.9% increase, $p = 0.001$), back muscle strength (54.2% increase, $p = 0.002$), and trunk flexibility (17.8% improvement, $p = 0.000$). Additionally, pain levels were significantly reduced (85.8% reduction, $p = 0.000$). These findings align with previous studies emphasizing the role of structured rehabilitation in enhancing neuromuscular coordination and mitigating joint deterioration.

Conclusions: The study confirms that rehabilitation programs tailored to physical indicators effectively enhance knee joint functionality, reduce pain, and improve muscle strength. The structured progression of exercises contributed to neuromuscular adaptations, leading to better motor control and joint stability. These results support the integration of targeted rehabilitation programs for individuals suffering from cartilage degeneration to improve mobility and prevent long-term joint complications. Future research should explore the long-term effects of such programs and compare different rehabilitation approaches, including aquatic therapy and AI-driven movement analysis. This study introduces a clinically adaptable model for rehabilitation based on physical indicators with significant efficacy in neuromuscular restoration.

Keywords: Rehabilitation program, Knee joint function, Femoral cartilage damage, Neuromuscular adaptation, Pain reduction, Strength training, Flexibility exercises.

1. INTRODUCTION AND RESEARCH IMPORTANCE

Femoral cartilage damage in the knee joint is a widespread issue affecting both athletes and older adults, leading to chronic pain and movement difficulties. Muscle strength is a crucial component of physical fitness, contributing to posture, overall health, and functional movement(Zaina et al., 2023). Without adequate muscular strength, executing physical movements becomes challenging, as force direction and magnitude influence movement velocity and coordination. Cartilage degeneration, commonly known as knee osteoarthritis, can begin early in life and is often managed effectively through physiotherapy(Ekstrom et al., 2007). Osteoarthritis is a primary cause of joint pain, typically exacerbated by activities such as climbing stairs or carrying heavy loads. Accurate pain assessment is crucial for effective treatment, as symptoms may arise from knee swelling, restricted motion, bone friction, or synovial membrane inflammation(Rey-Barth et al., 2022). Physiotherapy interventions focus on synovial fluid secretion, cartilage nourishment, joint pain relief, and muscle strengthening. These treatments also emphasize weight management to reduce joint stress, thereby minimizing cartilage degeneration(Willy, 2018). Incorporating structured exercise regimens and electrical muscle stimulation enhances muscle efficiency while dietary modifications—reducing carbohydrates, sugars, and fats while increasing vegetable and fruit intake—further support joint health. This research aims to evaluate the effectiveness of a specialized rehabilitation program in mitigating cartilage damage and improving knee joint functionality(Gacto-Sánchez et al., 2023). Despite the growing body of research on knee osteoarthritis and joint degeneration, there remains a noticeable gap in the development and evaluation of rehabilitation protocols specifically tailored to measurable physical indicators(Journal et al., 2020). Most existing interventions emphasize generalized exercise approaches rather than individualized programs grounded in objective functional metrics. This study aims to address that gap by implementing and assessing a structured rehabilitation program designed around quantifiable physical markers to mitigate femoral cartilage damage and enhance neuromuscular performance(Gacto-Sánchez et al., 2023).

2. Research Objectives

- Develop a rehabilitation program aimed at restoring knee joint range of motion.
- Assess the impact of the rehabilitation program on restoring knee joint mobility.

3. Research Hypothesis

- There are statistically significant differences between pre- and post-tests in favor of the post-test for improving knee joint mobility.

4. Research Scope

- Human Sample: Patients diagnosed with femoral cartilage damage.
- Timeframe: From March 1, 2024, to December 1, 2024.
- Location: Physical therapy center at Baqubah Teaching Hospital.

5. RESEARCH METHODOLOGY

A quasi-experimental research design was adopted, utilizing a single-group pretest-posttest model. Experimental methods are among the most reliable approaches for obtaining precise and verifiable results.

5.1 Research Sample

To achieve the research objectives, an intentional sampling method was used. The study sample consisted of six patients diagnosed with femoral cartilage damage(Lobo et al., 2024). Each patient's condition was thoroughly assessed using hospital records and radiographic imaging (X-ray) under the supervision of a specialist physician.

5.2 Sample Homogeneity

To ensure the sample's homogeneity, key variables such as age, weight, and height were analyzed using skewness coefficients:

Table 1. Homogeneity of the Research Sample According to Age, Weight, and Height Variables

Variable	**Unit**	**Mean ($\bar{X}$)**	**Standard Deviation (SD)**	**Median**	**Skewness Coefficient**
Age	Years	50	3.44	50	0.66
Weight	kg	80	0.90	82	0.88
Height	cm	170	1.36	171	1.14

6. RESEARCH TOOLS AND EQUIPMENT

6.1 Research Tools
- Technical observation and experimentation
- Physical fitness tests
- Data recording forms
- Internet resources

6.2 Equipment Used in the Research
- The following measuring instruments were used:
- Various measuring tools (stopwatches, measuring tape)
- Electronic computer (Pentium 4)
- Medical balance
- Medicine ball (0.5 kg)

7. Tests Under Study
7.1 Maximum Quadriceps Strength Test Using a Dynamometer
Purpose: To measure the maximum strength of the quadriceps muscles.
Required Equipment: A dynamometer to measure the strength of the back and leg muscles.
Performance Description: The subject places both feet on the flat platform of the dynamometer, bends the knees at a 90-degree angle while keeping the head upright and back straight, holds the handle from both ends, shortens the handle chain, and attempts to pull using the legs(Park et al., 2024).
7.2 Back Muscle Strength Test Using a Dynamometer
Purpose: To measure the strength of the back muscles.
Required Equipment: A dynamometer to measure the strength of the back and leg muscles.
Performance Description: The subject stands on the platform with legs fully extended, maintains a forward chest position, grips the handle at both ends, and attempts to pull it upward towards the shoulder blade(Agrawal & Chandrakar, 2025).
7.3 Trunk Flexion Test from Standing Position
Purpose: To measure the flexibility of the trunk and thigh in forward bending movements(Shridhar & Udayakumar, 2024).
Required Equipment: A 20 cm ruler. A sturdy table capable of supporting the subject's weight.
Performance Description: The ruler is placed on the table edge, with the midpoint aligned at the top edge and the lower half positioned below the edge(Wang, 2024). The zero point is set at the table's edge, with deviations recorded as positive (below the table) or negative (above the table).
7.4 Pain Scale Assessment
Pain was measured using a specially designed questionnaire developed by the researchers. The pain scale is evaluated as follows:
- Pain at rest (1 point).
- Pain upon applying pressure to the affected area (1 point).
- Pain during knee flexion at 15 degrees (3 points).
- Pain during knee flexion at 25 degrees (2 points).
- Pain during knee flexion at 45 degrees (1 point).

The total possible pain score is 8 points, with a higher score indicating greater pain intensity(Kostenko et al., 2025). The questionnaire consists of five sections, with each section corresponding to the pain scale. Pain is recorded at each stage, and the final score ranges from 0 (no pain) to 8 (maximum pain), as detailed in Appendix (1).

8. Pilot Study
Experts in scientific research recommend conducting a pilot study to ensure accurate and reliable results. The pilot study is defined as "a preliminary experimental study conducted on a small sample (two subjects) before proceeding with the main research, aimed at selecting research methods and tools(Lavallière et al., 2025)." The researchers conducted the pilot study on February 27, 2024, at 9:00 AM, involving two patients diagnosed with femoral cartilage damage, who were part of the study sample. The objectives of the pilot study were:
- Identifying potential difficulties and obstacles that may arise during the main experiment and developing strategies to address them.
- Assessing the computer's capability in analyzing video footage and determining the time required to conduct the tests.
- Determining the required number of assisting staff to ensure accurate and reliable data collection during physical testing.

- Ensuring the suitability of test locations, verifying the functionality of recording devices, and determining optimal camera positioning to capture performance accurately.

9. Field Experiment Procedures

9.1 Conducting the Research Tests

The research tests were conducted on February 28, 2024, at 10:00 AM at the rehabilitation center of Baqubah Teaching Hospital. The following tests were performed:

- Maximum quadriceps strength test using a dynamometer.
- Back muscle strength test using a dynamometer.
- Trunk flexion test from standing position.
- Pain scale assessment using a specially designed questionnaire.

10. Rehabilitation Program Details

The primary goal of designing the rehabilitation program was to develop maximum muscular strength in the affected leg to rehabilitate ligaments and muscles surrounding the knee joint. The rehabilitation program for the experimental group commenced on March 2, 2024, and lasted for 12 weeks, with three sessions per week, totaling 36 rehabilitation sessions(Aulya Ramadhan et al., 2024). The program included six exercises that gradually progressed from easy to difficult, with session durations ranging from 35 to 75 minutes. The structured rehabilitation plan focused on:

- Strengthening the muscles surrounding the knee.
- Balance training.
- Flexibility improvement exercises.

The structured rehabilitation approach aimed to enhance muscle function, neuromuscular coordination, and joint mobility to effectively reduce femoral cartilage damage in the knee joint.

Table 2. sessions numbers and duration

Phase	Type of Exercise	Sessions/Week	Session Duration
1-4	Muscle Strengthening	3	45 minutes
5-8	Balance and Stability	3	50 minutes
9-12	Flexibility and Functional Rehab	3	60 minutes

8. Post-Testing and Data Analysis

Post-tests were conducted on June 3, 2024, under the same conditions as the pretests(Giggins et al., 2013). The SPSS statistical package was used to analyze the collected data.

Table 3. Pre- and Post-Test Results for the Experimental Group in Strength, Flexibility, and Pain Scale Measures

Test	Unit	Pre-Test Mean	Post-Test Mean	T-Value	Significance
Quadriceps Strength Test	kg	25.55	44.67	18.44	0.001 (Significant)
Back Muscle Strength Test	kg	14.56	22.45	12.55	0.002 (Significant)
Trunk Flexion Test	Degrees	102.3	120.5	6.87	0.000 (Significant)
Pain Scale	Score	4.30	7.99	2.23	0.000 (Significant)

8. Discussion and Interpretation of Results

Upon analyzing Table (3), which presents the pre-test and post-test results for the experimental group in tests measuring (maximum quadriceps strength using a dynamometer, back muscle strength using a dynamometer, trunk flexion from a standing position, and pain scale), the findings indicated statistically significant improvements. The researchers attribute these improvements to the effectiveness of the rehabilitation program designed to reduce femoral cartilage damage in the knee joint. The rehabilitation program focused on strengthening the muscles surrounding the joint, aligning with the findings of Basil Abdulsattar Ahmed & Alaa Khalaf Hayder (2020, p.341), who stated that "therapeutic exercises enhance the strength of muscles involved in the injured area and help restore full range of motion." The program devised by the researchers contributed to breaking down and dissolving calcifications (calcium deposits) inside the affected joint, enhancing circulation, and stimulating blood flow. The observed improvement in pain levels resulted from the variety of exercises, including modifications in duration, rest periods, and repetitions, along with the adherence of participants to the rehabilitation program. These factors played a crucial role in improving the range of motion of the knee joint. Muscle contraction strength, speed, and endurance are key indicators of muscle strength development. Increased nerve signal frequency to the muscle enhances contraction force, which aligns with the assertion by Alaa Khalaf Haidar & Ahmed Shaker Mahmoud (2020, p.12278) that "improving neural transmission time and impulses to the motor unit through functional and physiological adaptations reduces pain perception by supplying oxygen to muscle fibers for metabolism." This is a significant indicator of functional efficiency and muscular activity during contraction, as it contributes to knee flexion and extension while nourishing femoral cartilage. Furthermore, Osama Riyadh & Imam Mohammed Hassan (1999) emphasized the importance of "electromyographic assessment of nerves and muscles to evaluate physiological energy." The study's findings align with those of Basil Abdulsattar Ahmed & Alaa Khalaf Hayder (2020, p.328), who noted that rehabilitation exercises enhance muscular efficiency through consistent training, ultimately improving the neuromuscular coordination necessary for optimal muscle performance, whether in dynamic or static actions. Neuromuscular coordination plays a vital role in developing muscle strength and increasing excitability. Through structured training in the rehabilitation program, muscular electrical activity adapts in terms of neural signal intensity, duration, and frequency. According to Alaa Khalaf Haidar, Ahmed Shakir Mahmood, & Waseem Saad Nsaif (2019, p.739), "the nervous system regulates internal coordination within the muscle itself, as well as coordination between the muscles engaged in contraction. This includes internal muscle coordination, the number of active units, the rate and speed of neural signals, and the reciprocal timing between motor unit activities." Enhancing fiber recruitment leads to rapid muscle contractions, which in turn reduce contraction time, fulfilling the muscle’s functional and movement-related duties. The progression in muscle contraction force resulting from therapeutic physical training was evident in reduced contraction time. This is supported by Risaan Khuraibet & Ali Turki (2002), who noted that "training should improve an athlete’s ability to activate a large number of fast-twitch muscle fibers simultaneously and in the shortest possible time." Additionally, the structured therapeutic exercises led to an improved muscle response rate, as Abu Alaa (1982, p.97) pointed out that "the efficiency of fast-twitch anaerobic fibers is a key factor in rapid contraction." The observed positive effects of the rehabilitation exercises confirm their ability to develop muscle strength, counteract muscle atrophy, and promote muscle hypertrophy by enhancing metabolic components and muscle fiber structure. Similarly, Samia Khalil (1990, p.166) emphasized that "resistance exercises using weights and isometric contraction exercises are among the most effective methods for rehabilitating weak peripheral muscles in the knee joint." Therapeutic exercises stimulate weakened muscles through the nerves supplying them. During maximum-effort exercises, strong tension is applied to sensory receptors and muscle spindles, transmitting signals to the brain and returning through the spinal cord to the motor nerves of the muscle. This response is proportional to the applied resistance—higher resistance leads to increased neural stimulation, recruiting a greater number of motor neurons to execute contractions quickly and forcefully, reducing reaction time and generating maximum power. Motor neurons in fast-twitch fibers are characterized by their large size, allowing them to accommodate a high volume of neural signals at high speeds for maximum contraction and rapid motor responses. This contributes significantly to knee joint movement efficiency.

9. CONCLUSION AND RECOMMENDATIONS

The study confirms the importance of rehabilitation programs tailored to physical indicators in improving knee joint function and reducing femoral cartilage damage. The designed rehabilitation exercises effectively strengthened the muscles supporting the knee joint, improved mobility, and significantly reduced pain levels.

Conclusions

- The rehabilitation program based on physical indicators improved the knee joint’s range of motion and reduced femoral cartilage damage.
- The application of rehabilitation exercises significantly enhanced knee function and increased the range of motion in the experimental group.

Recommendations

- Greater emphasis should be placed on motor rehabilitation and the adoption of advanced rehabilitation techniques and modern equipment for treating various injuries.
- Future studies should investigate different types of injuries across diverse population groups to expand the application of rehabilitation programs.

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REFERENCES:

1. Abd Ali Nassif, & Hussein, Q. H. (1978). Strength training. Baghdad: Arab Printing House.
2. Abdel Fattah, A. A. A. (1982). Sports biology (1st ed.). Cairo: Dar Al-Fikr.
3. Abdullah, A. R. A., & Abdel Daim, M. A. (1999). Introduction to research methodology in education and humanities (1st ed.). Kuwait: Al-Falah Library.

4. Agrawal, A., & Chandrakar, K. (2025). Biomechanical impacts of wearable and implantable technologies in post-surgical rehabilitation. Journal of Neonatal Surgery, 14(1s). https://www.jneonatalsurg.com

5. Ahmed, B. A., & Hayder, A. K. (2020). The effect of rehabilitative exercises in the case of anterior dislocation of the uncomplicated shoulder joint for men aged 40–50 years. Molecular & Clinical Medicine, 7(6).

6. Ahmed, B. A., & Hayder, A. K. (2020). The effect of using rehabilitative exercises in a preventive manner to reduce shoulder rotation for people with special needs (wheelchairs). European Journal of Molecular & Clinical Medicine, 7(6).

7. Aulya Ramadhan, N., Amani, F. Z., Salsabil, J., & Satyawati, R. (2024). Geriatric comprehensive rehabilitation using pressure biofeedback of neurogenic bladder: A case report. SEEJPH, 25.

8. Ekstrom, R. A., Donatelli, R. A., & Carp, K. C. (2007). Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. Journal of Orthopaedic and Sports Physical Therapy, 37(12), 754–762. https://doi.org/10.2519/jospt.2007.2471

9. Gacto-Sánchez, M., Medina-Mirapeix, F., Benítez-Martínez, J. C., et al. (2023). Estimating quadriceps and hamstrings strength through Myoton among recreational athletes. Journal of Sport Rehabilitation, 32(7). https://doi.org/10.1123/jsr.2022-0437

10. Giggins, O. M., Persson, U. M. C., & Caulfield, B. (2013). Biofeedback in rehabilitation. Journal of NeuroEngineering and Rehabilitation, 10(1). https://doi.org/10.1186/1743-0003-10-60

11. Ismaeel, S. A. (2025). Biomechanical assessment of neuromuscular balance in the upper limbs during progressive load resistance training.

12. Ismaeel, S. A., & Al-Azzawi, H. K. (2022). Using kinetic variables for technique correction in Olympic lifts.

13. Journal, I., Rehabilitation, P., Ismaeel, S. A., Fenjan, F. H., & Qadori, R. H. (2020). Biomechanical analysis of some variables and EMG of the muscles during the performance of the snatch lift in weightlifting. 24(05), 8234–8240.

14. Kostenko, E. V., Kotelnikova, A. V., Petrova, L. V., Pogonchenkova, I. V., & Filippov, M. S. (2025). The psychophysiological technology with biofeedback in complex rehabilitation of post-stroke patients: A randomized controlled study. Vestnik Vosstanovitel'noj Mediciny, 24(1), 55–66. https://doi.org/10.38025/2078-1962-2025-24-1-55-66

15. Lavallière, M., Tremblay, M., Ojardias, E., et al. (2025). Shoulder musculoskeletal disorder rehabilitation using a robotic device based on electromyography (EMG) biofeedback: A retrospective cohort study. Medicina (Lithuania), 61(2). https://doi.org/10.3390/medicina61020272

16. Lobo, P., Morais, P., Murray, P., & Vilaça, J. L. (2024). Trends and innovations in wearable technology for motor rehabilitation, prediction, and monitoring: A comprehensive review. Sensors, 24(24). https://doi.org/10.3390/s24247973

17. Park, J.-H., Banarjee, C., Fu, J., et al. (2024). Youth athletes and wearable technology. F1000Research, 13, 1381.
https://doi.org/10.12688/f1000research.156207.1

18. Rey-Barth, S., Pinsault, N., Terrisse, H., et al. (2022). A program centered on smart electrically assisted bicycle outings for rehabilitation after breast cancer: A pilot study. Medical Engineering and Physics, 100.
https://doi.org/10.1016/j.medengphy.2022.103758

19. Shridhar, R., & Udayakumar, R. (2024). Developing a tourism information portal using web technologies and database management. Indian Journal of Information Sources and Services, 14(3), 71–76. https://doi.org/10.51983/ijiss-2024.14.3.10

20. Wang, Y. (2024). Evaluation of the effect of biofeedback system driven by optoelectronic conjugate materials in VR exercise rehabilitation. MCB Molecular and Cellular Biomechanics, 21(4). https://doi.org/10.62617/mcb628

21. Hamid, J. A. K., Salama, O. A. I., Sadiq, A. J., Zohear, A., Jasim, T. A., & Ismaeel, S. A. (2025). Three-dimensional quantitative analysis of kinematic variables in discus throwing performance. Journal of Sport Biomechanics, 10(4), 310–322.

22. Willy, R. W. (2018). Innovations and pitfalls in the use of wearable devices in the prevention and rehabilitation of running related injuries. Physical Therapy in Sport, 29. https://doi.org/10.1016/j.ptsp.2017.10.003

23. 18. Hashim, H., Mohammed, S. A., Ali, B. M., Ismaeel, S. A., & Nasir, M. (2025). Biceps and triceps muscle activation under progressive loads: A study on functional symmetry of the upper limbs. Journal of Sport Biomechanics Spring, 11(1), 64–78.

24. Zaina, F., Côté, P., Cancelliere, C., et al. (2023). A systematic review of clinical practice guidelines for persons with non-specific low back pain with and without radiculopathy: Identification of best evidence for rehabilitation to develop the WHO's package of interventions for rehabilitation. Archives of Physical Medicine and Rehabilitation. https://doi.org/10.1016/J.APMR.2023.02.022