The effect of 8 weeks of resistance training on the angle of hip and knee flexion, proprioception, and muscle performance following anterior cruciate ligament reconstruction

El efecto de 8 semanas de entrenamiento de resistencia en el ángulo de flexión de la cadera y la rodilla, la propiocepción y el rendimiento muscular después de la reconstrucción del ligamento cruzado anterior

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Abstract

Objective: This study aimed to evaluate the effect of an eight-week strength training program, focusing on the uninjured side, on improving hip and knee function, enhancing proprioception, and increasing muscle strength in professional basketball players who had undergone anterior cruciate ligament (ACL) reconstruction surgery.
Methodology: The study included 30 professional athletes, all of whom had undergone ACL reconstruction surgery. Participants were randomly divided into two groups: Experimental Group: Underwent a strength training program targeting the uninjured side. Control Group: Did not undergo this training program. Hip and knee flexion angles, proprioception, and muscle strength were measured before and after the training period. Specialized analytical software and measuring devices were used to collect and analyze the data.
Results: The results showed significant improvements in hip and knee flexion angles, proprioception, and muscle strength in the experimental group compared to the control group ($P \leq 0.05$). The study demonstrated that contralateral strength training contributes to improved hip and knee mobility by increasing strength, flexibility, stability, and neuromuscular control.
Conclusion: Contralateral strength training is an effective method for improving motor function in athletes recovering from ACL reconstruction surgery. This type of training contributes to improved rehabilitation outcomes, including increased flexibility, proprioceptive ability, and muscle performance.

Keywords

Contralateral strength exercises; flexion angle; proprioception; muscle performance; anterior cruciate ligament reconstruction.

Resumen

Objetivo: Este estudio tuvo como objetivo evaluar el efecto de un programa de entrenamiento de fuerza de ocho semanas, centrándose en el lado no lesionado, en la mejora de la función de la cadera y la rodilla, la mejora de la propiocepción y el aumento de la fuerza muscular en jugadores profesionales de baloncesto que se habían sometido a una cirugía de reconstrucción del ligamento cruzado anterior (LCA).
Metodología: El estudio incluyó a 30 jugadores profesionales de baloncesto, todos los cuales habían sido sometidos a cirugía de reconstrucción del LCA. Los participantes se dividieron aleatoriamente en dos grupos: Grupo experimental: Se sometieron a un programa de entrenamiento de fuerza dirigido al lado no lesionado. Grupo Control: No se sometió a este programa de entrenamiento. Se midieron los ángulos de flexión de la cadera y la rodilla, la propiocepción y la fuerza muscular antes y después del período de entrenamiento. Se utilizaron software analítico especializado y dispositivos de medición para recopilar y analizar los datos.
Resultados: Los resultados mostraron mejoras significativas en los ángulos de flexión de cadera y rodilla, propiocepción y fuerza muscular en el grupo experimental en comparación con el grupo control. El estudio demostró que el entrenamiento de fuerza contralateral contribuye a mejorar la movilidad de la cadera y la rodilla al aumentar la fuerza, la flexibilidad, la estabilidad y el control neuromuscular.
Conclusión: El entrenamiento de fuerza contralateral es un método eficaz para mejorar la función motora en atletas que se recuperan de una cirugía de reconstrucción del LCA. Este tipo de entrenamiento contribuye a mejorar los resultados de la rehabilitación, incluido el aumento de la flexibilidad, la capacidad propioceptiva y el rendimiento muscular.

Palabras clave

Ejercicios de fuerza contralateral; ángulo de flexión; propiocepción; rendimiento muscular; reconstrucción del ligamento cruzado anterior.

Introduction

Resistance training is considered a fundamental component in improving muscle performance and enhancing joint function, particularly following major sports injuries such as an anterior cruciate ligament (ACL) tear. The ACL is one of the primary ligaments of the knee and plays a vital role in stabilizing the joint during athletic movements. When injured, patients often require ACL reconstruction surgery (Griffin et al., 2000). However, the surgical procedure is not the final step in the recovery process, as it must be followed by a comprehensive rehabilitation program aimed at restoring muscular strength and normal knee mobility.
While ACL reconstruction is a crucial step in regaining functional joint stability, the success of recovery largely depends on adherence to a targeted exercise regimen designed to improve joint flexibility and muscular strength. This approach facilitates faster recovery and significantly reduces the risk of future injuries. In this context, resistance training has been recognized as one of the most effective methods in post-ACL surgery rehabilitation. It plays a key role in enhancing muscle strength and joint flexibility, thereby improving knee flexion angle and the joint's ability to absorb mechanical stress. Studies indicate that these exercises help strengthen the muscles surrounding the knee, leading to significant improvements in overall joint function (Paterno et al., 2012; Myer et al., 2013).
Resistance training specifically targets major muscle groups, particularly the quadriceps and hamstrings, which provide essential support to the knee joint, especially after ACL reconstruction (Myer et al., 2013). Research suggests that resistance training increases both the knee and body flexion angles, which contributes to the restoration of normal joint movement and reduces the risk of further strain or injury (Paterno et al., 2012).
More specifically, studies have shown that an 8-week rehabilitation program incorporating resistance training can lead to marked improvements in the knee's capacity to endure sports-related movements and enhance muscular performance post-surgery (Ardern et al., 2014). These exercises support the rehabilitation of muscles and surrounding tissues, leading to better balance, muscle strength, and control during dynamic movements such as running or single-leg stance (Paterno et al., 2012).
Research Objective:
This study aims to examine the impact of an 8-week resistance training program on knee and body flexion angles, as well as its effect on muscle performance following anterior cruciate ligament (ACL) reconstruction. The study seeks to measure changes in knee flexibility and adaptability to sports movements, in addition to analyzing improvements in the strength of the muscles surrounding the knee (Ardern et al., 2014). With the growing number of athletes undergoing this surgery, it is increasingly critical to develop effective rehabilitation strategies that ensure a safe and prompt return to sports activities.

Method

Study Design

This pilot study was conducted using a pre-test and post-test design(Mohammed Hammood et al., 2025; Omar et al., 2025) .

Participants

included a sample of 30 professional athletes Participants were selected based on specific inclusion criteria, which included: having sustained an anterior cruciate ligament (ACL) tear within the past six months, structural integrity of the knee joint, a unilateral injury, and no prior lower limb injuries or other health conditions that could affect study outcomes.
Exclusion criteria included: Unwillingness to participate or cooperate, the presence of additional injuries, or failure to attend more than 30% of the rehabilitation sessions. At the outset of the study, all participants were informed about the nature and objectives of the research and signed a written informed consent form approved by the relevant statistical authority. Ethical approval was obtained from the Research Ethics Committee of the University of Isfahan, Isfahan, Iran (Code: IR.UI.REC.1402.021).
and their rights to leave the study were considered
Based on the inclusion and exclusion criteria, 30 eligible participants were purposively selected and then randomly assigned to two equal groups: a control group (15 participants) and an experimental

group (15 participants). The experimental group underwent an 8-week cross-training rehabilitation program.
The sample size was determined using G*Power statistical software (version 3.1.9.2), ensuring sufficient statistical power to detect significant differences between the two groups with accuracy and reliability.

Procedures

The experimental group underwent a specific training program that included targeted exercises, with strict adherence to avoiding any other physical activities. Painkillers for knee pain were permitted when necessary. Participants began the training one week after the initial assessment, attending three supervised sessions per week, with a minimum of 21 training sessions. Each session started with a 3-minute warm-up on a stationary bike. Upon completion of the training program, participants underwent the same assessments conducted prior to the intervention, with six anatomical markers placed on their bodies to ensure measurement accuracy.

Kinematic analysis was conducted using KINOVA motion analysis software (version 8.27) to evaluate biomechanical risk factors associated with anterior cruciate ligament (ACL) injuries. Key variables included knee flexion angles and the range of motion (ROM) for both knee and hip joints during landing tasks. The experimental setup involved a 30-cm-high platform from which participants performed landing trials. Movements were recorded using two high-resolution digital video cameras (Canon D600 and Nikon D90) positioned 3 meters away from the platform at a height of 1.5 meters to capture the sagittal plane.

Prior to testing, all participants completed a standardized 5-minute warm-up followed by dynamic stretching exercises focused on the lower extremities. Participants were not given specific instructions regarding landing mechanics but were advised to maintain a biomechanically appropriate landing posture throughout the trials.

Two types of landings were assessed: double-leg and single-leg landings. For double-leg landings, participants landed on a circular platform (30 cm in diameter), ensuring symmetrical weight distribution. Subsequently, single-leg landings were performed using the dominant limb, with participants required to stabilize and maintain balance for a minimum of one second before returning to the starting position.

Three successful trials were recorded for each condition (bilateral and unilateral landings). Trials were repeated if any compensatory or uncontrolled movements occurred, in order to ensure consistency and reliability of the recorded data.

Kinematic Analysis

KINOVA is an advanced tool designed for the analysis, comparison, and evaluation of kinematic data across diverse work environments. In this study, KINOVA software was employed to analyze risk factors related to anterior cruciate ligament (ACL) injuries during double-leg landings, utilizing angular measurements for biomechanical assessment.

The software allows users to import video recordings, adjust playback speed, and extract still images at precise time points, facilitating accurate graphical analysis of joint kinematics.

Previous research has demonstrated the high reliability of KINOVA in measuring flexion and extension angles of the neck joint in the sagittal plane, with intraclass correlation coefficients (ICC) indicating accuracy levels up to 95%, confirming the software's precision in angular measurements.

Additionally, Puig-Diví et al. (2019) validated the software's reliability and validity in measuring joint angles and distances from four different camera perspectives (90°, 75°, 60°, and 45°). Their findings confirmed KINOVA's ability to accurately measure distances up to 5 meters and angular ranges between 90° and 45°, underscoring its suitability for detailed biomechanical analysis (Puig-Diví et al., 2019).

Proprioception Test

To assess proprioceptive acuity, three target angles—30°, 60°, and 90°—were marked on a vertical wall using clear, visible indicators. A box of appropriate height was placed adjacent to the marked area to serve as a seating platform for participants during testing.

Prior to data collection, the testing protocol was thoroughly explained to each participant to ensure comprehension and compliance. Participants were seated on the box and blindfolded to eliminate visual input, thereby isolating proprioceptive feedback.

The participant was first instructed to position their foot at a 30° angle relative to the marked reference on the wall. Once the position was achieved and stabilized, the angle was recorded using precise measurement tools. Subsequently, participants returned their foot to the neutral starting position and rested momentarily to avoid sensory adaptation.

The procedure was then repeated at the 60° angle, with identical recording and rest intervals. Multiple trials were conducted for each angle to ensure reliability and consistency of the measurements. Any compensatory or extraneous movements were monitored and controlled to maintain data integrity.

This method effectively evaluates the participant's ability to perceive joint position without visual cues, providing insight into the integrity of proprioceptive function critical for balance and motor control.

Measurement of Hamstring and Quadriceps Muscle Strength

Quadriceps strength was assessed by having the participant sit on a chair with their leg in a flexed position. The dynamometer was placed below the knee joint on the lower leg. The participant was then instructed to exert force by extending the knee against the resistance of the device, and the maximum force applied was recorded.

For hamstring strength assessment, the same procedure was repeated with the leg in an extended position. The dynamometer was placed below the knee joint on the back of the lower leg. The participant was instructed to apply force by flexing the knee towards the device, and the maximum force applied was recorded.

These measurements were taken to ensure an accurate evaluation of muscle performance based on the applied force response, providing objective indicators of muscle strength in both muscle groups (Norouzi et al., 2015).

Research Training Protocol

Cross-training exercises for the opposite limb were initiated two weeks post-surgery, with sessions performed three times per week over the course of eight weeks. The training program included exercises such as knee extensions, hamstring flexions, and leg presses using the available resistance equipment. Each exercise was performed in three sets of 3 to 5 repetitions, with a rest period of 1.5 to 2 minutes between each set to ensure adequate muscle recovery before the next round.

In the first training session, participants were introduced to the exercises with detailed instructions on proper technique and the purpose of each movement in the rehabilitation process. The initial weights were selected based on the individual capacity of each participant, and an initial load test was performed to determine appropriate resistance for the first session.

The participants' performance was monitored weekly throughout the training program. The training load was assessed using a physical exertion scale, and observations were made by specialized trainers to ensure the appropriate intensity of the exercises. If a participant was able to perform more than 6 repetitions in two consecutive sets of a given exercise, the resistance was increased. The program was then adjusted to include three sets of 20 repetitions, which was aimed at further challenging the participants and enhancing the effectiveness of the exercises.

Throughout the sessions, verbal encouragement was continuously provided by the specialized trainers, alongside psychological support to help motivate the participants to engage fully with the program. All exercises were performed under the strict supervision of qualified trainers to ensure proper technique and prevent any risk of injury. A detailed tracking system was employed to record all aspects of the training, including performance quality, repetitions, resistance levels, and rest periods for each participant.

Over the eight-week period, the participants' responses to the training were regularly evaluated. Any improvements in muscular performance and joint flexibility were noted, helping to inform whether adjustments to the program were necessary based on the individual progress of each participant.

Table 1. Cross-Training Protocol

Type of exercise	Week One to Three	Week Four to Six	Week Seven and Eight
Straight Leg Raise	20		
Wall Leg Stretch for Increasing Range of Motion	20		
Weight-Bearing Exercise on One Leg	20		
Knee Flexion to 70 Degrees	20		
Standing Squat to 90 Degrees Flexion	20		
Endurance Exercises (Cycling)	20	25	
Progression of Resistance Exercises (Leg Press, Step-Ups)	20	25	
Dynamic Squat (0 to 110 Degrees)		25	
Balance Exercises		25	
Plyometric Exercises		25	25
Progression of Resistance Exercises to Full Range of Motion and Single-Leg Lifts Without Pain		25	25
Progression of Resistance and Endurance Exercises, Jumping, Running			25
Advanced Plyometric Exercises			25
Functional and strength training exercises for preparing patients and returning to sports.			25

Data analysis

The data collected from the assessments in this study were analyzed using SPSS software version 26(Hammood et al., 2024; Khalaf et al., 2025). Descriptive statistics were initially applied to summarize the data, including the calculation of means and standard deviations for the key variables in each group. The data were also presented in tables and charts to provide a comprehensive visual overview of the information, making it easier to understand the overall distribution and identify any trends or variations between measurements over the course of the study.

For inferential analysis, the Shapiro-Wilk test was used to check the normality of data distribution in both groups. The Shapiro-Wilk test is a reliable statistical tool for testing the null hypothesis that the data follow a normal distribution. The test was performed for both the experimental and control groups. If the data were found to be normally distributed ($p > 0.05$), repeated measures analysis of variance (Repeated Measures ANOVA) was used to evaluate the effects of the cross-training exercises on the variables within each group over time.

Repeated Measures ANOVA is particularly suitable for studies involving repeated measurements on the same subjects, as it allows for the assessment of differences within the same group over multiple time points. The significance level was set at $p \leq 0.05$, meaning that any differences found between the repeated measures would be considered statistically significant if the p-value was below this threshold. This method was applied to measure the temporal effects of the exercises on variables such as muscle strength, physical fitness, and endurance.

In cases where the data did not follow a normal distribution ($p < 0.05$), non-parametric tests were applied. Specifically, the Friedman test was used to evaluate differences between repeated measurements within the same group, and the Wilcoxon signed-rank test was used to assess differences between measurements at different time points. These non-parametric tests are appropriate when the assumption of normality is violated and are reliable methods for analyzing non-normally distributed data.

Effect size was also calculated using Partial Eta Squared (η^2) statistics to assess the strength of the impact of cross-training exercises on the targeted variables. Effect size is an important measure that reflects the magnitude of the relationship between the studied variables. Partial Eta Squared values were interpreted as follows: small effect (0.01), medium effect (0.06), and large effect (0.14).

Moreover, missing data were carefully examined to ensure that they did not bias the final results. In cases of missing data, techniques such as mean substitution or appropriate missing data analysis methods (e.g., time-series analysis or random effects models) were employed to minimize the impact on the overall analysis.

Range analysis was also conducted to compare the responses of individuals within each group and determine the degree of variation in responses to the training exercises. This step is crucial for assessing whether there are differing responses among individuals, which helps in understanding the effect of the exercise on a more individualized basis.

A confidence level of 95% was used in all statistical analyses, ensuring that the results obtained were statistically reliable with a 95% confidence interval. The results of the statistical analysis were fully reported, including F-values, p-values, and η^2, with a detailed interpretation of the effects of the exercises on the variables under study. This allows for clear conclusions regarding the effectiveness of the cross-training exercises in improving muscle performance and physical fitness.

Results

The demographic characteristics of the 30 athletes in the present study, including the mean and standard deviation of descriptive features such as age in years, weight in kilograms, and height in centimeters, are presented in Table 2.

Table 2. Demographic Characteristics of Participants

Index	Group	Average	Standard deviation	t value	Significance level
Age (yrs)	Experimental	24.3	4.3	3.15	0.33
	Control	25.4	4.6		
Height (cm)	Experimental	171.2	0.1	2.48	1.23
	Control	172.3	0.03		
Weight (kg)	Experimental	74.2	3.8	3.65	0.21
	Control	73.4	0.05		

Table 3. Comparison of means in pre and post intervention of parameters (ROM, proprioception and muscle strength) between groups

Variable	Exam Appointment	Experimental Group (n=15)	Control (n=15)	Intra-group changes	Intergroup changes	Interaction
Hip Flexion ROM(Degree)	Pre-test	34.5±7.9	27.4±7.3	F=12.05	F=9.05	F=50.01
	Post-test	35.8±9.9	27.2±6.7	P=0.002	P=0.01	P=0.002
Knee Flexion ROM(Degree)	Pre-test	52.8±3.1	51.6±7.8	F=28.8	F=21.2	F=37.1
	Post-test	58.1±4.7	50.7±3.8	P=0.02	P=0.01	P=0.001
Proprioception (Degree)	Pre-test	7.1±1.1	7.3±1.1	F=17.05	F=26.05	F=22.01
	Post-test	4.7±1.4	8.7±1.4	P=0.002	P=0.001	P=0.03
Quadriceps muscle strength (Newton)	Pre-test	53.6±2.1	55.9±2.7	F=73.05	F=98.05	F=80.01
	Post-test	60.1±0.4	54.7±0.2	P=0.02	P=0.01	P=0.02
Hamstring muscle strength (Newton)	Pre-test	48.5±2.1	47.8±2.5	F=44.05	F=28.02	F=22.1
	Post-test	53.4±1.2	48.6±1.2	P=0.002	P=0.005	P=0.02

Discussion

The results of the Shapiro-Wilk test confirmed that the data distribution in the study group was normal, allowing for the use of parametric statistics. Consequently, Table 3 presents the results from the pre-test and post-test of the research variables concerning the training protocol, analyzed using repeated measures ANOVA. The analysis indicated that the sphericity assumption was met ($p \leq 0.05$). The statistical findings revealed significant differences in the angles of hip and knee flexion, proprioception, and muscular performance between the pre-test and post-test in the experimental group ($p \leq 0.05$). This indicates that cross-training exercises significantly enhanced these variables for athletes following anterior cruciate ligament reconstruction. In contrast, no significant differences were found between pre-test and post-test measures in the control group ($p \geq 0.05$).

The statistical results of the study through repeated measures analysis of variance showed that there was a significant difference between the thigh and knee flexion angles, proprioception, and muscle function between the pre-test and post-test of the experimental group ($P \leq 0.05$). The overall results of this study showed that performing strength training for athletes with anterior cruciate ligament reconstruction caused a significant increase in the amount of hip and knee flexion angle, proprioception, etc, and muscular function. The results of this study also showed that there was no significant difference between the pre-test and post-test of the control group ($P \geq 0.05$).

Notes: This study aims to evaluate the effect of an eight-week cross-training program on improving muscle strength, proprioception, and knee and hip flexion angles in patients after anterior cruciate ligament (ACL) surgery. The results of the study showed significant improvement in the training group in terms of hip and knee flexion angles, proprioception, and muscular performance ($p < 0.05$ while the control group showed no significant changes in muscular performance ($p > 0.05$). These results are consistent with previous studies that have shown positive effects of exercise interventions on muscle strength and balance after ACL surgery, such as the studies by Minshull et al. (2021), Zhang et al. (2022), and Henderson et al. (2022) (Minshull et al., 2021; Zhang et al., 2022; Henderson et al., 2022).

On the other hand, some studies, such as Piedade et al. (2023), suggest that surgery remains the primary treatment for active patients after ACL injury, and rehabilitation programs should be tailored based on clinical diagnoses and individual patient expectations (Piedade et al., 2023). Additionally, Papandreou et al. (2013) highlighted that surgery leads to a 16% deficit in quadriceps muscle strength at nine weeks, compared to a 37% deficit following cross-training exercises, demonstrating the significant difference in recovery rates between various interventions (Papandreou et al., 2013).

Neural and Muscular Effects of Cross-Training

This study provides evidence that cross-training has positive effects on enhancing muscle strength in both the uninjured and injured limbs, reflecting the interaction of neural mechanisms involving the spinal cord and brain. The evidence suggests that training one limb can lead to brain activation in both hemispheres, which enhances neural efficiency and positively affects the injured limb. These neural changes contribute to improved muscle strength in the untrained limb by activating brain areas responsible for motor planning (Farthing et al., 2018)(Ali et al., 2022, 2024).

In terms of proprioception, cross-training exercises play a crucial role in restoring coordination and balance after surgery. Studies have shown that changes in proprioception due to injury or surgery can make it difficult to control movement and feel stable. Therefore, focusing on improving proprioception through targeted exercises can help restore motor coordination and reduce the feeling of instability, which enhances the clinical effectiveness of these exercises in rehabilitation programs (Minshull et al., 2021).

Limitations and Alternative Explanations

Although the results obtained indicate the effectiveness of cross-training interventions in improving muscle strength and proprioception, there are several limitations that require cautious interpretation. First, this study did not explore certain confounding factors, such as variations in patients' training backgrounds and prior experience with exercise, which may influence muscle response and recovery after surgery. Second, the results did not show significant improvements in strength symmetry between the uninjured and injured limbs, suggesting the need for further research to understand the mechanisms involved in improving muscular symmetry after ACL injuries(Hussein Fayyad et al., 2025).

Conclusions

The results of this study suggest that cross-training exercises are an effective intervention for improving muscle strength and proprioception after ACL surgery, contributing to better balance and enhanced motor coordination. However, it is important to note that these improvements were not associated with significant effects on strength symmetry between the injured and uninjured limbs. Therefore, future studies should focus on assessing the long-term effects of cross-training exercises, particularly by identifying the optimal training dose and type to achieve better clinical outcomes. These studies should also consider individual factors that may influence the effectiveness of the interventions, such as patients' training backgrounds and rehabilitation timelines this study contributes to expanding the current understanding of the neural and muscular mechanisms supporting the positive effects of cross-training and opens new avenues for developing more effective rehabilitation strategies for patients who have undergone ACL reconstruction surgery. However, it is crucial for future research to focus on identifying more specific ways to integrate these exercises into rehabilitation programs.

Recommendations

It is important to instruct participants in rehabilitation programs to continue exercising after the 8week period to ensure sustained improvement and achieve optimal results.

Resistance training should be optimized and customized for each patient based on their individual response and treatment needs

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References

Ali, O. A., Ahmed, W. H., Saeed Abd, A. Q., & Hummadi, J. N. (2022). Effect of a proposal of exercises on the development of basic motor abilities in men's artistic gymnastics. Sport TK, 11. https://doi.org/10.6018/sportk.539131

Ali, O. A., Mushref, A. J., Hummadi, J. N., & Awad, A. (2024). The effect of a proposed training curriculum to develop some special physical abilities and the accuracy of the movement scoring skill for the Ramadi football club players | El efecto de un plan de estudios de entrenamiento propuesto para desarrollar algu. Retos, 61, 193–200. https://doi.org/10.47197/retos.v61.107271

Ardern, C. L., Webster, K. E., Taylor, N. F., & Feller, J. A. (2011). Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. British Journal of Sports Medicine, 45(7), 596–606. https://doi.org/10.1136/bjsm.2010.079365

Caulfield, B., & Garrett, M. (2004). Changes in ground reaction force during jump landing in subjects with functional instability of the ankle joint. Clinical Biomechanics, 19(6), 617–621. https://doi.org/10.1016/j.clinbiomech.2004.02.004

Chappell, Jonathan D., & Limpisvasti, Orr. (2008). Effect of a neuromuscular training program on the kinetics and kinematics of jumping tasks. The American Journal of Sports Medicine, 36(6), 1081–1086. https://doi.org/10.1177/0363546508315635

Emery, Carolyn A., & Pasanen, Katja. (2019). Current trends in sport injury prevention. Best Practice & Research Clinical Rheumatology, 33(1), 3–15. https://doi.org/10.1016/j.berh.2019.01.003

Hammood, Y. M., Awad, A. K., Ali, O. A., Mushref, A. J., & Hummadi, J. N. (2024). Measuring the aggressive behavior of the teams in the Iraqi Premier League in football and its relation to the results and ranking of the league for the 2022-2023 season. Sportske Nauke i Zdravlje, 14(2), 127–134. https://doi.org/10.7251/SSH2402127H

Henderson, Frederick J., Konishi, Yujiro, Shima, Noriyuki, & Shimokochi, Yasuo. (2022). Effects of 8-week exhausting deep knee flexion flywheel training on persistent quadriceps weakness in well-trained athletes following anterior cruciate ligament reconstruction. International Journal of Environmental Research and Public Health, 19(20), 13209. https://doi.org/10.3390/ijerph192013209

Hussein Fayyad, F., saadalah kamees, I., Mohammed Hammood, Y., Adham Ali, O., Jaber Mushref, A., Khalid Awad, A., & Shanta, A. (2025). Construir y legalizar una prueba para medir el nivel de agilidad futbolística de los jugadores jóvenes. Retos, 68, 1578-1590. https://doi.org/10.47197/retos.v68.116368

Huston, Lawrence J., Vibert, Brian, Ashton-Miller, James A., & Wojtys, Edward M. (2001). Gender differences in knee angle when landing from a drop-jump. The American Journal of Knee Surgery, 14(4), 215–219. https://doi.org/10.1055/j.ajks.2001.34

Jung, Woo-Suk, Kim, Sung-Hoon, Nam, Seung-Soo, Kim, Jong-Woo, & Moon, Hyun-Woo. (2022). Effects of rehabilitation exercise with blood flow restriction after anterior cruciate ligament reconstruction. Applied Sciences, 12(23), 12058. https://doi.org/10.3390/app122312058

Khalaf, Y. A., AbdulJabbar, M. A., & Ali, O. A. (2025). The effect of sports job burnout on the performance of workers in student activities departments in Iraqi universities | El efecto del agotamiento laboral deportivo en el rendimiento de los trabajadores de los departamentos de actividades estudiantiles de. Retos, 66, 86–95. https://doi.org/10.47197/retos.v66.113271

Krosshaug, Tron, Slauterbeck, James R., Engebretsen, Lars, & Bahr, Roald. (2007). Biomechanical analysis of anterior cruciate ligament injury mechanisms: Three-dimensional motion reconstruction from video sequences. Scandinavian Journal of Medicine & Science in Sports, 17(5), 508–519. https://doi.org/10.1111/j.1600-0838.2007.00765.x

Lepley, Lindsey K. (2015). Deficits in quadriceps strength and patient-oriented outcomes at return to activity after ACL reconstruction: A review of the current literature. Sports Health, 7(3), 231–238. https://doi.org/10.1177/1941738115578112

Manca, Antonio, Dragone, Daniele, Dvir, Zeevi, & Deriu, Francesco. (2017). Cross-education of muscular strength following unilateral resistance training: A meta-analysis. European Journal of Applied Physiology, 117, 2335–2354. https://doi.org/10.1007/s00421-017-3662-7

Minshull, Claire, Gallacher, Paul, Roberts, Simon, Barnett, Antony, Kuiper, J. H., & Bailey, Adam. (2021). Contralateral strength training attenuates muscle performance loss following anterior cruciate ligament (ACL) reconstruction: A randomised-controlled trial. European Journal of Applied Physiology, 121, 3551–3559. https://doi.org/10.1007/s00421-021-04747-3

Mohammed Hammood, Y., Hussein Rashid, A., & Adham Ali, O. (2025). The effect of a proposed training method using play exercises to develop specific agility and skill performance in football | El efecto de un método de entrenamiento propuesto que utiliza ejercicios de juego para desarrollar la agilidad específica y el re. Retos, 63, 719–728. https://doi.org/10.47197/retos.v63.111095

Norouzi, Kamran, Hashemi Javaheri, Ali, Ariamanesh, Ali, & Khoshraftar Yazdi, Naser. (2015). The effect of cross exercise on the quadriceps muscle strength after anterior cruciate ligament reconstruction. Journal of Paramedical Sciences & Rehabilitation, 4(1), 49–57. https://doi.org/10.18869/acadpub.jpsr.4.1.49

Omar, A. F., Hammadi, W. K., Moseekh, L. Z., Muhammad, K. M., Saleh, M. M., & Ali, O. A. (2025). The impact of cognitive training on field intelligence growth and some composite skills of advanced football players | El impacto del entrenamiento cognitivo en el crecimiento de la inteligencia de campo y algunas habilidades compuestas de los jugadores d. Retos, 66, 46–58. https://doi.org/10.47197/retos.v66.113234

Palmieri-Smith, Riann M., Strickland, Mark, & Lepley, Lindsey K. (2019). Hamstring muscle activity after primary anterior cruciate ligament reconstruction—a protective mechanism in those who do not sustain a secondary injury? A preliminary study. Sports Health, 11(4), 316–323. https://doi.org/10.1177/1941738119844744

Papandreou, Maria G., Papaioannou, Nikolaos, Antonogiannakis, Emmanouil, & Zeeris, Haralambos. (2007). The effect of cross exercise on quadriceps strength in different knee angles after the anterior cruciate ligament reconstruction. Brazilian Journal of Biomotricity, 1(4), 123–138. https://doi.org/10.5935/1676-426X.20070017

Papandreou, Maria, Billis, Evangelos, Papathanasiou, George, Spyropoulos, Panagiotis, & Papaioannou, Nikolaos. (2013). Cross-exercise on quadriceps deficit after ACL reconstruction. The Journal of Knee Surgery, 26(1), 51–58. https://doi.org/10.1055/s-0032-1327749

Parker, Christopher, Robinson, Kevin, Lydon, Kieran, Schmidt, Robert, Pierre, Eric S., Springer, Michael, Villm, Alexander, & Sells, Patricia. (2022). Investigation of a three-week neuromuscular training intervention on biomechanical parameters of the lower quarter in female collegiate pivoting athletes. Open Access Library Journal, 9(12), 1–23. https://doi.org/10.4236/oalib.1109477

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