Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXV, ISSUE 1, 2025, Romania
The journal is indexed in: ERIH PLUS, Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Science, Movement and Health, Vol. XXV, ISSUE 1, 2025
January 2025, 25 (1): 118-123
Original article

THE IMPACT OF A 5-MONTH REHABILITATION PROGRAM ON ACL RECOVERY: INSIGHTS FROM BIODEX-ASSISTED EVALUATION

PARASCHIV ALIN[1], TEODORESCU SILVIA[1]

Abstract

Anterior Cruciate Ligament Injury (ACL) is a common injury that usually occurs in young and active people. It is also the most common knee injury that requires surgery, and the management of this injury is constantly evolving. The outcome of therapeutic interventions depends not only on the severity of the ACL injury, but also on any associated injuries to the anatomical structures of the knee, i.e. injuries to other knee ligaments, medial and lateral meniscal tears and articular cartilage damage.

As a result, specialists caring for patients with this pathology can influence the entire package of medical care starting with assessment and continuing with surgical treatment and medical recovery, leading to the functional outcome desired by the patient, depending on the patient's lifestyle - active or sedentary (Beynnon et al., 2014).

Aim. In the present study we aim to evaluate the efficacy of a structured 5-month rehabilitation program for patients recovering from anterior cruciate ligament (ACL) surgery. We note that at national level there is no standardized protocol and we hope that our program can become, after dissemination of the results, one of the best practices in the management of anterior cruciate ligament ruptures operated by minimally invasive techniques.

Methods. The program incorporated three weekly sessions of physiotherapy, electrostimulation therapy, and Game Ready cryotherapy during the initial phase, progressively advancing through five recovery phases aligned with physiological healing timelines. Muscle functionality and imbalances were assessed using the Biodex System 4 PRO dynamometer, with evaluations at the beginning of the program and post-rehabilitation to measure parameters such as peak torque, range of motion (ROM), and total work.

Results. Results demonstrated significant improvements in muscle strength, ROM, and total work, with peak torque deficits reduced from 25% to 10% and near-complete restoration of ROM in all participants. Despite these advancements, most participants did not achieve the thresholds necessary for a safe return to sports within the 5-month timeframe, highlighting variability in individual recovery rates. Enhanced electrostimulation showed potential in accelerating recovery in select cases, but persistent muscle imbalances indicated the limitations of time-based protocols.

Conclusions. The findings underscore the need for personalized and extended rehabilitation strategies guided by precise isokinetic assessments to optimize recovery and reduce the risk of re-injury. This study advocates for further research into integrating advanced therapies, such as prolonged electrostimulation, into standard rehabilitation protocols to improve long-term outcomes.

Keywords: ACL Recovery, Biodex Dynamometry, Isokinetic Testing, Rehabilitation Program, Return to Sports.

Introduction

Anterior cruciate ligament (ACL) injuries are among the most prevalent and debilitating knee disorders encountered by individuals engaging in sports activities (Shelbourne, Gray & Haro, 2009). These injuries compromise knee stability and functionality, frequently needing surgical treatment and prolonged rehabilitation. The primary challenge is achieving full functional rehabilitation and ensuring a safe return to sports, with early resumption often leading to re-injury and long-term complications such as joint instability and early-onset osteoarthritis.

Recent data highlight an alarming increase in ACL injury rates, particularly among adolescent and young adult athletes. Studies from 2019 onward report a 25.9% rise in ACL injuries among high school athletes in the United States, with female athletes exhibiting a 32.3% increase compared to 14.5% in males (Vincent 2023). In a recent paper, (Chia et al., 2022) suggests that high-risk sports such as soccer, basketball, and lacrosse account for the highest incidence, with adolescent females aged 14 to 18 and young adult males aged 19 to 25 being the most affected groups. The female athletes, face a two- to eight-times higher risk than male athletes, based on anatomical, biomechanical, and hormonal factors (Mancino et al., 2024).

In Europe, similar trends have been observed. A systematic review reported that female athletes have a higher incidence of non-contact ACL injuries compared to males, particularly in team ball sports such as soccer and basketball. The incidence rate for female athletes was found to be 0.14 per 1,000 player-hours, compared to 0.05 per 1,000 player-hours for male athletes (Chia et al., 2022).

[1] National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania; Corresponding author: paraschiv.alin96@gmail.com .

Effective recovery and injury prevention need to have integration of advanced diagnostic and therapeutic tools.

Computerized dynamometry, particularly the Biodex System 4 PRO dynamometer, has been an excellent instrument for biomechanical assessment during recovery. This tool provides precise measurements of muscle imbalances, range of motion (ROM), and mechanical work, offering valuable data for clinicians. Such data facilitate tailored interventions, ensuring progressive recovery and minimizing the risk of re-injury.

Despite the latest rehabilitation techniques, the timing of a return to sport is still an ever-present and controversial variable. Many athletes resume activities prematurely, guided by subjective markers such as pain absence, rather than objective assessments of functional readiness.

Approximately 35–45% of patients undergoing ACLR do not return to sport, with even elite athletes showing a 20–25% failure rate. Among those who do RTS, the re-injury risk remains high, with a 15% overall rate and up to 30% for young athletes within the first two years, highlighting significant challenges in current rehabilitation and RTS approaches. (Buckthorpe & Della Villa, 2019)

This discrepancy underscores the need for structured rehabilitation programs that incorporate periodic evaluations using tools like the Biodex System 4 PRO.

Objectives

This study examines the outcomes of a 5-month structured rehabilitation program in patients recovering from ACL surgery. By use of Biodex System 4 PRO, we aim to evaluate muscle recovery progress and provide evidence-based recommendations for safe return-to-sport protocols. Combining clinical expertise with advanced technology, this research seeks to contribute to the development of strategies that optimize recovery and to reduce the long-term impact of ACL injuries.

Methods

Participant Selection:

Fifteen recreational athletes (aged 18-35 years) diagnosed with ACL injuries participated in the study. Inclusion criteria were unilateral ACL reconstruction, no prior knee surgeries, and regular involvement in recreational sports. Participants were excluded if they exhibited contralateral knee injuries or significant comorbidities affecting rehabilitation.

Rehabilitation Program

The rehabilitation program lasted five months and adhered to international protocols. Since no unified knee rehabilitation program exists, particularly in Romania, the program was designed by selecting and adapting the most validated and verified international recommendations for post-anterior cruciate ligament (ACL) reconstruction recovery. This approach ensured a structured and evidence-based rehabilitation process.

Accordind to (Della, Kelikian & McInnis, 2018) the program was divided into five distinct phases, each with specific objectives to ensure progressive recovery and readiness for the next stage. The phases were aligned with the physiological healing timelines and included functional performance goals. Special consideration was given to the postoperative period of graft vulnerability, specifically during weeks 4 to 8, where the risk of failure is highest. To address this, Phase III was further divided into two sub-phases: Immediate (early) and Late (advanced). Phase III concluded by the 12th postoperative week.

Key Components of the Program

- *Three weekly sessions* of physiotherapy, each lasting 1 hour.
- *Electrostimulation therapy (STIM)* administered throughout the program.
- *Game Ready cryotherapy* utilized during the first month to manage inflammation and pain.

Objectives and Structure

1. *Phase I (0-4 weeks post-surgery):* Focused on pain reduction, inflammation control, and restoring range of motion (ROM). Gentle isometric exercises and patellar mobilization were introduced to prevent stiffness and adhesions.
2. *Phase II (4-8 weeks post-surgery):* Aimed at improving quadriceps and hamstring strength while maintaining joint stability. Closed kinetic chain exercises and proprioceptive drills were done during this period of graft vulnerability.
3. *Phase III (8-12 weeks post-surgery):*
   - *Sub-phase 1 (Immediate):* Focused on controlled strength and balance training while closely monitoring graft safety.
   - *Sub-phase 2 (Late):* Gradual integration of functional movement patterns and low-impact activities to prepare for more dynamic exercises.
4. *Phase IV and V (12 to 21):* Emphasized dynamic and sport-specific drills, agility training, and plyometrics to ensure safe return-to-sport readiness.

Each phase progressively intensified to match the individual's recovery level, ensuring that objectives were met before advancing to the next phase. By following this carefully designed program, the study aimed to validate its efficacy and establish a structured guideline for ACL rehabilitation.

Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXV, ISSUE 1, 2025, Romania
The journal is indexed in: ERIH PLUS, Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

Evaluation Protocol

Muscle functionality was assessed using the Biodex System 4 PRO dynamometer. The testing protocol involved three distinct settings: 5 repetitions at 60°/sec, 5 repetitions at 180°/sec, and 10 repetitions at 300°/sec. However, for the purpose of this study, we included only the evaluation data obtained at 180°/sec, which is considered optimal for assessing functional performance in the context of rehabilitation.

Subjects were evaluated in a seated position, with the axis of the dynamometer aligned perpendicular to the biomechanical axis of the knee joint. Participants were stabilized in the testing chair using safety straps to limit auxiliary movements and ensure test reproducibility and accurate evaluation.

To minimize stress on the joint and avoid excessive shearing forces on the graft, the distal arm of the dynamometer was positioned on the medial upper third of the tibia. This setup ensured proper stabilization and reduced the risk of undue strain on the knee.

Before testing, participants completed a short warm-up session consisting of 8 minutes of pedaling on a stationary bike. The test was conducted within pain-limited parameters, allowing subjects to exert maximal power without exceeding their pain threshold. This approach provided a reliable assessment of muscle functionality while ensuring participant safety.

1. Early rehabilitation: Baseline testing of both affected and healthy limbs after 3rd phase.
2. Post-rehabilitation: Final evaluation after five months.

Key parameters measured included:

- Peak torque (PT): Maximum muscle force generated during extension and flexion.
- Range of motion (ROM): Angular displacement of the knee.
- Total work (TWork): Maximum force generated over the repetition set.

Initial Assessment

Early-rehabilitation assessments revealed significant imbalances between the affected and healthy limbs. Peak torque values for the injured limb were, on average, 25-30% lower than those of the healthy limb (Myer et al., 2008). Range of motion and force-to-body weight ratios were also substantially reduced.

Table 1. Initial Assesment_Results

		ROM			TOTAL WORK EXTENSION			TOTAL WORK FLEXION			PEAK TQ EXTENSION			PEAK TQ FLEXION			PEAK TQ/G EXTENSION			PEAK TQ/G FLEXION		
		Affected		Healthy	Affected		Healthy	Affected		Healthy	Affected		Healthy	Affected		Healthy	Affected		Healthy	Affected		Healthy
Nr Crt.	NAME	Initial	Final	Final	Initial	Final	Final	Initial	Final	Final	Initial	Final	Final	Initial	Final	Final	Initial	Final	Final	Initial	Final	Final
1	A.D.	98	114.1	119.8	658	1165.3	1112.0	338.5	420.0	519.3	108.4	144.1	174.2	60.2	70.9	82.3	122.5	170.9	261.0	104.5	106.3	123.4
2	A.B.	97	110.7	116.2	437.4	850.5	1148.1	278.6	593.1	706.4	72.6	124.9	203.5	62.9	89.5	110.9	115.8	199.4	298.6	110.4	142.8	182.1
3	A.F.	99.2	104.5	115	368.2	713.2	1111.5	381.6	488.7	624	80	139.6	182.5	93.1	94.7	109.5	69.6	132.0	158.9	81.0	89.5	103.5
4	A.R.	100	115	118.4	490.4	734.2	1201	250	389.3	592	99.2	147.2	198.2	59.5	91.5	100.4	167.3	208.5	220.2	99.9	102.2	132.3
5	B.F.	99.4	109.3	117.7	422.2	1017.1	1159.4	283.6	488.5	597.1	98.6	141.5	183.1	73.2	78.7	108.6	105	150.2	201.4	107.3	110.2	146.6
6	C.I	99	102	104.2	472.5	748.9	852.4	246.4	343.3	481	80	96	106.3	46.6	70.7	85.5	124.2	182.2	202.3	87.1	116.2	150.6
7	C.R.	98.9	105.8	111.6	472.9	994.0	1186	260.3	566.6	714	98	112.6	124.9	49.8	73.6	76.9	179.1	205	227.5	90.6	134.0	140
8	D.V.	89.9	102.1	104.8	452.1	973.7	1091	204.1	695.2	698.5	43.4	87.4	104.0	21.5	59.7	66.9	94.6	126.7	150.7	46.9	86.5	97
9	M.I.	98.5	105.3	117.8	380.1	921.2	1170	348.5	582.8	700.1	81.2	140.9	177.5	87.7	86.9	101.2	102.5	152.9	232.9	102.4	112.5	127.4
10	M.R.	98	102	108.3	692.2	1020.6	1408.5	429.2	608.1	823.7	136.1	196.7	246.1	115.1	146.1	179.8	180.6	214.6	284.0	99.3	122.5	180.9
11	P.B	95.0	104.9	112.5	786.2	1345.4	1405	470.9	810.3	905.8	121.6	211.7	248.4	94.3	128.5	151.4	189.9	223.4	290	116.7	128.7	151.6
12	P.I.	98.9	109.8	116.7	475.7	1029.5	1179	321.8	482.6	670	99.2	135.4	182.9	85.1	73.2	103	94.4	181.3	159.2	83	126	168.2
13	S.M.	98.2	112	118	678	1020	1402.3	285	508.5	679.2	132.2	231	384	120.5	178.2	201	189.1	253.3	291.3	104.2	135.1	165.4
14	S.T.	89	110.9	117.4	729	1134.7	1195.3	232.3	432.2	444.6	146.6	197.5	218.8	68	89.1	89.9	219.6	263.9	101.6	110	137.1	144.0
15	S.M.	103	111.6	114	650	1298.3	1440.3	650.1	1298.3	1440.3	107.6	229.7	262.3	56.8	124.3	179.5	186.5	361.1	355.1	98.5	164.5	173.5

Results

A paired t-test confirmed the significance of recovery progress ($p < 0.05$) across all measured parameters. However, 11 participants did not meet the 85% threshold necessary for safe return to sports.

Table 2. Statistical Analysis

Key parameters		*Statistical indicator*	*Value*	*df*	*p*	*Mean dif*	*SE dif*
ROMIA	ROMFA	Student's t	-8,02	14	<.001	-10,53	1,313
		Wilcoson W	0		<.001	-10,3	1,313
ROMFA	ROMFS	Student's t	-8,25	14	<.001	-6,16	0,746

Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
Vol. XXV, ISSUE 1, 2025, Romania
The journal is indexed in: ERIH PLUS, Ebsco, SPORTDiscus, INDEX COPERNICUS JOURNAL MASTER LIST, DOAJ DIRECTORY OF OPEN ACCES JOURNALS, Caby, Gale Cengage Learning, Cabell's Directories

		Wilcoson W	0		<.001	-6,075	0,746
TotalWork ExIA	TotalWorkExFA	Student's t	-14,07	14	<.001	-453,45	32,224
		Wilcoson W	0		<.001	-451,35	32,224
TotalWorkExIA	TotalWorkExFS	Student's t	-5,29	14	<.001	-206,35	38,982
		Wilcoson W	1		<.001	-203,65	38,982
TotalWorkFlexIA	TotalWorkFlexFA	Student's t	-6,22	14	<.001	-248,44	39,94
		Wilcoson W	0		<.001	-221,2	39,94
TotalWorkFlexFA	TotalWorkFlexFS	Student's t	-8,1	14	<.001	-125,9	15,547
		Wilcoson W	0		<.001	-127,825	15,547
PeakTQExIA	PeakTQExFA	Student's t	-7,35	14	<.001	-55,43	7,542
		Wilcoson W	0		<.001	-51,825	7,542
PeakTQExFA	PeakTQExFS	Student's t	-4,89	14	<.001	-44,03	9,001
		Wilcoson W	0		<.001	-38,275	9,001
PeakTQ FlexIA	PeakTQFlexFA	Student's t	-4,37	14	<.001	-24,09	5,515
		Wilcoson W	6		<.001	-23,9	5,515
PeakTQFlexFA	PeakTQFlexFS	Student's t	-5,39	14	<.001	-19,41	3,605
		Wilcoson W	0		<.001	-18,5	3,605
CG_ExIA	CG_ExFA	Student's t	-6,24	14	<.001	-58,98	9,459
		Wilcoson W	0		<.001	-51,7	9,459
CG_FlexFA	CG_FlexFS	Student's t	-6,23	14	<.001	-24,83	3,984
		Wilcoson W	0		<.001	-23,9	3,984
Rom_IA	Rom_FA	Student's t	-6,24	14	<.001	-17,6	2,82
		Wilcoson W	0		<.001	-17	2,82
Rom_FA	Rom_IS	Student's t	1,26	14	0,229	1,27	1,007
		Wilcoson W	77,5		0,325	1	1,007
TWEx_IA	TWEx_FA	Student's t	-7,98	14	<.001	-451,13	56,558
		Wilcoson W	0		<.001	-422,75	56,558
TWEx_FA	TWEx_IS	Student's t	1,68	14	0.115	108,49	64,522
		Wilcoson W	80		0,277	57,075	64,522
TWFlex_IA	TWFlex_FA	Student's t	-6,94	14	<.001	-210,63	30,361
		Wilcoson W	0		<.001	-217	30,361
TWFLex_FA	TWFLex_IS	Student's t	2,99	14	0.01	75,7	25,348
		Wilcoson W	99,5		0.027	69,315	25,348

Table 3. Effect size

Key parameters		*Statistical indicator*	*Value*
ROMIA	ROMFA	Cohen's d	-2,071
		RBCorel	-1
ROMFA	ROMFS	Cohen's d	-2,131
		RBCorel	-1
Total Work Ex IA	TotalWorkExFA	Cohen's d	-3,633
		RBCorel	-1
TotalWorkExIA	TotalWorkExFS	Cohen's d	-1,367
		RBCorel	-0,983
TotalWorkFlexIA	TotalWorkFlexFA	Cohen's d	-1,606
		RBCorel	-1
TotalWorkFlexFA	TotalWorkFlexFS	Cohen's d	-2,091
		RBCorel	-1
PeakTQExIA	PeakTQExFA	Cohen's d	-1,898
		RBCorel	-1
PeakTQExFA	PeakTQExFS	Cohen's d	-1,263
		RBCorel	-1
PeakTQ FlexIA	PeakTQFlexFA	Cohen's d	-1,128
		RBCorel	-0,9
PeakTQFlexFA	PeakTQFlexFS	Cohen's d	-1,39
		RBCorel	-1
CG_ExIA	CG_ExFA	Cohen's d	-1,61
		RBCorel	-1

CG_FlexFA	CG_FlexFS	Cohen's d	-1,609
		RBCorel	-1
Rom_IA	Rom_FA	Cohen's d	-1,612
		RBCorel	-1
Rom_FA	Rom_IS	Cohen's d	0,325
		RBCorel	0,292
TWEx_IA	TWEx_FA	Cohen's d	-2,06
		RBCorel	-1
TWEx_FA	TWEx_IS	Cohen's d	0,434
		RBCorel	0,333
TWFlex_IA	TWFlex_FA	Cohen's d	-1,791
		RBCorel	-1
TWFLex_FA	TWFLex_IS	Cohen's d	0,771
		RBCorel	0,658

Table 4**.** Subject's percentage of recovery

Participant	ROM (%)	RTWork Ex (%)	RTWork Flex (%)	RPeakTQEx (%)	RPeakTQFlex (%)	RPeakTQ/GEx (%)	RPeakTQ/GFlex (%)
1	95.24	104.79	80.88	82.72	86.15	65.48	86.14
2	95.27	74.08	83.96	61.38	80.7	66.78	78.42
3	90.87	64.17	78.32	76.49	86.48	83.07	86.47
4	97.13	61.13	65.76	74.27	91.14	94.69	77.25
5	92.86	87.73	81.81	77.28	72.47	74.58	75.17
6	97.89	87.86	71.37	90.31	82.69	90.06	77.16
7	94.8	83.81	79.36	90.15	95.71	90.11	95.71
8	97.42	89.25	99.53	84.04	89.24	84.07	89.18
9	89.39	78.74	83.25	79.38	85.87	65.65	88.3
10	94.18	72.46	73.83	79.93	81.26	75.56	67.72
11	93.24	95.76	89.46	85.23	84.87	77.03	84.89
12	94.09	87.32	72.03	74.03	71.07	113.88	74.91
13	94.92	72.74	74.87	60.16	88.66	86.96	81.68
14	94.46	94.93	97.21	90.27	99.11	259.74	95.21
15	97.89	90.14	90.14	87.57	69.25	101.69	94.81

Post-Rehabilitation Outcomes

The rehabilitation program revealed notable improvements:

- Peak Torque Improvement: Average deficits decreased from 25% to 10%.
- Total Work: Enhanced in 12 out of 15 participants, with three exceptional cases surpassing healthy limb benchmarks.
- Range of Motion: All participants achieved near-complete restoration of knee flexion and extension.

Discussions and Conclusions

Results demonstrate that while a structured rehabilitation program significantly improves muscle strength and joint functionality, achieving the values necessary for a safe return to sports often requires extended recovery periods. The findings highlight the variability in individual recovery rates, underscoring the need for personalized rehabilitation protocols. (Grindem et al., 2016)

Notable exceptions were observed in patients receiving enhanced electrostimulation, suggesting its potential as auxiliary therapy. However, the persistence of muscle imbalances in most participants indicates that traditional time-based rehabilitation protocols may be inadequate (Palmieri-Smith & Lepley, 2015).

The study also emphasizes the importance of isokinetic testing in evaluating recovery progress. By providing objective data, tools like the Biodex System 4 PRO enable clinicians to tailor interventions and minimize the risk of re-injury.

The 5-month rehabilitation program significantly improved knee functionality in ACL surgery patients, but full recovery is not aviable for most within this timeframe. Personalized and extended rehabilitation plans, guided by isokinetic evaluations, are essential to achieving safe return-to-sport milestones (Zaffagnini et al., 2015). Further research is needed to explore the integration of advanced therapies, such as prolonged electrostimulation, into standard protocols.

Authors' Contributions
All authors have equally contributed to this study.

References

Beynnon, B. D., Vacek, P. M., Newell, M. K., Tourville, T. W., Smith, H. C., Shultz, S. J., Slauterbeck, J. R., Johnson, R. J. (2014). The effects of level of competition, sport, and sex on the incidence of first-time noncontact anterior cruciate ligament injury. *The American Journal of Sports Medicine*, 42(8), 1806–1812. https://doi.org/10.1177/0363546514540862 .

Buckthorpe, M., & Della Villa, F. (2019). Optimising the return to sport pathway after anterior cruciate ligament reconstruction: A critical review of current concepts and clinical implications. *British Journal of Sports Medicine*, 53(18), 1144–1150. https://doi.org/10.1136/bjsports-2018-100250.

Chia, L., De Oliveira Silva, D., Whalan, M., McKay, M. J., Sullivan, J., Fuller, C. W., Pappas, E. (2022). Non-contact anterior cruciate ligament injury epidemiology in team-ball sports: A systematic review with meta-analysis by sex, age, sport, participation level, and exposure type. *Sports Medicine*, 52(11), 2447–2467. https://doi.org/10.1007/s40279-022-01697-w.

Della Valle, C. J., Kelikian, A. S., & McInnis, K. C. (2018). Clinical orthopaedic rehabilitation: A team approach (4th ed.). *Elsevier*. https://doi.org/10.1016/C2014-0-02814-2 .

Grindem, H., Snyder-Mackler, L., Moksnes, H., Engebretsen, L., Risberg, M. A. (2016). Simple decision rules can reduce reinjury risk by 84% after ACL reconstruction: The Delaware-Oslo ACL cohort study. *British Journal of Sports Medicine*, 50(13), 804–808. https://doi.org/10.1136/bjsports-2016-096031.

Mancino, F., Kayani, B., Gabr, A., Fontalis, A., Plastow, R., & Haddad, F. S. (2024). Anterior cruciate ligament injuries in female athletes: risk factors and strategies for prevention. *Bone & Joint Open*, 5(2), 94-100. https://doi.org/10.1302/2633-1462.52.BJO-2023-0166 .

Myer, G. D., Paterno, M. V., Ford, K. R., & Hewett, T. E. (2008). Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *The Journal of Strength & Conditioning Research*, 22(1), 9–15. https://doi.org/10.1519/JSC.0b013e31815ef694 .

Palmieri-Smith, R. M., & Lepley, L. K. (2015). Quadriceps strength asymmetry following ACL reconstruction alters knee joint biomechanics and functional performance at time of return to activity. *The American Journal of Sports Medicine*, 43(7), 1662–1669. https://doi.org/10.1177/0363546515578252 .

Shelbourne, K. D., Gray, T., & Haro, M. (2009). Incidence of subsequent injury to either knee within 5 years after anterior cruciate ligament reconstruction with patellar tendon autograft. *The American Journal of Sports Medicine*, 37(2), 246–251. https://doi.org/10.1177/0363546508325665.

Vincent M. (2023). Analysis: Serious knee injury among teen athletes grows 26%. *Project Play*. https://projectplay.org/news/2023/11/22/analysis-serious-knee-injury-among-teen-athletes-grows-26 .

Zaffagnini, S., Grassi, A., Serra, M., & Marcacci, M. (2015). Return to sport after ACL reconstruction: How, when and why? A narrative review of current evidence. *Journal of Orthopaedics and Traumatology*, 16(1), 1–6. https://doi.org/10.1007/s10195-014-0309-4 .