Preoperative Corrective Exercise Training in ACL Rupture: Effects on Pain, Stability, and Functional Outcomes: A Single-Blind Randomized Controlled Trial

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Abstract

Aim: This study aimed to investigate the effect of corrective exercise training in addition to routine exercises on patients with anterior cruciate ligament (ACL) rupture.

Method: 36 ACL ruptured participants were included in the study. Patients were randomly divided into exercise and control groups. The exercise group (n=18) received corrective exercise training 5 days a week for 8 weeks in addition to the routine exercise program. The control group (n=18) received a routine exercise program. Demographic information, Visual Analog Scale for pain and instability feeling, Tegner Activity Scale, Lysholm Knee Scoring System, Kujala Patellofemoral Scoring System, and Functional Movement Screen evaluations were done. Evaluations were repeated before exercise training, at the end of the

Results: The average age of the participants was 26.5 years in the exercise group and 28.3 years in the control group. A statistically significant difference was found between the groups in the feeling of stability and FMS total score parameters. However, no difference was found between the groups in the pain parameters, Lysholm score, and Kujala score after exercise ($p<0.05$). In intra-group comparisons before and after exercise, a significant difference was observed in the feeling of stability and FMS total score values in both groups, and in the same parameter, a considerable difference was found between the two groups after exercise. A significant difference was observed in pain, Lysholm and Kujala scores only in the corrective exercise group.

Conclusion: Pre-operatively applied FMS-based corrective exercise therapy in patients with ACL injury led to significant improvements in pain, knee stability, function, and range of motion.

Keywords: Anterior cruciate ligament tear, corrective exercise, functional movement screen.

ACL Rüptüründe Ameliyat Öncesi Düzeltici Egzersiz Eğitimi: Ağrı, Stabilite ve Fonksiyonel Sonuçlar Üzerindeki Etkileri: Tek Kör, Randomize Kontrollü Bir Çalışma

Öz

Amaç: Bu çalışma, ön çapraz bağ (ACL) yırtığı olan hastalarda rutin egzersizlere ek olarak verilen düzeltici egzersiz eğitiminin etkisini araştırmayı amaçladı.

Yöntem: Çalışmaya 36 ÖÇB rüptürü olan katılımcı dahil edilmiştir. Hastalar rastgele egzersiz ve kontrol gruplarına ayrılmıştır. Egzersiz grubu (n=18), rutin egzersiz programına ek olarak haftada 5 gün, 8 hafta boyunca düzeltici egzersiz eğitimi almıştır. Kontrol grubu (n = 18) ise yalnızca rutin egzersiz programını uygulamıştır. Çalışmada demografik bilgiler, ağrı ve instabilite hissi için Görsel Analog Skalası, Tegner Aktivite Ölçeği, Lysholm Diz Skorlama Sistemi, Kujala Patellofemoral Skorlama Sistemi ve Fonksiyonel

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ETHICAL STATEMENT: This study was carried out with the approval of the Ethics Committee of University of Health Sciences Hamidiye Non-Interventional Research Ethics Committee, dated 25/01/2019 and numbered 19/03. A signed subject consent form in accordance with the Declaration of Helsinki was obtained from each participant.

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Hareket Tarama değerlendirmeleri yapılmıştır. Değerlendirmeler, egzersiz eğitimi öncesinde ve 8 haftalık program sonunda tekrarlanmıştır.

Bulgular: Katılımcıların ortalama yaşı egzersiz grubunda 26,5 yıl, kontrol grubunda ise 28,3 yıl olarak bulunmuştur. Gruplar arasında stabilite hissi ve FMS toplam puanı açısından istatistiksel olarak anlamlı bir fark tespit edilmiştir. Ancak, egzersiz sonrası ağrı parametreleri, Lysholm skoru ve Kujala skoru açısından gruplar arasında anlamlı bir fark bulunmamıştır ($p<0.05$). Grup içi karşılaştırmalarda hem egzersiz hem de kontrol grubunda stabilite hissi ve FMS toplam puanı açısından anlamlı gelişmeler gözlemlenmiştir. Bununla birlikte, egzersiz sonrası aynı parametrelerde gruplar arasında da belirgin bir fark saptanmıştır. Ağrı, Lysholm ve Kujala skorlarında anlamlı iyileşme yalnızca düzeltici egzersiz grubunda gözlenmiştir.

Sonuç: Ön çapraz bağ yaralanması olan hastalarda, ameliyat öncesi uygulanan FMS tabanlı düzeltici egzersiz tedavisi, ağrı, diz stabilitesi, fonksiyon ve eklem hareket açıklığında önemli iyileşmelere yol açmıştır.

Anahtar Sözcükler: Düzeltici egzersiz, fonksiyonel hareket taraması, ön çapraz bağ rüptürü.

Introduction

Anterior cruciate ligament (ACL) ruptures are a prevalent injury among athletes and active individuals, often resulting in significant functional impairments and prolonged rehabilitation periods[1,2]. These injuries can severely affect knee stability, leading to pain, functional limitations, and an increased risk of further damage if not managed properly[3]. Traditional rehabilitation protocols focus on restoring knee strength and range of motion; however, they may not sufficiently address the underlying biomechanical and neuromuscular deficiencies contributing to poor outcomes[4,5]. Recent advances in rehabilitation emphasize the integration of corrective exercises targeting the kinetic chain to enhance overall functional recovery and prevent re-injury[6].

Functional Movement Screening (FMS) has become an effective tool for identifying movement dysfunctions and asymmetries that may predispose individuals to injuries[7]. Research indicates that suboptimal movement patterns contribute to an increased risk of musculoskeletal injuries, particularly in individuals with pre-existing conditions such as ACL ruptures[8,9]. By incorporating FMS-based corrective exercises into rehabilitation programs, clinicians can address these dysfunctions, potentially improving outcomes for patients with ACL injuries[10,11]. Previous studies have demonstrated the benefits of functional movement training in enhancing knee function and reducing the risk of secondary injuries post-ACL reconstruction[12,13]. Additionally, neuromuscular training interventions incorporating FMS principles have been shown to improve balance, proprioception, and knee joint stability in ACL-injured individuals[14,15].

However, there is limited evidence on the efficacy of combining traditional rehabilitation approaches with corrective exercises in patients with primary ACL ruptures who have not yet undergone surgical intervention[16]. Addressing neuromuscular deficits through FMS-based exercises may provide a comprehensive approach to optimizing functional recovery. This study aims to evaluate the effects of a combined traditional and corrective exercise program on pain, knee insecurity, and functional movement in patients with primary ACL ruptures. We hypothesize that adding FMS-based corrective exercises will result in superior outcomes compared to a traditional exercise program alone. The findings of this study may provide valuable insights into optimizing rehabilitation protocols for ACL injuries, ultimately improving patient outcomes and reducing the burden of knee injuries in the active population.

Material and Methods

Design

This is a single-blind randomized controlled clinical study.

Participants

Patients with anterior cruciate ligament rupture and who have not yet been operated on will be included.

Inclusion criteria: Primary ACL Rupture, a maximum of 12 months have passed after the rupture, being between the ages of 18-35, not indicating emergency surgery.

Exclusion criteria: Accompanying multiple ligament injuries, accompanying Grade 3 Meniscus tear, presence of more than grade II chondromalacia according to the Outerbridge classification, having a history of operation/instability on the same knee[1].

Procedures

The patients who met the inclusion criteria were referred to the investigator by the orthopedic surgeon for rehabilitation. Participants were randomly allocated to groups using a computer-generated random number sequence in a 1:1 ratio. The allocation was concealed in sequentially numbered, sealed opaque envelopes. The outcome assessor was blinded to group assignment to minimize bias. After the initial evaluation, the traditional exercise approach, which will last for 8 weeks, was given to the control group, and the corrective exercise program, which was applied in addition to the traditional approach for the same period, was given to the corrective exercise group. The exercise program was carried out by the responsible researcher in the Physiotherapy and Rehabilitation Department three times a week. The first evaluation was taken before starting the exercises, and the second evaluation was taken at the end of the eight-week exercise program.

Evaluations were made by the other investigator, without knowing which group they belonged to.

Pain and knee instability feeling was measured with the visual analog scale (VAS).

Functional Movement Screen (FMS): FMS is a test consisting of 7 sub-parameters that reveal the functional inadequacies of individuals. These tests are deep squat, hurdle step, in-line lunge, shoulder mobility, active leg raise, trunk stability push up, and rotary stability. Scoring between 0-3 is given in the scoring of the test, and 0 points are given in the presence of pain, even if the movement is performed successfully[7,10].

Functional Evaluation and Classification: Tegner Activity Level Scale, Lysholm Knee Scoring Scale, and Kujala Patellofemoral Scoring Scale were used. The Tegner Activity Scale was utilized solely to ensure group homogeneity in terms of participants' pre-injury activity levels and was not used as an outcome measure.

Exercise Program: The weight was adjusted according to the muscle strength of the patient, in painful cases, the exercise was started without weight, and weight was added according to tolerance.

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Standard Program:

1- Concentric knee extension exercise with free weight in the sitting position.

2- Concentric knee flexion exercise with a free weight in the prone position.

3- Prone knee flexion exercise, with the help of the other leg at the end of the range.

4- Exercise to increase the range of motion of extension by placing a roll under the heel in a sitting position.

5- The exercise of pulling a resistance band with one end attached to a place and the other end on the ankle in four directions.

Corrective Exercises:

1- Dorsi flexion mobility exercise with a stick in a half-kneel position. In this exercise, the patient moves forward without raising the front heel, holding the stick so that it remains on the outside of the front foot and the inside of the knee.

2- Half-knee position hip flexor stretching exercise

3- Rotation exercise to the left and right in the half-kneel position while holding the stick on the neck with both hands.

4- Prone to supine, supine to prone progressions

5- Side plank with knees flexed, and after that legs straight

6- Rolling from the supine position to the side by squeezing the roll between the knee and the elbow

Quadriceps and hamstring strengthening, knee flexion-extension range of motion, and knee stabilization exercises will be applied to the control group. In addition to these exercises, corrective exercises based on FMS will be applied to the application group. These exercises include the upper and lower joints and trunk in addition to the knee, addressing the integrity of the kinetic chain[7,10].

The exercises were done in three sessions a week under the control of a physical therapist for eight weeks. After the exercise program, measurements were repeated.

Ethical Statement

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Statistical Analysis

Statistical analyses were performed using SPSS version 21.0 (IBM Inc., Armonk, NY, USA) software. The normality of the data was investigated by the One-Sample Kolmogorov-Smirnov test. Assessing the differences between the two measurements before and after the same group was done with the Wilcoxon test. The Mann-Whitney-U test was used for numerical comparisons between independent groups of the study. The significance level was set to $p < 0.05$. Cohen's d was calculated for the clinical effect size.

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Results

The demographic information of the participants is shown in Table 1.

Table 1. Demographic characteristics of the participants

	Group 1 (Corrective Exercise Group) (n=18) (Mean ± SD)	**Group 2 (Control Group) (n=18) (Mean ± SD)**	**Significance level* (p-value)**
Age	26.5± 8,42	28.38± 7.93	0.514
Body Mass Index	24.46± 2.40	25.25± 3.40	0.580
	n (%)	**n (%)**	
Gender	5 female (27.77%) 13 male (72.23%)	6 female (33.33%) 12 male (66.66%)	
Tegner Activity Score Before Injury	4.66± 1.64	4.16± 1.29	0.687

SD: Standard Deviation, * Mann-Whitney U Test

Pain and stability feel comparisons in-group and between-group pre-exercise and post-exercise shown at Table 2.

Table 2. Pain and stability feel comparisons in-group and between-group pre-exercise and post-exercise

Pain and Stability Feel (Visual Analog Scale)	**Pre-exercise**				**Post-exercise**				**Differences between pre- and post-exercise**
	Pain		**Stability Feel**		**Pain**		**Stability Feel**		
	Mean	**SD***	**Mean**	**SD***	**Mean**	**SD***	**Mean**	**SD***	
Corrective Exercise Group	2.16	2.20	5.5	2.25	0.89	1.19	2.31	1.45	Pain p= 0.006$^{\beta*}$ Stability Feel p= 0.001$^{\beta*}$
Control Group	3.22	2.28	6.66	2.65	2.05	2.09	5	2.14	Pain p= 0.119 $^{\beta*}$ Stability Feel p= 0.014 $^{\beta*}$
Differences between groups	p= 0.164$^{\alpha*}$ Cohen's d: 0.47		p= 0.038$^{\alpha*}$ Cohen's d: 0.47		p= 0.109$^{\alpha*}$ Cohen's d: 0.63		p= 0.001$^{\alpha*}$ Cohen's d: 1.53		

α= Mann Whitney U test, β= Wilcoxon test, SD: Standard Deviation

Functional movement screen total score comparisons in-group and between-group pre-exercise and post-exercise shown at Table 3.

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Table 3. Functional movement screen total score comparisons in-group and between-group pre-exercise and post-exercise

FMS TOTAL SCORE	**Pre-exercise**		**Post-exercise**		**Differences between pre and post-exercise**
	Mean	SD	Mean	SD	
Corrective Exercise Group	10.83	1.88	13.83	1.54	p= 0.001$^{\beta*}$
Control Group	10.44	2.09	12.22	1.73	p= 0.006 $^{\beta*}$
Differences between groups	p= 0.550$^{\alpha*}$ Cohen's d: 0.19		p= 0.004$^{\alpha*}$ Cohen's d: 0.98		

α= Mann Whitney U test, β= Wilcoxon test, FMS=Functional Movement Screen, SD: Standard Deviation

Lysholm and Kujala score comparisons in-group and between-group pre-exercise and post-exercise shown at Table 4.

Table 4. Lysholm and Kujala score comparisons in-group and between-group pre-exercise and post-exercise

Lysholm and Kujala Scores	**Pre-exercise**				**Post-exercise**				**Differences between pre and post-exercise**
	Lysholm		**Kujala**		**Lysholm**		**Kujala**		
	Mean	**SD***	**Mean**	**SD***	**Mean**	**SD***	**Mean**	**SD***	
Corrective Exercise Group	68.16	15.12	70.55	14.99	80.83	13.12	80.33	14.59	Lysholm p= 0.001$^{\beta*}$
									Kujala p= 0.001$^{\beta*}$
Control Group	70.5	14.43	70.5	14.81	76.27	13.39	76.22	12.71	Lysholm p= 0.246 $^{\beta*}$
									Kujala p= 0.191 $^{\beta*}$
Differences between groups	p= 0.486 $^{\alpha*}$ Cohen's d: 0.15		p= 0.912$^{\alpha*}$ Cohen's d: 0.003		p= 0.288$^{\alpha*}$ Cohen's d: 0.34		p= 0.235$^{\alpha*}$ Cohen's d: 0.30		

α= Mann-Whitney U test, β= Wilcoxon test

Discussion

In the present study, the effects of corrective exercises, in addition to traditional exercises, on pain, stability perception, and Functional Movement Screen (FMS) scores were examined in two groups who participated in an 8-week rehabilitation program before undergoing Anterior Cruciate Ligament Reconstruction (ACLR). It was observed that corrective exercises significantly reduced pain severity, which is a key concern in

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ACL injuries[2,15]. Although both groups showed significant improvement in stability perception, the corrective exercise group demonstrated superior results compared to the control group. Similarly, the FMS total score improved significantly in both groups; however, the corrective exercise group exhibited a greater improvement in between-group comparisons[3,5].

Pain and proprioceptive deficits, commonly observed in ACL injuries, contribute to joint instability and impaired neuromuscular control[6,17]. The FMS protocol emphasizes the activation of proprioceptors throughout the kinetic chain, facilitating improved movement coordination and stabilization[7]. Deficiencies in proprioceptive function can negatively impact the kinetic coupling system, leading to altered mobility, compromised stability, and movement asymmetries that are difficult to compensate for[12,14]. Therefore, rehabilitation should not only focus on isolated knee strengthening but should also incorporate strategies targeting global movement quality and neuromuscular efficiency[5].

Traditional rehabilitation programs often prioritize agility, strength, and power while overlooking fundamental movement patterns and neuromuscular efficiency[13,15]. FMS-based corrective exercises, however, address movement deficiencies and provide a structured approach to enhancing dynamic stability and injury prevention[8,9]. The clinical significance of preoperative rehabilitation lies in its potential to reduce postoperative complications and optimize functional recovery[16]. Research has suggested that individuals scoring below 14 on the FMS are at a heightened risk for injury, emphasizing the importance of preoperative movement screening and correction[3,8].

Our findings align with previous studies demonstrating the effectiveness of corrective exercises in improving FMS scores and overall knee function[11]. However, comparative studies in this domain remain limited, making it challenging to benchmark our results against a robust body of literature. Bodden et al.[18] (2015) investigated the effects of an FMS-based corrective exercise program on mixed martial arts (MMA) athletes and found significant improvements in movement quality after just four weeks of training. Similarly, a six-week FMS-integrated rehabilitation program for military personnel successfully bridged the gap between clinical rehabilitation and return-to-duty readiness[19].

In ACL rehabilitation, neuromuscular training incorporating FMS principles has been associated with superior functional outcomes and reduced reinjury rates[6,14]. Chao et al.[11] (2018) reported improved Lysholm Knee Scores and FMS scores in patients undergoing ACLR when corrective exercises were added to routine rehabilitation. While most studies have focused on postoperative interventions, our study uniquely evaluates the impact of FMS-based exercises in the preoperative phase, highlighting its potential for optimizing recovery trajectories before surgery. To our knowledge, no other studies have assessed FMS-based corrective exercises in preoperative ACL rehabilitation, making our findings a valuable contribution to this field.

Many FMS-related studies have centered on athletic populations and injury prevention strategies. Future research should explore whether correcting movement deficiencies leads to long-term reductions in injury risk and improved functional outcomes across diverse populations, including non-athletes and sedentary individuals[15,16]. Additionally, further investigation is required to determine the most effective exercise prescription

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and duration for sustaining functional improvements beyond the rehabilitation period. To our knowledge, few studies have specifically investigated FMS-based interventions in the preoperative setting. Most existing research focuses on using FMS for injury risk screening or athletic season comparison—for example, Suzuki et al.[20] compared FMS scores between preparative and competitive periods in high school baseball players.

This study has some limitations. Firstly, this was a single-center study with a relatively small sample size, which may limit the generalizability of our findings. Secondly, while our results demonstrate the short-term benefits of preoperative FMS-based training, we were unable to assess postoperative effects and long-term treatment outcomes. More randomized controlled trials are needed to establish the clinical efficacy of integrating FMS-based corrective exercises into preoperative ACL rehabilitation programs.

Conclusion

FMS-based corrective exercise therapy in the pre-operative period for patients after ACL injury provided significant improvement in pain, sense of stability, knee function, and knee movements. We recommend integrating FMS-based assessment and exercise into pre-operative period routine rehabilitation practices.

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REFERENCES

1. Murray MM. Current status and potential therapies to stimulate repair of the anterior cruciate ligament. *J Orthop Res*. 2009;27(4):515-521.
2. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. *Br J Sports Med*. 2011;45(7):596-606.
3. Myer GD, Ford KR, Paterno MV, Nick TG, Hewett TE. The effects of generalized joint laxity on dynamic knee motion in ACL-injured girls. *Clin J Sport Med*. 2008;18(1):2-9.
4. Risberg MA, Lewek M, Snyder-Mackler L. A systematic review of evidence for anterior cruciate ligament rehabilitation: How much and what type? *Phys Ther Sport*. 2004;5(3):125-145.
5. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med*. 2013;34(2):299-311.
6. Paterno MV, Rauh MJ, Schmitt LC, Ford KR, Hewett TE. Incidence of second ACL injuries 2 years after primary ACL reconstruction and return to sport. *Am J Sports Med*. 2010;38(7):1276-1283.
7. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: The use of fundamental movements as an assessment of function-Part 1. *Int J Sports Phys Ther*. 2014;9(3):396-409.
8. Kiesel K, Plisky PJ, Voight ML. Can serious injury in professional football be predicted by a preseason functional movement screen? *N Am J Sports Phys Ther*. 2007;2(3):147-158.

9. Chorba RS, Chorba DJ, Bouillon LE, Overmyer CA, Landis JA. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *N Am J Sports Phys Ther*. 2010;5(2):47-54.
10. Cook G, Burton L, Hoogenboom BJ, Voight M. Functional movement screening: The use of fundamental movements as an assessment of function-part 2. *Int J Sports Phys Ther*. 2014;9(4):549-63.
11. Chao WC, Shih JC, Chen KC, Wu CL, Wu NY, Lo CS. The effect of functional movement training after anterior cruciate ligament reconstruction: A randomized controlled trial. *J Sport Rehabil*. 2018;27(6):541-545.
12. Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE, Beutler AI. The landing error scoring system (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. *Am J Sports Med*. 2012;37(10):1996-2002.
13. Grooms DR, Myer GD, Paterno MV, Ford KR, Hewett TE. Neuroplasticity mechanisms associated with ACL injury prevention and rehabilitation. *J Orthop Res*. 2017;35(10):2266-2274.
14. Sugimoto D, Myer GD, Barber Foss KD, Hewett TE. Specific exercise effects of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young females: Meta-analysis and subgroup analysis. *Br J Sports Med*. 2015;49(5):282-289.
15. Dingenen B, Gokeler A. Optimization of the return-to-sport paradigm after anterior cruciate ligament reconstruction: A critical review of the literature. *Br J Sports Med*. 2017;51(22):1323-1328.
16. Chaudhari AM, Briant PL, Bevill SL, Koo S, Andriacchi TP. Knee kinematics change due to age and walking speed, but not gender. *Gait Posture*. 2011;31(1):17-22.
17. Riemann BL, Lephart SM. The sensorimotor system, part I: The physiologic basis of functional joint stability. *J Athl Train*. 2002;37(1):71-79.
18. Bodden JG, Needham RA, Chockalingam N. The effect of an intervention program on functional movement screen test scores in mixed martial arts athletes. *J Strength Cond Res*. 2015;29(1):219-225.
19. Gross DL, Christopher GE, Faulk RT. Functional training program bridges rehabilitation and return to duty. *J Spec Oper Med*. 2009;9(2):29-48.
20. Suzuki K, Akasaka K, Otsudo T, et al. Effects of functional movement screen training in high-school baseball players: A randomized controlled clinical trial. *Medicine (Baltimore)*. 2021;100(14):e25423.

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