"The Effect of Functional Movement Training After Anterior Cruciate Ligament Reconstruction - A Randomized Controlled Trial" by Chao WC et al.
Journal of Sport Rehabilitation

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Running Head: FMS-based exercise for ACLR patients

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ABSTRACT

Objectives: To evaluate the effect of functional movement screen (FMS) based functional exercise in patients after anterior cruciate ligament reconstruction (ACLR). **Design:** Randomized controlled single-blind trial. **Setting:** Institutional, single center. **Patients:** A total of 38 patients who underwent ACLR were recruited and randomly assigned to group 1 (n = 19) or group 2 (n = 19). **Interventions:** Both groups received 6-month routine rehabilitation immediately after surgery. From the postoperative 4th to 6th month, group 1 received FMS-based functional exercise plus routine rehabilitation and group 2 received routine rehabilitation only. The FMS-based functional exercise was individualized and customized functional corrective exercise, which was designed based on the 3-month postoperative FMS results. The frequency of rehabilitation was one hour per session, twice a week, for a total duration of 6 months. **Main Outcome Measures:** At 3 months and 6 months postoperatively, patients were evaluated by FMS scoring, Lysholm Knee Score, and International Knee Documentation Committee (IKDC) 2000 Score. **Results:** After the intervention, both groups had significantly increased FMS, Lysholm Knee Score, and IKDC score. Group 1 had significantly greater changes in FMS (median 4 vs. 3, $P < 0.001$), Lysholm Knee score (median 24 vs. 16, $P = 0.001$), and IKDC (median 22 vs. 8, $P < 0.001$) than group 2 **Conclusions:** The application of FMS-based functional exercise to patients after ACLR resulted in significant improvement in knee function and movements. We suggested integrating FMS evaluation and FMS-based training into post-ACLR routine rehabilitation program.

Keywords: anterior cruciate ligament, sports injury, reconstruction, sports performance, exercise therapy

INTRODUCTION

Anterior cruciate ligament (ACL) injury is one of the most common knee injuries. In recent years, with the increase of exercise population, the number of incidence has increased significantly.[1] Previous studies indicated that the mechanisms of ACL injuries could be divided into two categories: contact injuries and non-contact injuries.[2] The prevalence of contact injuries is about 30% and of non-contact injuries is 70%,[2] meaning most injuries happen under non-body-contact situations for most athletes. The main reasons of injuries are deceleration, quick cut-in movements, or jump-stop tasks.[3] These movements increase the anterior shear force on tibia and cause knee valgus. Consequently, it leads to higher tension on ACL and causes injuries.[3] Currently, anterior cruciate ligament reconstruction (ACLR) is the standard treatment of ACL rupture. But the return to pre-injury sports after ACLR only averaged around 60%, and only 40% for return to competitive sports.[4] Therefore, a prompt and effective rehabilitation for ACL injury is deserved much attention.

Functional movement screen (FMS) is a comprehensive assessment of seven different fundamental movements in order to evaluate human functional limitations, muscle imbalances and asymmetries.[5, 6] Conventionally, it is used to evaluate athletes' functional movements before season. Previous studies showed that the athletes who recorded lower FMS scores tend to have higher risk of injuries.[7-9] In addition to as a screening tool, FMS is also an aid in designing personalized corrections and trainings. According to the results of evaluation, a set of exercises can be designed and customized to correct the imbalances and functional limitations.[10-12] It has been noted that FMS-based intervention could reduce the risk of injury.[12] However, most studies utilized FMS in professional, recreational sports, firefighters, or military. Very few studies applied

FMS to patients after ACLR. Therefore, we hypothesized that FMS evaluation and FMS-based intervention would improve the functional recovery in patients who received ACLR.

In this randomized controlled study, we designed a post-ACLR rehabilitation program integrating FMS, FMS-based functional exercise, and routine rehabilitation. We evaluated the effect of FMS-based functional exercise by comparing patients taking FMS-based functional exercise plus routine rehabilitation with those taking routine rehabilitation only.

METHODS

Subjects

This prospective randomized controlled single-blind study was approved by Institutional Review Board of Show Chwan Memorial Hospital. All patients provided written informed consents.

From January 2014 to December 2015, patients who underwent arthroscopic single-bundle ACLR using Hamstrings autografts were included. Patients were excluded for any one of the following: (1) having other musculoskeletal problems in lower limbs, for examples fractures or multi-ligament injuries, (2) combined other surgery, such as osteotomy, (3) unstable physical fitness level or unable to exercise, and (4) experiencing surgical complications (e.g., bleeding, infection, donor site complications).

Procedures

The study design was illustrated in Figure 1. After explaining the study goals, experimental procedures and subject rights to all patients, they were requested to read and sign the informed consents. Patients were then randomly assigned to either group 1 (routine rehabilitation and FMS-based functional exercise) or group 2 (routine rehabilitation only) with a 1:1 allocation by a random table. Patients were not aware of their allocation.

After ACLR, both groups immediately received 6-month routine rehabilitation. Both groups received evaluation twice: at 3 months and 6 months postoperatively. Evaluation tools included FMS,[5, 6] Lysholm Knee Score,[13] and International Knee Documentation Committee scoring (IKDC) 2000 Score.[14] Additional to the routine rehabilitation, the group 1 received FMS-based functional exercise from the postoperative 4th to 6th month. For both groups, the frequency of rehabilitation was one hour per session, twice a week, for a total duration of 6 months. All patients were requested to maintain their normal daily activities and diet during the whole study period.

Evaluation

All patients were evaluated at 3 months and 6 months postoperatively (Figure 1). Evaluation tools included FMS,[5, 6] Lysholm Knee Score,[13] and IKDC 2000 Score.[14] All of the evaluations were performed by the same qualified physiotherapist familiar with these tools. All the chosen tools were approved based on their reliability and validity tests.

Functional Movement Screen

FMS offers a simple and quantifiable method of evaluating movement patterns quality. The test consists of seven fundamental movements that require a balance of mobility and stability: deep squat, hurdle step, in line lunge, shoulder mobility, active straight leg raise, trunk stability pushup, and rotary stability.

For each movement, patients were placed in extreme positions in where any weaknesses and imbalances would be detectable if appropriate stability and mobility was not used. Each movement was scored 0 to 3, where 3 indicated the proper performance of the movement; 2 indicated the performance of the movement with compensation; 1 indicated the inability to perform the movement; 0 indicated pain during the movement regardless of quality. The maximal total score was 21. To reduce potential bias, all tests were carried out by the same physiotherapist and a mock test was performed before the formal test.[5, 6]

Lysholm Knee Score

Lysholm Knee Score provides subjective evaluation of eight items: limp, support, locking, instability, pain, swelling, stair climbing, and squatting. The total score is the sum of each response to the 8 items and it ranges from zero to 100. The higher score indicates better performance.[13]

IKDC 2000 Score

IKDC 2000 Score contains 18 items from three domains: symptoms, sports and daily activities, pre-injury and current knee function. The total score is the sum of scores of all items and ranges from zero to 100. The higher score also represented of better function and less symptoms. IKDC 2000 Score provides both subjective and objective evaluation of knee function.[14]

Intervention

Functional Movement Screen-based functional exercise

The FMS-based functional exercise was applied on the patients of the group 1 from the postoperative 4th to 6th month. It was individualized and customized based on the results of the postoperative 3-month FMS evaluation (Figure 1). The patients who scored < 2 points in certain movements were prescribed the FMS-based functional exercise to correct the identified movement deficits. The FMS-based functional exercise was a set of gradual progression of corrective training exercise, which followed the order of mobility, static motor control, dynamic motor control and lastly strength and was designed with reference to previous studies[10, 12, 15-18] and the information available on the official website of the FMS.[19]

Routine rehabilitation

Routine rehabilitation comprised three parts: modality therapy, basic treatment, and strengthening exercise. The modality therapy included hot packing, interferential current therapy, and therapeutic ultrasound. The basic treatment included passive range of motion less than 60 degree, partial weight bearing and knee brace. The strengthening exercise included hip abduction and adduction, toe raising, straight leg raising, quadriceps isometrics, and mini-squats. Patients were also educated of what to do and what not to do after reconstruction surgery.

Statistical analysis

All continuous variables were presented as median with interquartile range and categorical variables were presented as count with percentage. To compare the characteristics and outcomes between two groups, the Mann-Whitney U Test and Chi-square test were used for continuous variables and categorical variables respectively. The comparison of pre- and post-intervention outcomes was performed by Wilcoxon signed-rank test. A two-tailed $P < 0.05$ indicated statistical significance. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 19.0 (Armonk, NY, USA).

RESULTS

This study enrolled 38 patients (19 in group 1 and 19 in group 2). No patients were lost to follow-ups. Table 1 revealed the demographic characteristics of the enrolled patients. There was no significant difference between the two groups regarding gender, age, education level, and affected side. At 3 months postoperatively, no differences in FMS and Lysholm Knee score were noted between the two groups. But IKDC score of group 1 was significantly higher than that of group 2 (median 66 vs. 58, P = 0.013) (Table 1).

At the end of intervention, both groups had significantly increased FMS, Lysholm Knee score, and IKDC scores. Group 1 had significantly greater changes in FMS (median 4 vs. 3, P < 0.001), Lysholm Knee score (median 24 vs. 16, P = 0.001), and IKDC (median 22 vs. 8, P < 0.001) than group 2 (Table 1).

During the study period, no re-injuries occurred. Post hoc power analysis revealed the power of the study to be 99%, 86%, and 100% respective for detecting the significant difference of FMS, Lysholm Knee Score, and IKDC Scores between the two groups.

DISCUSSION

An effective rehabilitation program for ACL injury has always been a topic of concern. In this study, we demonstrated the way of integration FMS evaluation and FMS-based functional exercise into routine rehabilitation. The results revealed that additional FMS-based functional exercise significantly improved the knee function in patients after ACLR.

Post-ACLR rehabilitation program mainly aims at helping patients to return to their former activity level. However, a meta-analysis including 48 studies and 5770 patients reported that about only 60% patients could return to their pre-injury activity level after ACL reconstruction. The risk of subsequent ACL injury (either re-injury or contralateral) after return to sports ranged from 6% to 25%, which was even higher than the risk of initial ACL injury.[20-22] Inadequate rehabilitation has been recognized as one of the risk factors of re-injury.[23] Therefore, it needs to be more cautious to design a postoperative rehabilitation for patients after ACLR.

Many studies suggested that to identify risk factors of predicting future injuries was the first step of exercise training as well as of post-ACLR training.[11, 24-26] FMS is an assessment technique to identify any undiscovered imbalances in mobility and stability weaknesses, which have been recognized as significant risk factors for re-injury.[5, 6] The study by Peate et al. designed a subject specific training program based on FMS assessment for 433 firefighters. The results showed reduced number of injuries by 42% over one year as comparing with a historical control group. They concluded that to implement FMS and to develop a functional movement enhancement program in high risk workers is necessary.[12] In a study including 62 football players, FMS evaluation and a following 7-week intervention were performed to correct all identified movement deficits. The intervention was part of the athletes' offseason program and included movement preparation, partnered stretching, self-administered trigger point treatment, and supervised corrective exercises. The result revealed a reduction from 31 to 20 subjects possessing asymmetries and a mean of 11% increase in their total FMS scores. The author commented that FMS could aid in the design of appropriate intervention to address specific muscle and balance deficits identified by FMS.[10] Song et al. designed a 16-week, three times weekly FMS training program on the strength and flexibility for 62 male high school baseball players. The results showed significant improved of hand grip strength, squat for one-repetition maximum, trunk extension backward, and splits between training group and control group. It commented that the benefit of FMS was not limited to predicting injuries. If the FMS results were used as basic data in developing a training program, FMS training could improve physical strength and flexibility.[18] In a study recruiting 90 soldiers who were about to be discharged from physical rehabilitation, the author designed a 6-week program integrating FMS evaluation and functional training to prepare them for returning to full duty. Because of the favorable outcomes, the author commented that functional training program could serve as a bridge between traditional clinic-based rehabilitation and return to duty.[27]

The FMS-based functional exercise presented in this study was in concordant with the above suggestions. After a 3-month routine rehabilitation, patients after ACLR were evaluated by FMS for identifying any undiscovered movement-pattern limitations, which have been recognized as significant risk factors for re-injury. Then, we customized a 3-month corrective exercise training targeted to the deficits which were identified by FMS evaluation. Our results were also comparable with previous reported outcomes. Notably, recent studies found that the functional deficits assessed after returning to prior activity level were independent of the time from ACLR surgery.[25] Therefore, it would be necessary to integrate a personalized intervention program into post-ACLR rehabilitation.

There were several limitations in this study. Firstly, this study came from a single center with limited sample size. All surgeries were operated by the same orthopedic surgeon and all assessments were performed by the same physiotherapist. We were unable to determine whether the results are appropriate to apply to the general public. Secondly, the study assessor was not blinded in this single-blind study. Potential detection bias might have existed. Third, we only followed the patients after the 3-month FMS-based intervention, therefore lacking long-term outcomes. Despite its limitations, this study could well serve as an anchor for future studies involving the application of FMS-based functional exercise on ACL injuries.

CONCLUSION

The application of FMS-based functional exercise to patients after ACLR resulted in significant improvement in knee function and movements. We recommended integrating FMS evaluation and FMS-based training into the post-ACLR routine rehabilitation program in order to improve the functional performance and decrease the risk of re-injuries.

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Conflict of interest:

None

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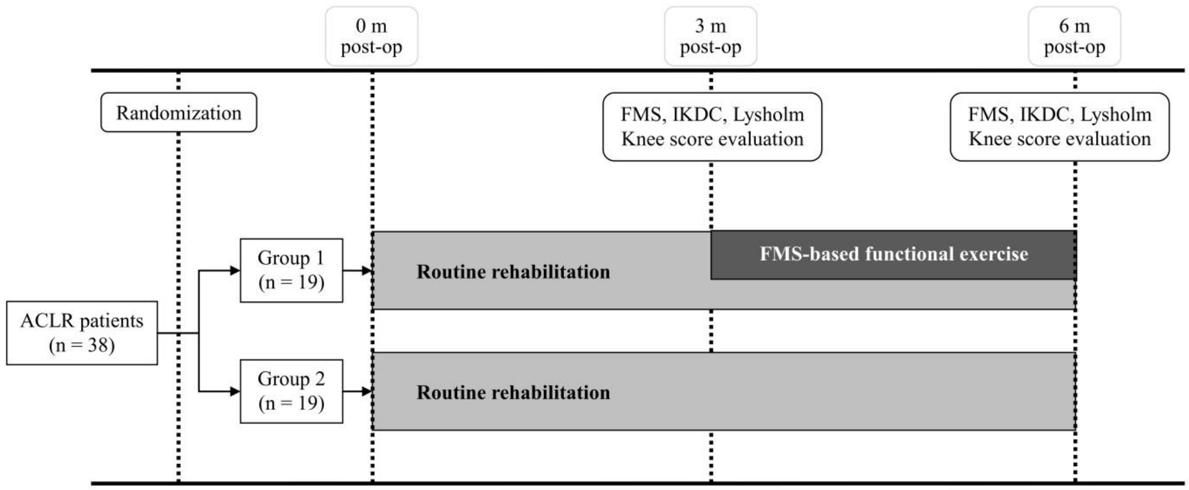

Figure 1. Flowchart of study design.

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Journal of Sport Rehabilitation

	0 - 2 w	2 - 4 w	4 - 6 w	6 - 8 w	8 - 12 w	10 - 12 w	4 m	5 m	6 m
Modality therapy									
Hot packing									
Interferential current therapy									
Therapeutic ultrasound									
Basic treatment									
Passive range of motion	0°	0° - 30°	0° - 60°	0° - 90°	0° - 90°	0° - 120°	Full	Full	Full
Partial weight bearing									
Knee brace									
Strengthening exercise									
Hip abduction & adduction									
Toe raising									
Straight leg raising									
Quadriceps isometrics									
Mini-squats									
Gait training									
Abdominal & back core-muscle training									
Proprioception									

Figure 2. Routine rehabilitation program for patients underwent anterior cruciate ligament reconstruction

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Journal of Sport Rehabilitation

Table 1. Demographic characteristics and outcomes of evaluation.

	Exercise Group (n = 19)	Control Group (n = 19)	P
Age (Year) †	26 (24 - 31)	27 (25 - 31)	0.473
Sex*			
Male	15 (0.8)	13 (0.7)	0.714
Female	4 (0.2)	6 (0.3)	
Education*			
University	14 (0.7)	13 (0.7)	1.000
High School	5 (0.3)	6 (0.3)	
Affected Side*			
Right	10 (0.5)	8 (0.4)	0.746
Left	9 (0.5)	11 (0.6)	
FMS†			
Post-ACLR 3 months	10 (10 - 12)	10 (9 - 11)	0.554
Post-ACLR 6 months	15 (14 - 16)	13 (12 - 14)	<0.001
Change	4 (4 - 5)	3 (1 - 4)	<0.001
Lysholm Knee Score†			
Post-ACLR 3 months	66 (62 - 72)	58 (56 - 65)	0.013
Post-ACLR 6 months	88 (86 - 93)	75 (72 - 85)	<0.001

	Exercise Group (n = 19)	Control Group (n = 19)	P
Change	24 (20 - 26)	16 (12 - 22)	0.001
IKDC†			
Post-ACLR 3 months	62 (60 - 70)	61 (55 - 70)	0.342
Post-ACLR 6 months	85 (82 - 90)	71 (65 - 78)	<0.001
Change	22 (19 - 24)	8 (4 - 16)	<0.001

Data were presented as count (percentage)* or median (interquartile range)†.

Abbreviation: ACLR, anterior cruciate ligament reconstruction; FMS, functional movement screen; IKDC, International Knee Documentation Committee scoring.