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Effect of Adding Preoperative Exercise to Postoperative Rehabilitation Program of Progressive Exercises on Anterior Cruciate Ligament Reconstruction

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Abstract:

Objectives: to investigate the effects of adding preoperative exercises to postoperative progressive exercises on knee function, single hop distance, and global function post ACLR.

Methods: Fifty male subjects undergone unilateral primary ACLR. They were divided randomly into two groups (A) and (B). Six weeks of exercises program given to Group (A) only preoperatively, while twenty four weeks of postoperative progressive exercises program given to all subjects in two groups. Knee function was assessed by knee injury and osteoarthritis outcome score (KOOS), single leg hop distance was measured by single leg hop test, and global function was evaluated by visual analogue scale (VAS) mm. All measured variables were taken 6 weeks before operation (pre-test), 12 weeks after operation (intermediate test), and 24 weeks after treatment program (post-test).

Results: (Intermediate test) after 12 weeks group (A) showed significant improvement in KOOS and global function, while group (B) that treated only by postoperative program showed no significant differences in all variables. (Post-test) After 24 weeks postoperative both groups showed significant improvement in all variables, with superiority to group (A).

Conclusions: Adding pre-operative exercises can give better results than only postoperative progressive rehabilitation in subjects with ACLR.

Keywords: Anterior cruciate ligament reconstruction, Prehabilitation, postoperative progressive exercises.

1. Introduction:

The anterior cruciate ligament (ACL) is a connective tissue like band. ACL is essential for knee stability and directly influences the neuromuscular control of the knee joint due to influence of its mechanoreceptors. Individuals with an unstable knee caused by an ACL rupture depend heavily on quadriceps and hamstring function to preserve dynamic balance while performing functional activities (1).

Injury to ACL can affect the neuromuscular interactions, leading to impaired proprioception and kinesthesia, decreased muscle activity, and dynamic knee joint stability (2,3).

ACL injuries are common in athletes who involved in jumping, pivoting, skiing and soccer games (4). The ACL ruptures represent 1.2% of all

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traumas or injuries according to a prospective study that was conducted in the second Egyptian league at Dakahlia (5), 55.4% in male college Saudi students (2), and 3,000 ACL ruptures occur annually at Japanese junior and high school athletes (6).

Anterior cruciate ligament reconstruction (ACLR) is the usual operation treatment for athletes after ACL tears, followed by physiotherapy (7). Usually ACLR with proper rehabilitation aimed to regain mechanical stability of the knee as early as possible, allowing subjects to resume preoperative daily activities and return to sports early while decreasing the risk of re-injury (8).

In literature, rehabilitation programs after operation have evolved tremendously. The rehabilitation has moved from a protocol-based paradigm to a progression-based program with gradual increases in program difficulty. Early in the process of rehabilitation, the goal of knee function return and good muscle strength need to be achieved (10,11). Recently, integrated neuromuscular training and core stability programs are advocated (11). The progression of ACLR rehabilitation should be guided by objective criteria rather than time frames to limit the risk of re-injury (9). Several studies created evidence-based post-operative protocols that provide criterion and time-based guidance for rehabilitation procedures to gain fast and safe recovery in athletes following ACLR in recent years (8).

Rehabilitation before surgery is considered as physical preparation for a time of immobility and limited activity after surgery (12). Prehabilitation considered in literature as the process of enhancing function for participants to enable them to tolerate stress of inactivity (13). Literature supports the use of neuromuscular training in preoperative rehabilitation to enhance results after an ACL injury (10). It was supported that earlier recovery and quicker restoration of physical activities could come from a decreased loss in functional capacity and reduction of pain severity prior to operation. Prehabilitation is considered as the process of preventing future development of symptoms (14). Unfortunately there is currently limited, very low quality evidence to support the use of prehabilitation for ACLR (15). Several studies recommended combination of both rehabilitations before and after operation to minimize the reconstructed ligament's potential adverse effects and accelerates recovery (17,18). Additionally progressive pre- and postoperative rehabilitation was recommended in many protocols (12).

Return to pre-injury and sports participation after ACLR is commonly cited in the literature to be inadequate despite participants achieving a successful functional outcome (19,20). Up till know there is the lack of scientific evidence, about utilizing particular protocol either prehabilitation or post-operative rehabilitation to prepare participants for better recovery. It was suggested that improved postoperative recovery may be achieved by combination of knee muscle strength, integrated neuromuscular control, knee joint stability, and good function gains (8). Unfortunately the optimal preoperative rehabilitation program is, still unknown (12) and no consensus regarding the optimum prehabilitation program content, frequency or length (15).

Consequently, the aims of the current study was to investigate the benefit of suggested preoperative exercises combined with postoperative progressive rehabilitation exercises, on improvement of knee function (KOOS), Single leg hop test, and global function (VAS) mm post ACLR.

2. Patients and Methods:

2.1. Study Design:

A randomized clinical study was conducted in out-patient clinic of Zagazig university hospital from, (January 2021 to January 2022). The study was approved by the institutional review board of the Zagazig university hospital (ZU-IRB No# 9196/6-6-2021). All subjects were informed that the collected data would be submitted for publication and a consent form was signed before participating in current study.

2.2. Sample size:

The subject's number required to achieve a power of greater than 0.80 was calculated by using Open Epi program. The number of subjects used per group in this study was comparable to published prospective ACL rehabilitation studies (17).

Assuming the mean single leg was 85.3±7.4 versus 80.5±4.2 among pre- exercises group versus no pre-exercises group at 80 % power and 95% confidence level. The calculated sample was 50 subjects divided equally in both groups.

2.3. Subjects Enrollment:

Fifty male subjects with ACL rupture were included in this study after evaluating by specialized orthopedic surgeon according to sample size calculation using Open Epi program. The participants' demographic data including age, involved limb, body mass index (BMI), and dominant side are shown in table 1. The 50 subjects were divided randomly into two groups by using Graph Pad software of randomization before assessment and treatment of participants. Group (A: n=25) received preoperative and postoperative progressive rehabilitation program and Group (B: n=25) received postoperative progressive rehabilitation program only.

2.4. Inclusion criteria:

All subjects included in the study were male presenting with primarily unilateral ACL rupture with their ages were between 18 and 40, and their BMI between 18.5 and 29.9 and undergone (anatomical single-bundle ACLR using autologous hamstring

tendon graft) by orthopedic knee arthroscopic specialist (20).

2.5. Exclusion criteria:

The subjects were excluded from the study if they have; ligamentous, bony or other soft tissue surgery, insecure graft fixation (due to bone quality or suspension) which confirmed by orthopedic surgeon, active infection, postsurgical excess knee swelling which affect exercise performance, ACLR using bone tendon bone graft, any cardiovascular disease, any lower limb trauma or pathology or BMI more than 30% (22,23).

2.6. Assessment procedures:

Assessment of functional outcome was done at six weeks before operation, 12 weeks after operation, and 24 weeks after treatment program. Evaluation is based upon (KOOS) subscale, single leg hop test and global function (VAS) mm as the following;

2.6.1. Knee injury and Osteoarthritis Outcome Score (KOOS):

Knee-specific self-assessment instrument for knee injuries called the (KOOS). KOOS is a valid and reliable outcome measure commonly used in the ACL-injured patient's to evaluate outcomes in knee pain, knee symptoms, knee function in daily activity, knee function in sporting activity, and knee-related quality of life (24). It is a 42- item self-administered self-explanatory questionnaire and has 5 participant-relevant dimensions were scored separately: Pain (9 items); Symptoms (6 items); Activities of Daily Living (ADL) (17 items); Sport and Recreation Function (5 items); Knee-related Quality of Life (4 items). All items were scored from 0 to 4, and each of the 5 scores was calculated as the sum of the items included, in accordance with score calculations of the WOMAC Osteoarthritis Index (24,11).

Raw scores were then transformed to a 0-100 scale, with zero representing extreme knee problems and 100 representing no knee problems, as common in orthopedic scales Scores between 0 and 100 represent the percentage of total possible score achieved (24).

2.6.2. Single leg hop distance test:

This functional knee test has shown better reliability and validity (25). The participant jumps as far as he can on one leg, with maintaining balance and landing firmly (17). For the single legged hop test, the distances were measured in centimeters for each leg, and the side-to-side differences in performance between affected and non-affected legs were measured as an index: (injured leg/non-injured leg) × 100) (27,28,29).

2.6.3. Global function VAS mm (visual analogue scale in millimeter):

Knee global function was evaluated by VAS that is, a global rating of knee function, as used in several other studies. "0" represents worst possible knee function, and "100" represents same knee function as pre injury (27,28).

2.7. Treatment procedures:

Six weeks exercise program before operation were given to Group (A) only while twenty four weeks progressive program were given to all subjects after operation in both groups (A) and (B) (29).

2.7.1. Preoperative program for group (A) only:

The program included 4 sessions per week for 6 weeks before surgery. The exercises were adapted according to subject's needs and conditions. The exercise program mainly concentrate on range of motion (ROM) (seat flexion, extension), balance/proprioception exercise (standing on one leg, balance board) and lower limbs strengthening, with concentration directed to strengthening of the quadriceps muscles (29) in form of short arc extension, mini squats, wall squat, straight leg raising, leg press, isometric leg extension, and knee flexion curls, then ice application after exercises (31,32,11,13).

2.7.2. Postoperative progressive rehabilitation program for both groups:

The program was progressive rehabilitation program applied 4 sessions per week for 24 weeks after surgery (10,31,32).

Phase 1- 1st three weeks:

The main aim was to decrease post-operative pain, inflammation, swelling; and to obtain ROM up to 90◦ through mild active exercises e.g., straight leg raising (all planes), quadriceps setting, leg press, Hip progressive resisted exercises, partially then full weight bearing after 2 weeks of surgery.

Phase 2- (3-6) weeks:

Participant moved through full-ROM of knee joint motion and perform closed chain exercise. Continue strength exercise and proprioception training, by end of this stage the participant restores normal gait and ascend stairs with good control without pain.

Phase 3 (weeks 6–14):

The participants achieved enough strength, activity of daily living (ADL) endurance and proprioception. They could work on improving functional performance with good control without pain and improve ADL. They maximized strength and flexibility and demonstrate ability to run pain free. The exercises focused on forward, and backward treadmill ambulation/running, advanced proprioception training (perturbations) and agility exercises

Phase 4 (weeks 14–20):

The participants in this stage practiced ADL pain free and start participating in sports like activity. The training was focusing on sports activity and plyometric program. They continue advanced kinetic chain (e.g., Leg press, Lunges, Stair climbing) and advanced proprioception exercises.

Phase 5 (20-24 weeks):

The participants in final stage of rehabilitation haven't any apprehension with sport specific movements; gain maximum strength and flexibility that meet demands of individual's sport activity; hop test ≥90% limb symmetry; have acceptable quality movement assessment. In training continue advance lower extremity strengthening, flexibility, and agility programs, and focused on advanced sports and plyometric program. Encourage compliance to home therapeutic exercise program.

2.8. Statistical Analysis:

Data were analyzed by using SPSS version 22. It was presented as mean, standard deviation for quantitative variables, frequency and percentage for qualitative variables. Group differences were analyzed using chi-square tests for nominal variables and t tests for continuous variables. Independent T test for comparison between groups. Paired t test was used for paired analysis within each group for KOOS, VAS, and single leg hop test. P values less than 0.05 were considered to be significant.

Table (1): Demographic and baseline data in both groups.

Variables	Group A (n=25) Mean ±SD	Group B (n=25) Mean ±SD	P value
Age (years)	30.0 ±8.7	29.5 ±7.6	0.24
Height (cm)	169.1 ±6.1	169.92 ±11.2	0.6
Weight (Kg)	71.3 ± 4.9	69.3 ±5.4	0.22
BMI (kg/m2)	24.7 ± 2.7	23.8 ±2.86	0.27
Injured side (right/left)	20/5	23/2	
KOOS	60 ±7.3	63.1 ±6.9	0.13
Pain Symptoms	56.8 ±7.7	58.9 ±7.53	0.36
ADL	69.96 ± 7.3	72.9 ±6.6	0.24
Sports	37.2 ±7.1	38.9 ±6.9	0.37
QOL	32.08 ±7.4	35.04 ±6.27	0.12
One leg hop test, %	83 ±5.64	84.3 ±5.05	0.39
Global function (VAS) mm	70.08 ±7.23	71.6 ±7.8	0.45

SD: Standard Deviation, BMI: Body Mass Index, KOOS: Knee injuryand Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, VAS: Visual Analogue Scale

3. Results:

3.1. Demographic and Baseline data

There were no significant differences between both groups in age, height, weight and body mass index (BMI) (P>0.05) table (1). Also, there were no significant differences between the two groups at 6 weeks preoperative in all variables, KOOS subscales, one leg hop test, and global function (P>0.05) as shown in **table (1) and figure (3).**

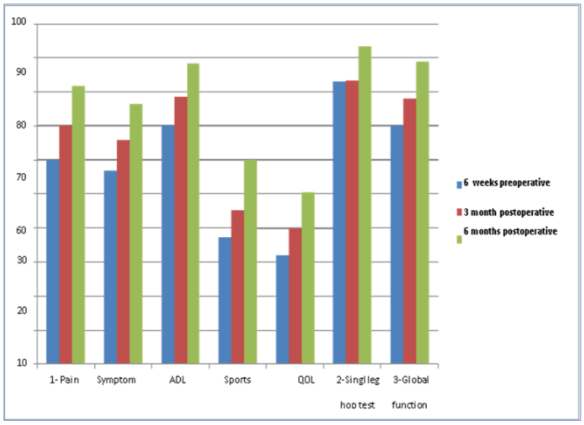

Figure 1. Within group A comparison

3.2. Within group's difference after 3 and 6 months postoperative rehabilitation:

After 3 months; postoperative group (A) showed significant differences in KOOS subscales, and global function, except single leg hop test. There was no significant difference were found in group (B) in all variables after 3 months (P>0.05), **table (2), figures (1) and (2).** After 6 months, both groups showed significant differences in all measured variables with a favor to group (A), p < 0.05, as in **table (3) and figure (1) and (2).**

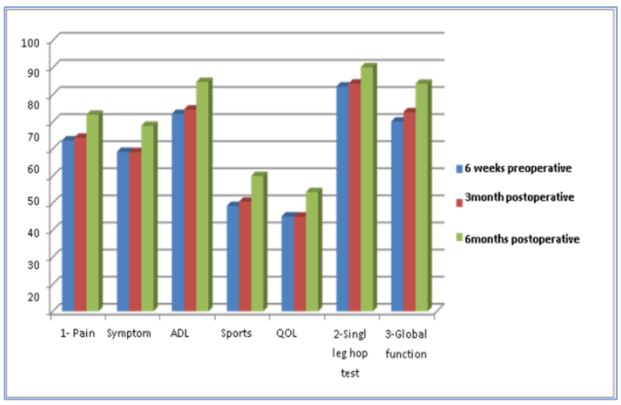

Figure 2. Within group B comparison

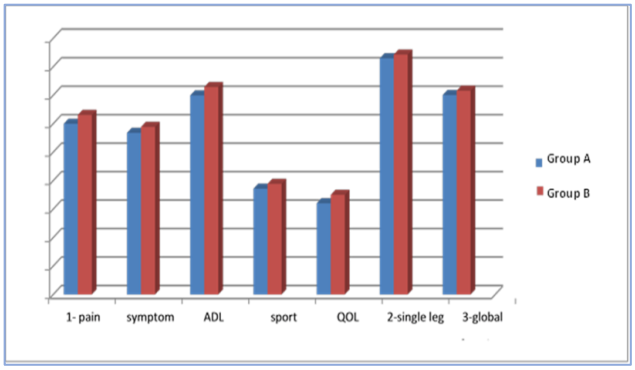

Figure 3. Between groups difference 6 weeks preoperative

Table 2. Comparison within groups after 3 months postoperative.

Variables		Group A			Group B		
		6 weeks preoperative Mean±SD	3 months postoperative Mean±SD	P-value	6 weeks preoperative Mean±SD	3 months postoperative Mean±SD	P-value
1-KOOS Subscale	Pain	60±7.3	70.2±7.2	0.001	63.1±6.9	64.1± 6.6	0.72
	Symptom	56.8±7.7	65.9±7.3	0.001	58.9±7.53	58.8±6.5	0.94
	ADL	69.96±7.3	78.52±6.61	0.001	72.9±6.6	74.52±8.25	0.35
	Sports	37.2±7.1	45.1 ±7	0.001	38.9±6.9	40.5±6.9	0.55
	QOL	32.08±7.4	40±7.3	0.001	35.04±6.27	35±7.36	0.94
2-Single leg hop test		83±5.64	83.3±5.6	0.90	84.3±5.05	84.08±4.25	0.41
3-Global function		70.08±7.23	78.1±6	0.001	71.6 ±7.8	73.5±6.9	0.3

SD: Standard Deviation, KOOS: Knee injury and Osteoarthritis Outcome Score,
ADL: Activities of Daily Living, QOL: Quality of Life

Table 3. Comparison within groups after 6 months postoperative.

Variables		Group A			Group B		
		6 weeks preoperative Mean±SD	6 months postoperative Mean±SD	P-value	6 weeks preoperative Mean±SD	6 months postoperative Mean±SD	P-value
1-KOOS Subscale	Pain	60 ±7.3	81.9 ±6.9	0.000	63.1 ±6.9	72.6 ±7.8	0.001
	Symptom	56.8 ±7.7	76.4 ±7.4	0.000	58.9 ±7.53	68.5 ±6.9	0.001
	ADL	69.96 ±7.3	88.5 ±6.1	0.000	72.9 ±6.6	84.7 ±7.0	0.001
	Sports	37.2 ±7.1	60 ±7.3	0.000	38.9 ±6.9	50 ±7.3	0.001
	QOL	32.08 ±7.4	50.5 ±7.36	0.000	35.04 ±6.27	44 ±7.36	0.001
2-Single leg hop test		83 ±5.64	83 ±5.64	93.3 ±1.84	0.000	84.3 ±5.05	90.1±1.9
3-Global function		70.08 ±7.23	70.08 ±7.23	89 ±4.6	0.000	71.6 ±7.8	84±7.46

SD: Standard Deviation, KOOS: Knee injury and Osteoarthritis Outcome Score,
ADL: Activities of Daily Living, QOL: Quality of Life

Table 4. Comparison between groups after 3, and 6 months postoperative rehabilitation

Variable		Group	3 months postoperative		6 months postoperative	
			Mean ± SD	P-value	Mean ±SD	P-value
1-KOOS subscales	Pain	A	70.2±7.2	0.008	81.9±6.9	0.001
		B	64.1±6.6		72.6±7.8	
	Symptoms	A	65.9±7.3	0.001	76.4±7.4	0.001
		B	58.8±6.5		68.5±6.9	
	ADL	A	78.52±6.61	0.001	88.5±6.1	0.04
		B	74.52±8.25		84.7±7	
	Sports	A	45.1±7	0.025	60±7.3	0.001
		B	40.5±6.9		50±7.3	
	QOL	A	40±7.3	0.02	50.5±7.36	0.001
		B	35±7.36		44±7.36	
2-Single leg hop test		A	83±5.60	0.44	93±1.84	0.000
		B	84.08±4.25		90.1±1.9	
3-Global function		A	78.1±6	0.04	89±4.6	0.001
		B	73.5±6.9		84±7.46	

SD: Standard Deviation, KOOS: Knee injury and Osteoarthritis Outcome Score,
ADL: Activities of Daily Living, QOL: Quality of Life

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3.3. Between groups differences after 3 months, 6 months postoperative.

There were significant differences between groups regarding to KOOS subscale, and global function. The single leg hop test showed no significant difference after 3 months. There were significant differences between groups in all variables with favor to group (A) after 6 months ($p < 0.05$), (**table 4**), and **figures (4) and (5).**

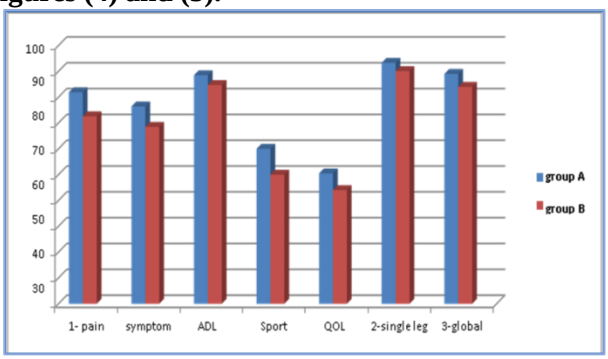

Figure 4. Between groups difference 3 months postoperative

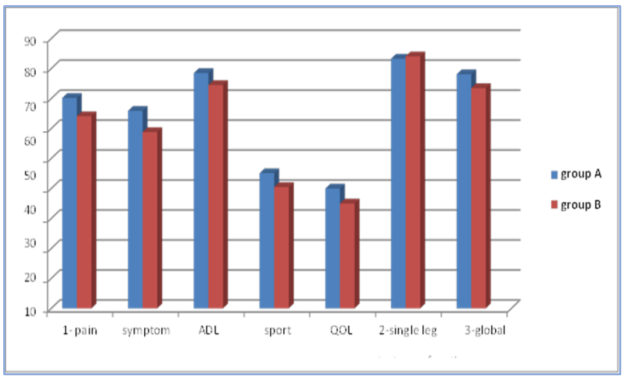

Figure 5. Between groups difference 6 months postoperative

4. Discussion:

The aim of this study was to evaluate the effect of adding 6 weeks prehabilitation to 6 months postoperative rehabilitation of ACLR on KOOS subscales, one leg hop test, and global function. There is agreement in literature that ACLR is the best option for athlete with an ACL injury to get back into sports as soon as possible and the rehabilitation program is highly important for ACLR success (13). The principle behind the rehabilitation treatment that person undergoes is supported by numerous studies. It significantly affects how quickly they are able to resume their pre-injury level of athletic and functional activities (32).

The results of current study showed that at 3 months post-operative follow up. Participants who performed prehabilitation had significant improvement in KOOS and global function, while group (B) that treated only by postoperative rehabilitation showed no significant differences in all variables. These results support the concept of importance of Prehabilitation as enhancing factor in recovery after ACLR in short term effect. the results of The current study came in agreement with many previous studies (13,14,18,32,16). Actually the reduction of inflammation, restoring mobility, and enhancement of muscle strength and neuromuscular control through preoperative rehabilitation are common out comes that serve in early recovery after surgery (34,35). In particular, surgeons believed that preoperative range of motion (ROM) was the best indicator of postoperative ROM and could be fully restored during the rehabilitation period (31).

Additionally, preoperative neuromuscular function is the main predictive for knee function and return to sports after reconstruction surgery (35). Many authors considered gradual efficient preoperative rehabilitation is a significant element in achieving the best postoperative results (37,13).

The prehabilitation of 4 sessions/week for 6-weeks exercise program has applied in the current study. There is agreement in literature on that preoperative or post-injury training protocols 4 to 6 weeks, 2 to 4 times per week are efficient for good recovery of participants with ACLR (18,38). The finding of this study was consistent with investigators who found that a 5-weeks preoperative program enhanced functional results after ACLR. the results of the current study agreed with previous studies (37,13). They proved that gradual preoperative rehabilitation was a significant element in achieving the best postoperative results. Another study found that four weeks preoperative rehabilitation of cardio exercise, strengthening and balance training lead to faster recovery of knee extensor strength and single-leg hop ability (17).

The difference between the two groups after 3 months in short term period (intermediate test) in favor of the subjects who received prehabilitation program was supported by some investigators (10). They proved that rehabilitation before (ACLR) was effective at improving postoperative outcomes at least in the short term. Additionally the prehabilitation in the current study mainly involved strengthening, kinetic chain exercises and neuromuscular training which are supported by many studies (10). some authors contradicted the benefits of prehabilitation program as there was a very low quality evidence of training 3 months after ACLR compared with no prehabilitation (15). However, Carter and their colleagues didn't apply specific training program in clinical trials, but this suggestion was depend on systematic review while current study is clinical trial and the program applied to participants and the assessment performed pre and post rehabilitation.

In contrast to the results of this study about one leg hop test, Shaarani et al. (13) found higher increases in the one -leg hop scores of the affected limb in the prehabilitation group compared to the

control subjects. They stated that the improvements were significant with prehabilitation group only. The control subjects in their study were not discouraged to do exercise or any normal activity of daily living before the ACLR. There was no significant difference in single leg hop test distance in the current study. This difference may attributed to that prehabilitation exercises; in Shaarani et al. (13)were 6-week gym- and home-based exercise program, as home exercise consisted of the same program as the gym. But in the current study, 6 weeks exercises were adapted to participants' specific condition and needs under closed supervision from physical therapist. In addition assessment in Shaarani et al. (13) was done at baseline, preoperatively, and 12 weeks postoperatively, while in this study, the assessment was done 6 weeks before operation (pre-test), 3 months after operation (intermediate-test) and, 6 months after treatment program (post-test).

The results of current study showed that the 6 months postoperative exercise programs were efficient for good post-operative recovery, and this matched with previous programs in literature (28,25). The postoperative program in this current study focused on strength quadriceps muscle through different modes of exercises as the good quadriceps control is considered as early goal of post-operative ACLR rehabilitation (9). The post-test assessment of both groups showed significant improvement in all measured variables. At the same time at 3 and 6 months, participants who received prehabilitation showed more significant improvement in all variables than group B that treated only by postoperative rehabilitation. Combination of preoperative training and post-operative programs are commonly supported in most of literature, especially in terms of enhanced peak knee-related function and high neuromuscular integrity (39,33). In spite of agreement of the importance of rehabilitation and training pre and post-operative period, the best components of a program of rehabilitation still debated until know (33,40).

In this study, the authors chose to use KOOS as the primary outcome after ACLR and rehabilitation because knee function, pain, ADL and sport are most common challenging outcomes (24). Some authors used progressive pre and postoperative rehabilitation, which is consistent with the larger improvement in KOOS across all subscales in the current study for participants who had rehabilitation and 6 months of postoperative rehabilitation, they looked at participant-reported outcomes from 2 years after surgery and discovered that both preoperative and postoperative participant-reported outcomes were superior (12). The improvement in global function after prehabilitaion and postoperative training is supported by previous clinical studies (27). Some authors found significant improvement in knee global function measured by VAS after 6 months of neuromuscular exercises (27).

The study was limited to the small sample size and the functional activity before surgery can't be performed.

The strength of this study were same inclusion and exclusion criteria to both groups for a homogeneous comparison, and use of criterion-based postoperative rehabilitation.

Future studies were recommended to better assess the value of preoperative rehabilitation directly after an ACL rupture.

5. Conclusion:

Addition of progressive preoperative rehabilitation to postoperative rehabilitation program result in high improvement in KOOS subscales, one-leg hop test, and global function than only post-operative progressive rehabilitation program after 3 months and 6 months in subjects with ACLR.

Declaration of Interest:

The authors declare that there is no conflict of interest.

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