Effectiveness of Preoperative Combined With Postoperative Progressive Rehabilitation on Early Outcomes Following Anterior Cruciate Ligament Reconstruction


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ABSTRACT

Background: The anterior cruciate ligament (ACL) is the main contributor of knee stability. ACL reconstruction (ACLR) is the most common surgery after ACL injury. The exercise programs are the main concern after surgery.

Objective of this study: evaluate effect of preoperative rehabilitation in addition to postoperative progressive rehabilitation exercises on knee function (KOOS), single leg hop distance test, and global function (VAS) mm following ACLR. Methods: Fifty participants’ males’ undergone primary unilateral ACLR with ages 18-40 years were included in the study at Zagazig University Hospital. They randomly assigned into two groups (A) and (B). Treatment was 6-weeks exercises program preoperatively given to Group (A) only while 24-weeks postoperative progressive program given to all participants in both groups. The outcome measurements were knee function, single leg hop distance, and visual analogue scale (VAS) mm, respectively, all were taken 6 weeks preoperative (pre-test), 3 months postoperative (intermediate-test) and, 6 months after treatment program (post-test). Results: At 3 months group (A) that received prehabilitation showed significant improvement in KOOS, and global function, while group (B) that treated only by postoperative rehabilitation showed no significant differences in all variables. At 6 months postoperative both groups showed significant improvement in all measured variables, with high significant improvements in group (A) than (B). Conclusion: Pre-operative exercises and post-operative progressive rehabilitation program showed significant more improvement in KOOS, single leg hop test, and VAS mm, than only postoperative progressive rehabilitation after 3 months and 6 months in participants with ACLR.

Keywords: ACLR, Prerehabilitation, Postoperative progressive rehabilitation, KOOS.

I-INTRODUCTION

The anterior cruciate ligament (ACL) is a band-like connective tissue and essential for knee joint stability. ACL directly influences the neuromuscular control of the knee 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 (Gashbat & Jahan, 2017). Injury to ACL can affect the neuromuscular interactions, leading to impaired proprioception and kinesthesia, decreased muscle activity, and dynamic knee joint stability (Dafalla et al., 2020), (Van Melick et al., 2016), (Lee et al., 2019).

There is high prevalence of knee injuries among athletes (Almaawi et al., 2020). Especially ACL tears are so common in athletes who involved in jumping, pivoting, skiing and soccer games. (Awad et al., 2017). The ACL injuries represent 1.2% of all injuries according to a prospective study that was conducted in the second Egyptian league at Dakahlia (Ali et al., 2019). In Saudi community the prevalence of knee injuries was 23% among male college
Saudi students (Almaawi et al., 2020) and (55.4%) of the injured ligaments was the ACL (Dafalla et al., 2020) . Additionally in Japan it was found that about 3,000 ACL injuries occur annually at Japanese junior high and high school athletes, and the injury rate was 0.80 per 1000 athletes (Takahashi & Okuwaki, 2017).

Anterior cruciate ligament reconstruction (ACLR) is the usual treatment for athletes after ACL tears, followed by physical rehabilitation therapy (Van Melick et al., 2016), (Gränicher & Scherr, 2021). Usually ACLR with proper rehabilitation seeks to restore mechanical stability of the knee joint as quickly as possible, allowing participants to resume preoperative activities and return to sports as soon as possible while reducing the risk rate of re-injury (Gränicher & Scherr, 2021). In the United States, approximately 200 thousand ACLR procedures are performed each year, costing more than $3 billion (Alshewaier et al., 2017).

In literature post-operative rehabilitation programs have evolved tremendously. The rehabilitation has moved from a protocol-based paradigm to a progression-based program with gradual increases in difficulty. Early in the process of rehabilitation, the goal of knee function and good muscle strength need to be achieved (Cavanaugh & Powers, 2017), (Failla et al., 2016). Recently integrated neuromuscular training and core stability programs are advocated (Gupta et al., 2021). The progression of ACLR rehabilitation should be guided by objective criteria rather than time frames to limit the risk of re-injury (Cavanaugh & Powers, 2017). Several studies created evidence-based post-operative protocols that provide criterion and time-based guidance for rehabilitation procedures aimed gains fast and safe recovery in athletes following ACLR in recent years (Gränicher & Scherr, 2021).

Prehabilitation considered in literature as the process of enhancing function for participants to enable them to tolerate stress of inactivity (Shaarani et al., 2012) Rehabilitation before surgery considered as physical preparation for a time of immobility and limited activity after surgery (Grindem et al., 2015). Many authors support use neuromuscular training in preoperative rehabilitation to enhance results after an ACL injury (Failla et al., 2016). It was supported that faster recovery and earlier restoration of activities of daily living could come from a reduced loss in functional capacity and a suppression of pain exacerbation prior to surgery. Prehabilitation is considered as the process of preventing future development of symptoms (Banugo & Amoako, 2017). Unfortunately there is currently limited, very low quality evidence to support the use of prehabilitation for ACLR (Carter et al., 2020). Several studies recommended combination of Pre-operative and post-operative rehabilitation to minimize the reconstructed ligament's potential adverse effects and accelerates recovery (Wang et al., 2012), (Kim et al., 2015) and (Grindem et al., 2015). Additionally progressive pre- and postoperative rehabilitation was recommended in many protocols (Grindem et al., 2015).

Return to sports participation after ACLR is commonly cited in the literature to be inadequate despite participants achieving a successful functional outcome (Dingenen & Gokeler, 2017), (Ardern et al., 2013). 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 (Gränicher & Scherr, 2021). Unfortunately the optimal preoperative rehabilitation program is, still unknown (Grindem et al., 2015) and no consensus regarding the optimum prehabilitation program content, frequency or length (Carter et al., 2020).

Consequently, the objective of this study is examining the suggested preoperative exercises in addition to postoperative progressive rehabilitation exercises can improve knee function (KOOS), Single leg hop distance test, and global function (VAS) mm following ACLR.

II- MATERIALS & METHODS

- Study Design:

Prospective randomized clinical study 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 participants were informed that the collected data would be submitted for publication, and a consent form was signed before the study.
Sample size:

The number of participants required to achieve a power of greater than 0.80 was estimated by using Open Epi program. The number of participants used per group in this study was comparable to published prospective ACL rehabilitation studies (Kim et al., 2015). 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 estimated sample was 50 cases, 25 cases in each group.

Participant Enrollment

Fifty male participants with ACL rupture were recruited to this study after screening by specialized orthopedic surgeon according to sample size calculation using Open Epi program. The participants’ demographic data, including age, involved limb, BMI, dominant side are shown in Table 1.

Inclusion criteria

All male participants ages between of 18 and 40 years, BMI between 18.5 and 29.9 were presenting with primarily unilateral ACL rupture in the knee and undergone (anatomical single-bundle ACLR using autologous hamstring tendon graft) by orthopedic knee arthroscopic specialist (Ohta et al., 2003).

The exclusion criteria

The participants were excluded from this study if they have; ligamentous, bony or other soft tissue surgery, insecure graft fixation (due to bone quality or suspension), 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% (Brandner et al., 2018); (DePhillipo et al., 2018).

The 50 participants were randomly assigned 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.

Assessment procedure

Assessment of functional outcome was done at 6 weeks preoperative (pre-test), 3 months postoperative (intermediate-test), and 6 months after treatment program (post-test). Evaluation is based upon KOOS, single leg hop distance and global function (VAS) mm by the following:

1) KOOS (Knee injury and Osteoarthritis Outcome Score) (Roos et al., 1998), (Grindem et al., 2015). The KOOS is knee-specific self-assessment instrument for knee injuries which can lead to posttraumatic osteoarthritis. It is a 42-item self-administered self-explanatory questionnaire. The KOOS has five participant-relevant dimensions were scored separately: Pain (nine items); Symptoms (seven items); Activities of Daily Living (ADL) (seventeen items); Sport and Recreation Function (five items); Knee-related Quality of Life (four items). All items were scored from 0 to 4, and each of the five scores was calculated as the sum of the items included, in accordance with score calculations of the WOMAC Osteoarthritis Index (Failla et al., 2016). 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 (Wypych et al., 2021).

2) Single leg hop distance test: This functional knee test has shown good validity and reliability (Reid et al., 2007). The participant jumps as far as possible on single leg, without losing balance and landing firmly (Kim et al., 2015). For the single legged hop test, the distances were measured in centimeters for each leg, and the side-to-side differences in performance between injured and non-injured legs were calculated as an index: (injured leg/non-injured leg) × 100 (Risberg et al., 1999) (Risberg & Holm, 2009), (Nawasreh et al., 2018).

3) Global function VAS mm (visual analogue scale in millimeter). VAS was used to self-evaluate knee global function—that is, a global rating of knee function, as used in several other studies. In it, 0 represent worst possible knee function, and 100 represent same knee function as before the injury (Risberg et al., 1999) (Risberg & Holm, 2009).
Treatment procedure

6-week exercise program preoperatively given to Group (A) only while 24-week postoperative progressive program given to all participants in both groups (A and B) (Pottkotter et al., 2020).

Preoperative program for group (A) only

This includes 4 sessions per week for 6 weeks before surgery. The exercises were adapted to participants’ specific condition and needs. The exercise program mainly focused on range of motion (seat flexion, extension), balance/proprioception exercise (single leg standing, balance board) and lower limbs strengthening, with particular attention paid to strengthening of the quadriceps muscles (Pottkotter et al., 2020) in form of short arc extension, mini squats, wall squat, straight leg raising, leg press, isometric leg extension, and leg curls, then ice application after exercises (Reddy et al., 2020) (Ellman et al., 2015), (Failla et al., 2016), (Grindem et al., 2015), (Kim et al., 2015).

Postoperative progressive rehabilitation program for both groups:

The program was progressive rehabilitation program applied 4 sessions per week for 24 weeks after surgery (Cavanaugh & Powers, 2017), (Reddy et al., 2020), (Ellman et al., 2015)

Phase 1- 1st three weeks:

The main goal was to control postoperative pain, inflammation, swelling; and to gain 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 move through full-range 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 8th 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 maximize 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

Statistical Analysis:

Data were checked entered and analyzed by using SPSS version 22. Data were expressed as means, standard deviation for quantitative variables, frequency and percentage for qualitative variables. Independent T test, Chi-squared used 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.
III- RESULTS

- **Demographic and Baseline Characteristics**

  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).

  ![Table 1. Demographic data and baseline characteristics in both groups.](image)

  P>0.05 was considered no statistically significant, SD: Standard Deviation, BMI: Body Mass Index, KOOS: Knee injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, VAS: Visual Analogue Scale

- **Comparison of both groups 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 also group (B) showed no significant differences in all variables after 3 months (P>0.05), the detailed are presented in Table (2) and figures (1) and (2). After 6 months the both groups showed significant differences in all subjective and objective measured variables with favor to group (A), p < 0.05, as shown in table (2) and figure (1) and (2).

  ![Table 2. Comparison within groups after 3 months postoperative](image)

  P>0.05 was considered no statistically significant, SD: Standard Deviation, BMI: Body Mass Index, KOOS: Knee injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, VAS: Visual Analogue Scale
Table 3. Comparison within groups after 6 months postoperative

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>60±7.3</td>
<td>61.9±6.9</td>
</tr>
<tr>
<td>Symptom</td>
<td>56.8±7.7</td>
<td>76.4±7.4</td>
</tr>
<tr>
<td>ADL</td>
<td>69.96±7.3</td>
<td>88.5±6.1</td>
</tr>
<tr>
<td>Sports</td>
<td>37.2±7.1</td>
<td>60±7.3</td>
</tr>
<tr>
<td>QOL</td>
<td>32.08±7.4</td>
<td>50.5±7.36</td>
</tr>
</tbody>
</table>

P>0.05 was considered no statistically significant, SD: Standard Deviation, BMI: Body Mass Index, KOOS: Knee Injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, VAS: Visual Analogue Scale

- Comparison between groups after 3 months, 6 months postoperative.

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

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

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>3 months postoperative</th>
<th>6 months postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>A</td>
<td>70.2±7.2</td>
<td>81.9±6.9</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>64.1±6.6</td>
<td>72.6±7.8</td>
</tr>
<tr>
<td>symptoms</td>
<td>A</td>
<td>65.9±7.3</td>
<td>76.4±7.4</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>58.8±6.5</td>
<td>68.5±6.9</td>
</tr>
<tr>
<td>ADL</td>
<td>A</td>
<td>78.52±6.61</td>
<td>88.5±6.1</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>74.52±8.25</td>
<td>84.7±7</td>
</tr>
<tr>
<td>Sports</td>
<td>A</td>
<td>45.1±7</td>
<td>60±7.3</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>40.5±6.9</td>
<td>50±7.3</td>
</tr>
<tr>
<td>QOL</td>
<td>A</td>
<td>40±7.3</td>
<td>50.5±7.36</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>35±7.36</td>
<td>44±7.36</td>
</tr>
<tr>
<td>2-Single leg hop test</td>
<td>A</td>
<td>83±5.60</td>
<td>93±1.84</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>84.08±4.25</td>
<td>90.1±1.9</td>
</tr>
<tr>
<td>3-Global function</td>
<td>A</td>
<td>78.1±6</td>
<td>89±4.6</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>73.5±6.9</td>
<td>84±7.46</td>
</tr>
</tbody>
</table>

P>0.05 was considered no statistically significant, SD: Standard Deviation, BMI: Body Mass Index, KOOS: Knee Injury and Osteoarthritis Outcome Score, ADL: Activities of Daily Living, QOL: Quality of Life, VAS: Visual Analogue Scale
Figure 1. Intergroup A comparison

Figure 2. Intergroup B comparison

Figure 3. Between groups difference 6weeks preoperative
The purpose of this study was to investigate the effect of 6 weeks prehabilitation with 6 months postoperative rehabilitation of ACLR on KOOS subscales, single leg hop test, and global function (VAS). 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 (Shaarani et al., 2012). Previous studies support the idea of that type of rehabilitation program that individual receives has a big impact on how quickly they return to their pre-injury level of sport and functional activity (Lobb et al., 2012).

The results of current study showed that at 3 months post-operative follow up participants that received Prehabilitation showed 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. This is come in agreement with many previous studies (Grindem et al., 2015), (Shaarani et al., 2012), (Kim et al., 2015), (Ellman et al., 2015), (Carter et al., 2020). 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 (Logerstedt et al., 2013) and (Myer et al., 2009). Especially the surgeons considered that preoperative ROM is the strongest predictor of postoperative ROM, to regained complete range of motion in stages.

### IV- DISCUSSION

The purpose of this study was to investigate the effect of 6 weeks prehabilitation with 6 months postoperative rehabilitation of ACLR on KOOS subscales, single leg hop test, and global function (VAS). 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 (Shaarani et al., 2012). Previous studies support the idea of that type of rehabilitation program that individual receives has a big impact on how quickly they return to their pre-injury level of sport and functional activity (Lobb et al., 2012).

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of rehabilitation (Ellman et al., 2015). Additionally, preoperative neuromuscular function is main predictive for knee function and return to sports after reconstruction surgery (Chen et al., 2018). Many authors consider gradual efficient preoperative rehabilitation is a significant element in achieving the best postoperative results (Eitzen et al., 2010) and (Grindem et al., 2015).

The Prehabilitation of 4 sessions / week for 6-weeks exercise program has applied in 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 (Kim et al., 2015), (Giesche et al., 2020). In support of the finding of this study some investigators found that a 5-weeks preoperative program enhanced functional results after ACLR. Our findings agree with previous studies (Eitzen et al., 2010) and (Grindem et al., 2015). They proved that gradual preoperative rehabilitation is 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 (Kim et al., 2015).

The difference between the two groups after 3 months in short term period (intermediate test) in favor of the subjects that receive Prehabilitation program supported with some investigators (Failla et al., 2016). They proved that —rehabilitation before (ACLR) is effective at improving postoperative outcomes at least in the short term. Additionally the prehabilitation in current study mainly involved strengthening, kinetic chain exercises and neuromuscular training which are supported by many studies (Failla et al., 2016). Contradict to the benefit from prehabilitation program in current study some authors suggests that benefit of prehabilitation is very low quality evidence of training three months after ACLR compared with no prehabilitation (Carter et al., 2020). However Carter and their colleagues don’t apply specific training program in clinical trials but this suggestion is built 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 current study about single leg hop test distance Shaarani et al ., 2012 found higher increases of the single-leg hop scores of the injured limb in the prehabilitation group compared to the control subjects. They added 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 current study. This difference may attributed to that prehabilitation exercises; in (Shaarani et al., 2012) were 6-week gym- and home-based exercise program, as home exercise consisted of the same program as the gym. But in current study 6 weeks exercises were adapted to participants’ specific condition and needs under close supervision from responsible physical therapist. In addition assessment in (Shaarani et al., 2012) done at baseline, preoperatively, and 12 weeks postoperatively, while in this study the assessment was done 6 weeks preoperative (pre-test), 3 months postoperative (intermediate-test) and, 6 months after treatment program (post-test).

The results of current study showed that the 6 months postoperative exercise programs are efficient for good post-operative recovery, and this matched with previous programs in literature (Risberg & Holm, 2009) and (Wypych et al., 2021). The postoperative program in 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 (Cavanaugh & Powers, 2017). The post-test assessment of both groups showed significant improvement in all measured variables. At the same time at 3 and 6 months, participants that 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 (Alshewaier et al., 2017) and (Lobb et al., 2012). 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 (Lobb et al., 2012) and (Nelson et al., 2021).

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 (Wypych et al., 2021). In agreement with the greater improvement in KOOS all subscales in current study for participants that received Prehabilitation and 6 months postoperative rehabilitation some authors applied progressive pre- and postoperative rehabilitation. They take 2 year postoperative participant-reported outcomes and found that superior participant-reported outcomes both preoperatively and 2 year postoperatively (Grindem et al., 2015). The global function in current study measured by VAS scale that was proved to be valid reliable (Risberg & Holm, 2009). The improvement in global function after prehabilitation and postoperative training is supported by previous clinical studies (Risberg & Holm, 2009). Some

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authors found significant improvement knee global function measured by VAS after 6 months of neuromuscular exercises (Risberg & Holm, 2009).

- **Limitations of this study were:**
  - The small number of participants,
  - Short time of rehabilitation,
  - Another limitation is the lack of KOOS evaluation early after injury,
  - Expenses for surgery
  - Rehabilitation for 6 weeks after injury and 6 months after surgery,

- **Strengths of this study were:**
  - The application of similar inclusion and exclusion criteria to both groups for a homogeneous comparison,
  - Use of criterion-based postoperative rehabilitation.

- **Recommendation**
  Future studies should use the randomized controlled trial study design to better assess the value of preoperative rehabilitation directly after an ACL rupture.

### V- CONCLUSION

The progressive pre- and postoperative rehabilitation program showed significant more improvement KOOS subscales, single leg hop test, and global function than only postoperative progressive rehabilitation after 3 months and 6 months in participants with ACLR.

### REFERENCES
