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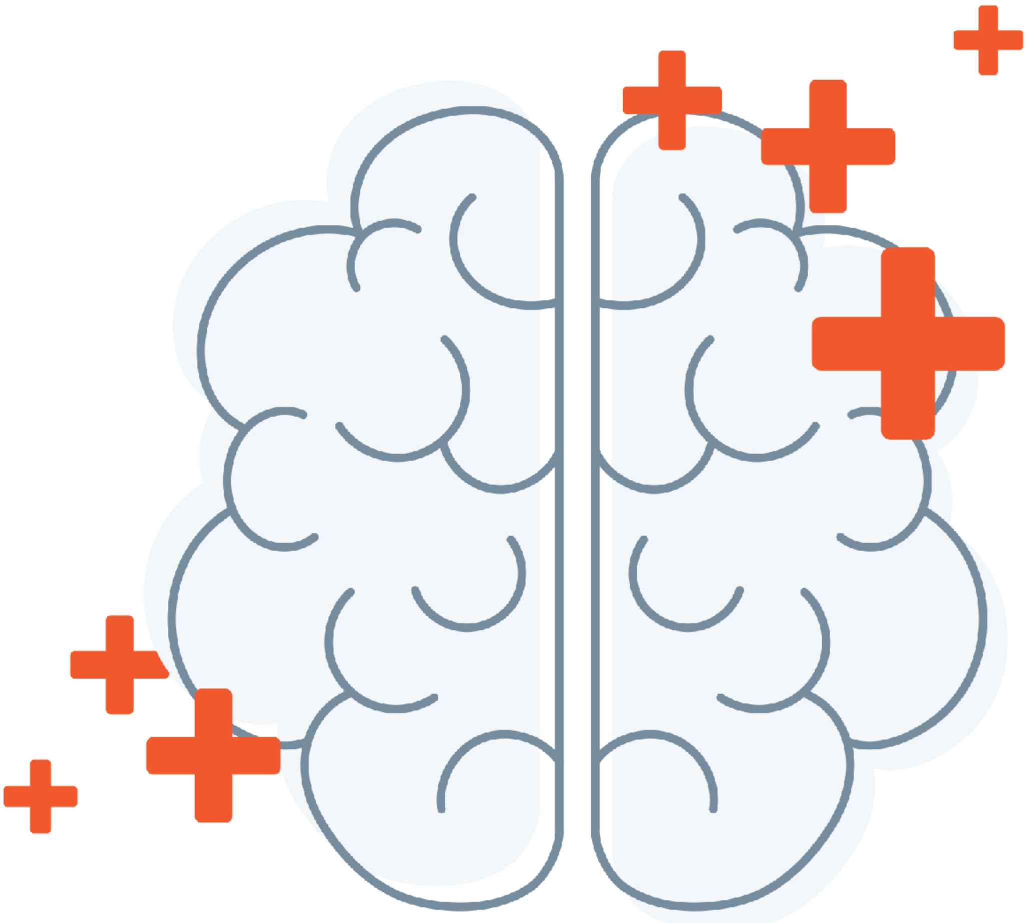

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Effects of both hip and traditional strengthening exercises on early outcomes post anterior cruciate ligament reconstruction

Wpływ ćwiczeń wzmacniających biodra i tradycyjnych ćwiczeń wzmacniających na wczesne wyniki po rekonstrukcji więzadła krzyżowego przedniego

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Abstract
Background. Lower extremity muscles weakness occur after the reconstruction of the anterior cruciate ligament (ACLR), specifically the hip muscles. The literature suggests that decreased hip strength which results from ACLR can lead to biomechanical changes in lower extremity. Objective. The aim of the current study was to assess effects of adding hip strengthening exercises with traditional strengthening exercises on early outcomes after ACLR. Materials and methods. Randomized controlled study was conducted on 50 male participants with primary unilateral ACLR, they were tested pre-operative and after 12 weeks postoperative; for pain intensity by visual analog scale (VAS), side to side difference knee extension limitation range of motion (ROM) by goniometer, and lower extremity function tests by side-to-side single-leg hop test and 10-yards test. They were assigned into two groups; group A (hip strengthening exercises with traditional strengthening exercises) and group B (traditional strengthening exercises only). Both groups received the treatment 3 sessions/week for 12 weeks. Results. The results of independent t-test showed that there were significant improvements ($p < 0.05$) in all variables (pain intensity, side to side difference knee extension limitation ROM, side-to-side single-leg hop test and 10-yards test) in both groups with superiority of group A. Conclusion. Adding of hip strengthening exercises to traditional strengthening exercises were effective on early outcomes post ACLR.

Keywords
ACLR, hip strengthening exercises, traditional strengthening exercises, single leg hop test, 10-yards test

Streszczenie
Wprowadzenie. Po rekonstrukcji więzadła krzyżowego przedniego (ACLR) dochodzi do osłabienia mięśni kończyn dolnych, a szczególnie mięśni bioder. Z piśmiennictwa wynika, że zmniejszenie siły stawu biodrowego po ACLR może prowadzić do zmian biomechanicznych w obrębie kończyny dolnej. Cel. Celem niniejszego badania była ocena wpływu wprowadzenia ćwiczeń wzmacniających staw biodrowy do tradycyjnych ćwiczeń wzmacniających na wczesne wyniki po rekonstrukcji więzadła krzyżowego przedniego. Materiał i metody. Randomizowane badanie kontrolowane przeprowadzono na 50 pacjentach płci męskiej po jednostronnej rekonstrukcji więzadła krzyżowego przedniego. Pacjenci zostali zbadani przed operacją i 12 tygodni po operacji; natężenie bólu zbadano za pomocą wizualnej skali analogowej (VAS), różnice między stronami, ograniczenie zakresu ruchu wyprostu kolana (ROM) za pomocą goniometru, a funkcje kończyn dolnych za pomocą testu podskoku na jednej nodze z boku na bok i testu na 9 metrów. Pacjenci zostali podzieleni na dwie grupy; grupa A (ćwiczenia wzmacniające biodra i tradycyjne ćwiczenia wzmacniające) i grupa B (tylko tradycyjne ćwiczenia wzmacniające). Obie grupy wykonywały ćwiczenia 3 sesje/tydzień przez 12 tygodni. Wyniki. Wyniki niezależnego testu t wykazały znaczną poprawę ($p < 0,05$) we wszystkich zmiennych (natężenie bólu, ograniczenie zakresu ruchu wyprostu w kolanie, test podskoku na jednej nodze z boku na bok i test na 9 metrów) w obu grupach z przewagą na korzyść grupy A. Wniosek. Dodanie ćwiczeń wzmacniających biodra do tradycyjnych ćwiczeń wzmacniających okazało się skuteczne w celu osiągnięcia poprawy wyników po rekonstrukcji więzadła krzyżowego przedniego.

Słowa kluczowe
ACLR, ćwiczenia wzmacniające biodra, tradycyjne ćwiczenia wzmacniające, test podskoku na jednej nodze, test 9 metrów

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Introduction

The utmost often injured knee ligament is the anterior cruciate ligament (ACL), with yearly prevalence rate of rupture estimated at 68.6 per 100,000 person-years [1]. The tibia and femur are connected by the ACL, which is important for knee stability. It generates around 85% of the entire force that opposes anterior tibial translation, plays a negligible part in opposing knee extension and hyperextension, and helps to maintain little medial and lateral tibial rotation [2].

About 70% of ACL injuries are related to non-contact injuries and the remaining 30% is contact trauma or sports. Dynamic knee valgus is a mechanism that contributes to non-contact injuries (tibial external rotation, knee valgus, and femoral internal rotation). It is believed that inadequate neuromuscular regulation of the hip and trunk muscles is the cause of dynamic knee valgus [3]. In one-leg stance, weak core and hip muscles (external rotators and abductors) can cause dynamic knee valgus, which raises the possibility of non-contact ACL rupture. An abrupt alteration in movement results in a significant amount of valgus stress, internal rotation, and anterior tibial displacement [4]. As a result, research showed that having a stable core and hip muscles is essential for preventing ACL injuries [3]. Static and dynamic instability of the knee can result from ligament injuries. The most frequent side effects following ACL damage and reconstruction are pain, edema, strength loss, decreased range of motion (ROM), diminished balance, and functional activity [5].

The standard course of treatment for ACL tear starts with RICE therapy, which stands for rest, ice, compression, and elevation. After that, a decision of non or operative treatment is required. The decision to operate is complex and is influenced by factors such as the patient's level of activity, age, severity of the injury, and the physician's experience [6]. For active individuals with ACL ruptures, early ACLR continues to be the gold standard. Regaining primary passive restraint, engaging in pre-injury activities, functioning at pre-injury levels, and maintaining long-term knee joint health are the objectives of ACLR. The prevention of post-traumatic knee osteoarthritis and a restoration to previous activities are not however, guaranteed by reconstruction [7].

The main limitations following an ACL injury are impaired strength and neuromuscular control of the lower limbs; as a result, these problems are frequently addressed during rehabilitation after the injury [8]. Sports and daily activities both demand coordinated neuromuscular control and muscles strength to carry out the necessary activities. With slow, progressive therapeutic exercises performed in a range of settings and situations, the rehabilitation program objectives are to attain full knee extension, reduce swelling and pain, normalize dynamic knee joint stability, and strengthen lower limb muscles [9, 10].

So as to decrease the danger of re-injury, lower limb strength is crucial. According to Grindem et al. [11], weak quadriceps prior to intenerating sport was a prognosticator of re-injury; for each 1% gain in strength, the rate of re-injury was reduced by 3%. According to Kyritsis et al. [12], those with a decreases hamstring to quadriceps strength ratio encountered a higher chance of re-injuring their ACL. Grindem et al. [11] also discovered a link amongst time from the operation and re-injury after ACLR, finding that 40% of patients who returned to sports before nine months had re-injuries, compared to 19% of those who did so after nine months. According to some reports, the amount of time after surgery is just a substitute for the additional time needed for a patient to address their strength deficiencies [13].

The lumbo-pelvic-hip complex often known as the core, is made up of the hip joint, which connects the upper thigh, pelvic, and abdominal muscles. The role of the hip or core is to position control of the trunk and the pelvis over lower limbs [14]. The role of core stability exercises in the prevention of injuries to the lower limbs is well established. Core stability is believed to be critical to athletes who had ACLR to recover more quickly and effectively [15]. In pivoting sports such as football, hip and core stability become more crucial since they can support the trunk during abrupt changes in position [16]. Hip abduction strength and knee valgus had a negative correlation, and neuromuscular impairments at the hip and trunk were directly correlated with a greater risk of ACL injury [17, 18].

Therefore, hip and core weakness might result from ACL deficit. In a study by Werner and Barrios [19], it was found that patients still had weaker hips and core muscles than healthy patients, even after ACLR. As a result, the ACL rehabilitation program must include hip and core stability exercises [15]. ACLR patients ambulate with reduced hip and knee joint movements. The changed kinematic patterns may result in abnormal knee joint stress throughout activities of daily living as walking [20].

A Few researches studied particular hip strengthening exercises in postoperative rehabilitation of ACL patient. Therefore, the current study was designed to examine the effect of adding hip strengthen exercises to traditional strengthen program on pain intensity, side to side difference knee extension limitation ROM, side-to-side single-leg hop test and 10-yards test post ACLR.

Subjects and Methods

Study design

A single blinded randomized controlled study was conducted on patients with ACLR from May 2020 to February 2022. The current study was accepted and approved by the institutional review board of faculty of medicine, Zagazig university hospital number (ZU IRB # 9728-1-3-2022).

Participants

Fifty male participants underwent primary, unilateral ACLR with semitendinosus-gracilis graft were referred to outpatient clinic of physical therapy by orthopedic surgeons in the first week (1–5 days) post-operative. Their age was ranged from 18 to 45 years old. They were physically or recreationally active for at least three times a week for three months. Subjects were excluded from the study if they demonstrated any history of chondral defect requiring surgical intervention, neurological diseases, previous surgery in either limb or degeneration so as not to affect the baseline data [21] [22]. Participants were assigned equally and randomly into two groups; group (A) hip

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strengthening with traditional strengthening exercises, group (B) traditional strengthening exercises only. All participants were informed of the purpose of the study and signed a consent form.

Assessment Procedures

All participants were assessed for pain severity, side to side difference, knee extension limitation ROM, contralateral limb single hop test and 10-yard test. The measurements were collected before operation, and after 12 weeks postoperative [15].

Intensity of pain

The pain was measured by visual analog scale (VAS). VAS was valid and reliable for assessing pain sensitivity. It consists of a straight line 10 cm long with endpoints that set maximum limits such as "no pain at all" at zero on the left side and "maximum pain" at 10 degrees on the right side. Participants were asked to indicate on scale the degree of knee pain during and after activities of daily living [23, 24].

ROM of knee extension

The knee extension ROM was measured using the universal plastic goniometer scale. The participant was in a supine position with both knees in extension. The axis of the goniometer was placed in the center of the knee. The fixed arm was parallel to the femur shaft while the moving arm was parallel to the fibula shaft. The participant was instructed to actively tighten the quadruple thigh muscles and push his knee as far down as possible. The difference from side to side and the measurements were taken three times and the average was taken. The goniometer scale of knee ROM was found to have a correlation coefficient value of 0.98 for intra-tester and 0.99 for inter-tester reliability [24].

Lower extremity functional tests

Single-leg hop test

This test which has been used to examine objective performance or restore muscle strength in patients or athletes, is one of the valid and reliable functional tests for evaluating the knee. It is believed that this examination is a key factor in determining whether an ACLR patient will successfully resume daily activities [25-27]. The participant was asked to stand behind a line, put both hands behind his back, maintain the position of one leg, jump as much as possible, and land on the same foot. A maximum jump record was taken for each subject individually after repeating the test three times per foot, measuring the distance from the tip of the toe in the starting line to the base of the toe after landing [28]. Distances were measured in centimeters per leg, side to side differences in performance between injured and uninjured legs, single hop test jump distance of contralateral limb were measured postoperatively after 12 weeks and only healthy side was measured immediately post operatively [15].

10-yards test

The test consists of two parallel lines (A and B), the distance between the two lines is equal to 10 yards, and the subject sprinted 10 meters forward from line A to line B and returned to line A. Then participant was side sprinted line B then back to line A. After this, subject shuffled to line B and back to line A. Finally, they sprinted across line B. The person was instructed to make sure that his foot touched each line. According to reports, the average time records for this test for males is 17–20 seconds, while for females, it is 19–23 seconds [28, 29].

Treatment program

Participants in both groups received three sessions per week for 12 weeks, each session lasted one hour, and each participant was guided to a daily home exercise program. The strengthening program for both groups was divided into two phases, phase 1 (0-8) weeks with the main goals were to reduce pain, swelling and inflammation caused by surgery and increase the knee ROM (0–100°) or normalize the ROM to reach the full flexion and extension, increase muscle strength, withstand the permissible weight as before, and the knee in a brace with full flexion and extension as allowed. Phase 2 (8–12) weeks with aim to return to daily and sports activities, continue all exercises besides climbing stairs, walking backwards, running, and increasing running speed and weights during strengthening exercises. The transition to the second phase depends on the participant's endurance and ability to perform correctly [21, 23, 30].

Group (A)

Hip strengthening exercises with traditional strengthening exercises

Consisted of 25 participants who received hip strengthening exercises in phase 1 in the form of hip abduction (from side lying and standing), hip extension from prone, leg bridges (double and single), side bridge, and quadruped arm/lower limb lift [21]. In addition to the hip exercises the participant received traditional strengthening exercises in the form of heel slides, patellar mobilizations, quadriceps isometric contraction, hamstring isometric contraction, gastrocnemius stretch, straight leg raise, mini-squats, short arc exercises, single leg balance, leg dead lift (double and single), and leg press.

When participant reach full ROM of knee, perform four sets of 20 repetitions of straight leg raising with full extension, and maintain one-minute single leg balance on a solid surface with the affected side, subject can transfer to phase 2 which include progression of phase 1 exercises with increase repetition in addition to the progression of shuttle, lunge, balance, setup exercises and return to daily living activities [23, 30].

Group (B)

Traditional strengthening exercises only

Consisted of 25 participants who received same traditional strengthening exercises of group A in phases (1 and 2) but without hip strengthening exercises, especially first eight weeks, but they were allowed to start performing exercises as part of their program after eight weeks.

Sample size

All subjects with ACL injury needing reconstruction have been admitted to the orthopedic department and after ACLR they referred to physical therapy outpatient clinic during the period from May 2020 to Feb 2022 were enrolled in the study. The

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total number during this period was 53. Three participants were excluded from the study, making the sample of 50 randomly divided into two groups, 25 subjects within each group as in figure (1).

Randomization
Was done by using a computer-generated randomization card. A blind and independent research assistant opened sealed envelopes containing the cards was used [21].

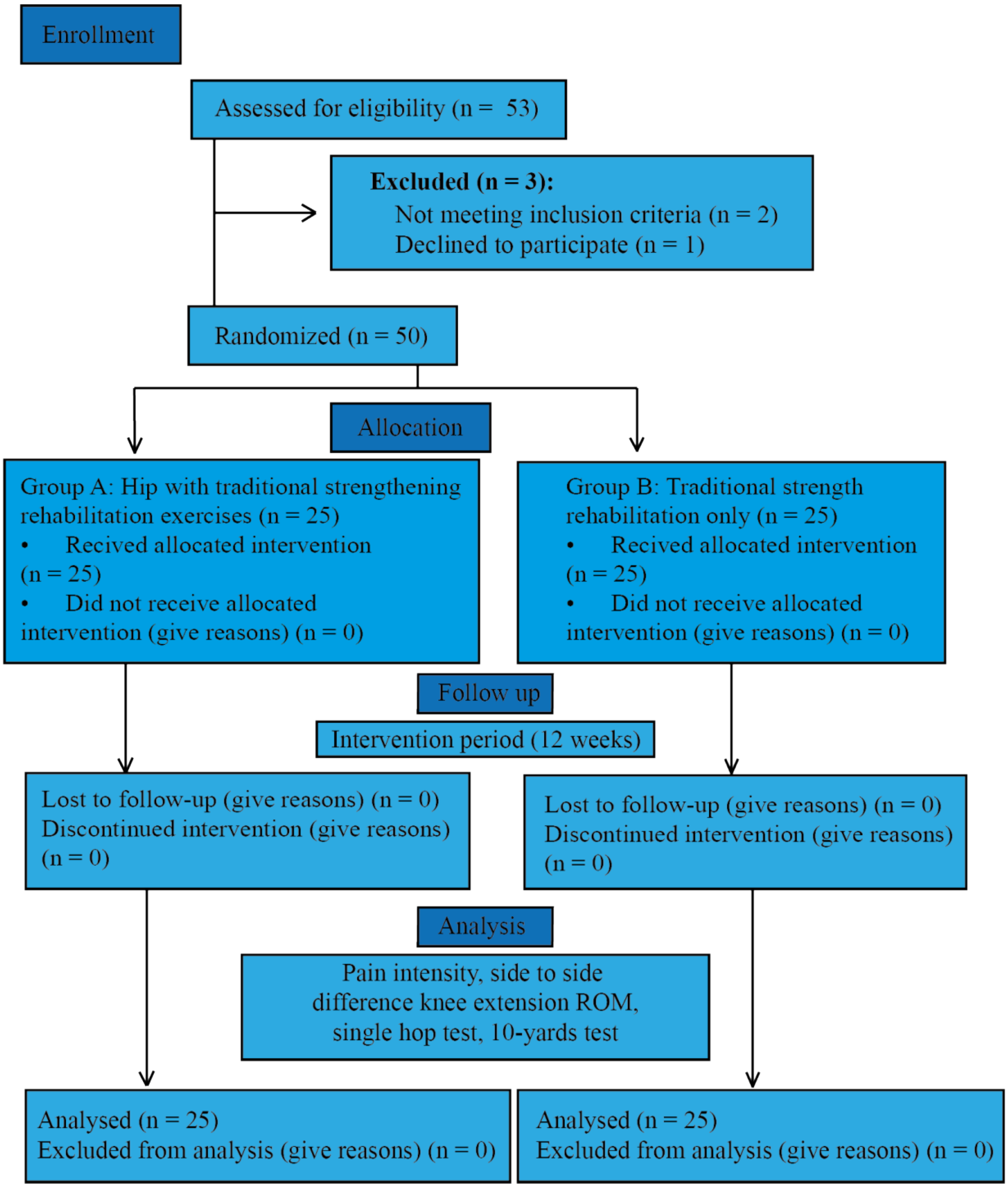

Figure 1. Subjects assessment flowchart throughout the study

Data analysis
The statistical package for social studies (SPSS) version 22 for windows (IBM SPSS, Chicago, IL, USA) was used to conduct the statistical analyses. Mean and standard deviation were used to express the data from the two groups. Paired t-test was used to compare the within group differences which had two levels (pre and post). The differences between the group's demographic data, baseline, and 12 weeks' results were determined using an independent t-test. Results are considered significant when a P value equals 0.05 or less for comparing between before and after intervention within and between groups. The data were collected in the same sequence and procedures for all subjects.

Results

Demographic data
There was no significant difference in demographic data among the two groups in age, height, weight and BMI ($p > 0.05$) as displayed in the table (1).

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Table 1. Demographic data of subjects

	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 [left/right]	20/5	23/2	

SD: Standard deviation; p-value: probability value; significance level (p < 0.05)

Within group (Intragroup) comparison
Post-operative and after 12 weeks of treatment the mean values within each group revealed a significant decrease in pain intensity, side-to-side knee extension limitation of ROM, side-to-side single leg hop test differences and 10-yard test, As regard difference between pre- and post-treatment in group (A), there was a significant differences in all variables (($p < 0.05$). Also in group (B) there was a significant decrease and differences in all variables between pre- and post-treatment (($p < 0.05$) (Tables 2).

Between groups (intergroup) comparison
At pre-operative and at the baseline assessment, results showed a non-significant difference in all measured variables regarding to pain, side-to-side knee extension limitation ROM, single leg hop test of healthy side and 10-yard test as in table (2), ($p > 0.05$) (Table 2). Post-treatment also between groups differences revealed significant differences in all variables with superior to group A (hip strengthen exercises with traditional strengthen exercises) compared with group B (traditional strengthen exercises only) where P-value was < 0.05 as in table (2).

Table 2. Within and between groups comparison

Variables		Group (A), (n = 25) Mean ± SD	Group (B), (n = 25) Mean ± SD	P-value
Pain [VAS]	Pre	6.44 ± 1.15	6.64 ± 1.42	0.58
	Post	2.14 ± 0.78	3.68 ± 1.11	0.00
	p-value	0.00	0.00	
Knee extension ROM [degree]	Pre	9.68 ± 2.51	9.02 ± 2.71	0.38
	Post	3.72 ±.84	4.34 ± 1.05	0.024
	p-value	0.00	0.00	
Single leg hop test [cm]	Pre	87.58 ± 19.87	83.44 ± 19.74	0.46
	Post	55.32 ± 12	66.28 ± 17.18	0.012
	p-value	0.00	0.00	
10 yards [17–20 second]	Pre	33.2 ± 4.93	33.12 ± 5.01	0.95
	Post	22 ± 3.27	25.84 ± 3.23	0.00
	p-value	0.00	0.00	

SD: Standard deviation, p: probability value, significance level (p < 0.05)

Discussion

In the current study, it was found that the adding of hip strengthening exercises to traditional strengthening exercises post ACLR was related to greater function outcomes and high rate of return to daily activities. Although the impact of hip strengthening exercises on functional outcomes following ACLR has not been well established.

In the present study following ACLR patients demonstrated high pain level, limitation of knee extension ROM, inability to perform single leg hop test and lower degree of 10-yards test. The success of ACLR involves more than just placing grafts in their proper anatomical locations; but also involves assisting patients in succeeding in the activities they need. No differences were seen between groups in pain intensity, side to side knee extension limitation of ROM, single leg hop test and 10-yards test before operation. Because no exercises were performed before operation, any improvements in hip strengthen or traditional strengthen exercises groups are due to the effect of interventions. Following the intervention, the participants demonstrated great improvements in all variables favoring group (A), which were accompanied by decreased in functional disability and improvements in subject-reported knee outcomes. There were also no adversative effects during the training. These results suggest that combining both strengthening exercises is a safe and effective way to increase knee strength and function.

According to the study's findings, both hip and traditional strengthen groups experienced significant pain decrease after three months of training, which swelling and pain result in reduction of quadriceps strength, restriction of ROM, thro-

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ugh muscle inhibition. Additionally, patients with knee pain have shown abnormal knee kinematics or weakening in the gluteal muscles, both of which may be contributing factors [31-33]. The results are supported by a study of Garrison et al [21] who examined the special effects of 12 weeks of specific hip strengthening exercises and discovered that both groups experienced positive outcomes, particularly the hip group, which outperformed the conventional exercises group regarding of pain levels during activities.

In addition, these finding are consistent with Cooper et al [34] who in excess of the course of a 6-week intervention, compared the effect of traditional strengthening exercises and neuromuscular training exercises program. After surgery, the participants were included for follow-up 4 to 14 weeks later. The authors reported better outcomes, but the follow-up pain and hop tests revealed no changes between the two groups. However, compared to the neuromuscular training group, the strength training group experienced reduced swelling, pain, and improved walking and squatting. In a study completed by Risberg et al. [35], after six months of intervention, they used the VAS to quantify pain and found a significant improvement. There were also no statistically significant differences between the standard group, who received traditional strength training, and the neuromuscular training group for balance and proprioception.

The results of the current study supported the effectiveness of traditional strengthening exercises after ACLR, either alone or in combination with hip strengthening exercises in knee extension ROM. These findings agreed with Adams et al. [36] in that traditional strengthening exercises are necessary to enhance knee ROM and function. These findings supported research by Garrison et al. [21], who examined the effects of including isolated hip strengthening exercises in traditional strengthening on early outcomes after ACLR. They discovered a significant improvement in knee ROM differences side by side in both groups as well as a significant difference between the groups after three months. Risberg and Holm [23] who compared the long-term results of a 6-month neuromuscular exercise training program with a traditional strength training program after ACLR concluded that both training programs generated long-term equivalent improvements to knee extension, muscle strength and knee performance (single legged hop test). Also, Risberg et al. [35] compared between neuromuscular and strength exercises after ACLR and found that both interventions improve knee flexion, extension and functional performance.

Current study's findings come in accordance with Holm et al. [37] who examined at how knee motion, proprioception, and function were affected by traditional and neuromuscular training. They came to the conclusion that there were no variations in static balance and that knee dynamic motion balance had significantly improved. This is understandable given that after ACLR, the most common issues are related to endurance, muscle strength, and optimal biomechanical movement pattern, all of which can be improved by supplementing rehabilitative exercises with traditional strengthening and neuromuscular training [38]. Williams et al. [39] and research by Palmier-Smith et al. [40] found a residual deficit in the strength of the quadriceps muscles by 10% to 27%, 12 months after ACLR, while 10 other studies reported a deficit in knee extensor muscle strength, ranging from 24% to 40.5%, six months after ACLR. Delaloye et al. [41] showed in their study that the most important indicator of cyclops ACLR syndrome in a large group of patients was the inability to restore full knee extension in the early postoperative phase. Other previously proposed risk variants, such as maintaining large ACL residues, were insufficient to increase the likelihood of developing these severe postoperative complications.

Additional essential part of this study was the outcome of hip strengthening which is a part of core stability exercises may indirectly contribute to pain relief, the restoration of knee extension range of motion (10 yards), improved proximal stability for distal mobility, and the improvement of movement efficiency, all of which are necessary during single-leg or limb activities, particularly with long periods of rehabilitation [21. 27, 42]. In the current study, single leg hop test was improved in both groups and perceived to be superior in participants who underwent a hip strengthening exercises. The findings are in line with those of Gupta et al. [15], who investigated the early outcomes of adding core stability exercise to conventional rehabilitation for three months. They discovered that participants who underwent core stability or hip strengthening programs performed better on the single leg hop test.

Risberg et al. [35] evaluated hop tests and found significant improvement in both groups (traditional strength and neuromuscular group). Additionally, Gholami et al. [28] employed the single-leg hop test in their study to assess the subjects' functional state. In accordance with their findings, kinesio tape was applied after ACLR in order to increase test scores in immediate phase assessments (10 minutes after baseline) and short-term phase (2 days after baseline), which were used to evaluate the subject's single-legged hop test. Their research found that reducing pain and increasing the deep sense of the joints increased the score of the single-legged jump test. Furthermore, Herrington et al. [43] found that the single-legged hop test in healthy people did not have a significant effect when applying patellar stripe after ACLR. The reason for their results is attributed to the state of health of people. Therefore, there may not be pain that the tape reduces and improves the test of one leg hop.

Participants' performance on the 10-yard test considerably improved in both groups after hip strengthening and traditional strengthening exercises, demonstrating a significant difference between the two groups. The findings of the current study were also consistent with those of the study by Gholami et al. [28], which revealed no significant differences between groups following ACLR and reported a significant effect of kinesio taping and placebo on 10-yards. The results of the 10-yard lower extremity test, which was used to assess the agility of the subjects or athletes, revealed that both the treatment (kinensio taping and placebo) and control groups saw a decline in test outcomes throughout the course of the intervention. Since the 10-yard lower limb test score represents the amount of time needed to complete the test in seconds, a decrease in this score indicates progress.

The current study found improvement in all variables within

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12 weeks due to interventions as Dai Sugimoto et al. [44] studied restoring lower limb strength and function after ACLR in structurally immature patients and came to the conclusion that after about seven months of ACLR, approximately 3/4 of the patients achieved > 90% of the quadriceps, hip abductor, hip extensor strength, but not hamstring strength, while more than 4/5 of the patients achieved > 90% in the Y balance test. Injuries to the lower extremities caused by sprains and strains were not associated with the power of hip abduction, according to a study by Abdullah et al. [45], although 56% of injuries were ankle sprains, this study did not focus specifically on knee injuries. Thus, a knee-specific analysis of data from our previous investigation could indicate the involvement of hip abductor force in knee injury. Unfortunately, it was not implemented.

The current study was delimited to small sample size and to male participants therefore, the results cannot be generalized to other gender. There was short follow-up period, and the results could be influenced by other aspects besides strength training within the rehabilitation of ACLR. Future studies are recommended including both gender and long duration of follow up.

Conclusions

Both hip strengthening with traditional strengthening exercises and traditional strengthening exercises only are effective training to improve measurements of early outcomes such as pain reduction, knee extension ROM, single leg jump test, and 10-yard lower limb test, and there was a significant difference between groups that preferred the hip strengthening after ACLR.

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