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# EFFECTIVENESS OF ECCENTRIC ORIENTED STRENGTH TRAINING VERSUS PLYOMETRIC TRAINING FOR POST ACL RECONSTRUCTION ON RETURN TO SPORTS IN FOOTBALL PLAYERS

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## INTRODUCTION

ACL reconstruction current concepts the first described surgical treatment of an anterior cruciate ligament (ACL) injury was an anatomic repair performed in 1895 by Mayo-Robson of Leeds, UK [1]. In 1917, Hey Groves of Bristol, UK, performed the first anterior cruciate ligament reconstruction (ACLR)[2] and since then surgeons have used a variety of intraarticular and extra-articular procedures to restore stability to the injured knee [1]. Over this time, debate has revolved around the ideal graft choice, open versus arthroscopic, tunnel placement, graft fixation method, and more recently extra-articular augmentation [3–5] of an intra-articular graft [6,7]. The anterior cruciate ligament (ACL) is a ligament responsible for knee stability primarily by restricting anterior translation of the tibia but also limiting knee joint medial and lateral rotation. Ligament is heavily engaged in activities including deceleration, change of direction, and/or jump landing actions—all movements that team sports like basketball, soccer, and handball are well saturated with. Consequently, ACL injuries are frequent in team sport athletes for both men and women [1], followed by surgical reconstruction and a prolonged period of rehabilitation.

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The rehabilitation process is long and multifactorial, with return to sport (RTS), defined as a return to unrestricted training or competition, generally acknowledged as the primary Outcome for athletes [2]. Although the time frame from surgery was traditionally used as the main criteria to establish whether an athlete is ready for RTS, a shift towards comprehensive functional testing has dominated in recent years [3]. ACL injury has a detrimental impact on fitness attributes, with deficits in strength, reactive strength, and power commonly reported [4]. Consequently, RTS testing typically relies on strength and power assessment, with a battery of tests to assess strength/power capacity but also symmetry between Limbs [5]. The most common functional performance outcomes are lower body strength (isokinetic or isometric), single-leg hop, single-leg triple hop, single-leg triple crossover Hop [6], and recently, vertical jump [7].

Anterior cruciate ligament (ACL) injury is one of the most Common knee injuries in sports medicine, typically requiring Surgical reconstruction to restore knee joint stability.[1] Despite

Continuous advancements in ACL reconstruction (ACLR) Surgical techniques, post-operative rehabilitation continues to Face significant challenges, including muscle atrophy, impaired

Neuromuscular control and decreased functional mobility.[2] Collectively, these factors contribute to low return-to-sport Rates and a high risk of re-injury.[3] The restoration of

Neuromuscular function is considered a core objective of rehabilitation, as it directly influences dynamic joint stability and athletic performance.[4]

However, conventional Rehabilitation protocols often emphasise linear movement Patterns and muscle strength recovery while neglecting Multidirectional dynamic stability and power training, which May lead to inadequate neuromuscular adaptations.[5] Current ACLR postoperative rehabilitation protocols primarily Include progressive resistance training, balance training and Flexibility exercises.[6] Although these methods are effective In improving fundamental muscle strength and static balance, they exhibit limitations in restoring the neuromuscular control Required for complex movements [7]

This is particularly evident During the advanced stages of return-to-sport, were patients Need to regain the ability to perform high-risk maneuvers Such as jumping and cutting, an aspect inadequately addressed by traditional rehabilitation.[8] Consequently, exploring Innovative training methods capable of effectively enhancing Neuromuscular function is crucial.

**General anatomical characteristics**

As a broad definition, the ACL has been described as a single structure connecting the tibial and femoral joint.[5] It originates at the tibial plateau, anterior to and between the intercondylar eminences and continues posteriorly to attach to the posteromedial portion of the lateral femoral

condyle.[6,7]The ACL has its own synovial membrane but is still considered an intra-articular structure.6 Characterized by its singularity, the ACL is immanently subject to both anatomic and morphological variations as well as physiological aging.[8,9]

At first, the ACL was viewed as a single homogenous structure. In 1938, Ivar Palmer made the first description of the two-bundle ACL.[11] However, this double bundle description

was not well known for several decades.[1] These two bundles are classically defined as the anteromedial (AM) and posterolateral (PL) bundles.[5,6,10] They are often distinguished by a tissue sheath between the bundles and the disparate locations of their insertion sites.[5] Both bundles are named according to their relative attachments on the tibia. Specifically, the medial and lateral intercondylar tubercles of the tibia have been described as the distal attachment sites for both ACL bundles. The existence of the anteromedial and posterolateral bundles of the ACL is broadly accepted, recent research findings suggest that the ACL is a triple-bundle structure.[4---6,10,12] In those studies, the bundles have usually been defined as anteromedial, intermediate, and posterolateral bundles. Previous research has found that up to 26% of knees have a single bundle[12] whilst Mac Kay et al.23 results showed an intermediate bundle was found by means of magnetic resonance imaging (MRI) visualization in approximately20% of 73 patients.5 However, several studies were unable(anatomically or histologically) to confirm the presence of distinct intermediate bundle in human specimens.[12]

ACL length

Anatomic studies of the ACL and its bundles have shown that the ACL length ranges from 27 to 38 mm in length (a length that may vary depending on the position of the knee) and 10---12 mm in width, whereas the anteromedial and posterolateral bundles range from 6 to 7 mm and 5 to 6 mm in width, respectively.[1,6,8,13]

Biomechanics

Functionally, the ACL serves several purposes. It prevents anterior translation of the tibia on the femur, acts as a secondary stabilizer against the internal rotation of the tibial and valgus angulation of the knee. It sustains normal biomechanical knee motion to prevent meniscal damage. The two bundles that comprise the ACL have unique functions that allow for the ACL's normal biomechanics. The anteromedial bundle is tight in flexion, whereas the posterolateral bundle is tight in extension.6 The anatomical and biomechanical properties of the intermediate bundle are similar to that of the AM bundle.1In full extension, the ACL absorbs 75% of the anterior translation load and 85% between 30 and 90 degrees of flexion. Loss of the ACL leads to a decreased magnitude of this coupled rotation during flexion and an unstable knee. The average tensile strength of the ACL is ~2200 N but is altered with age and repetitive loads.

Symptoms

Signs and symptoms of an ACL injury usually include:

- A loud pop or a "popping" sensation in the knee
- Severe pain and inability to continue activity
- Rapid swelling
- Loss of range of motion
- A feeling of instability or "giving way" with weight bearing

**Grades of ACL Injury**

**Grade 1 (Mild):** The ligament is mildly stretched but remains intact, allowing it to hold the knee joint stable.
**Grade 2 (Moderate):** The ligament is stretched and partially torn, causing it to become loose.
**Grade 3 (Severe):** The ligament is completely torn into two separate pieces, resulting in an unstable knee joint.

Surgical goal in ACL anatomic reconstruction is to mimic native ligament anatomy as closely as possible to recover the function of the knee. That means restoring the native dimensions, collagen orientation and insertion sites.[9,19]

**Anatomic ACL reconstruction is based on four fundamental principles:**

I. Restoring the anteromedial and posterolateral bundles.
II. Restoring the native ACL insertion sites by aligning the tunnels in proper anatomic positions.
III. Correctly tension each bundle; and
IV. (4) adapting the reconstruction to each patient by ensuring that tunnel diameter and graft size are determined in accordance with the characteristics of their native insertion sites.[1]

ACL injury has a detrimental impact on fitness attributes, with deficits in strength, reactive strength, and power commonly reported [4]. Consequently, RTS testing typically relies on strength and power assessment, with a battery of tests to assess strength/power capacity but also symmetry between limbs [5]. The most common functional performance outcomes are lower body strength(isokinetic or isometric), single-leg hop, single-leg triple hop, single-leg triple crossover hop [6], and recently, vertical jump [The rehabilitation process is long and multifactorial, with return to sport (RTS), defined as a return to unrestricted training or competition, generally acknowledged as the primary outcome for athletes [2]. Although the time frame from surgery was traditionally used as the main criteria to establish whether an athlete is ready for RTS, a shift towards comprehensive functional testing has dominated in recent years [3]. ACL injury has a detrimental impact on fitness attributes, with deficits in strength, reactive strength, and power commonly reported [4]. Consequently, RTS testing typically relies on strength and power assessment, with a battery of tests to assess strength/power capacity but also symmetry between limbs [5]. The most common functional performance outcomes are lower body strength (isokinetic or isometric), single-leg hop, single-leg triple hop, single-leg triple crossover hop [6], and recently, vertical jump [7].

Plyometric training

Plyometric training, a regimen emphasizing the rapid stretch-shortening cycle (SSC), enhances muscle power and reactivity by activating the neuromuscular system.[9,10] In ACLR rehabilitation, plyometric training may optimize dynamic joint stability by improving central neural drive, motor unit synchronization and muscle-tendon stiffness.[11] However, existing research on plyometric training post ACLR predominantly focuses on isolated outcome measures (such as lower limb symmetry or jump distance), lacking a systematic evaluation of its multidimensional effects on integrated neuromuscular function.[12-14] Furthermore, the differential effects of introducing plyometric training at various recovery stages have not been analyzed, limiting the precision of clinical decision-making.[15]

Eccentric oriented training

In this context, eccentric training has emerged lately. It has been reported that eccentric overload exercises could optimize muscle fiber length [14], add sarcomeres in series [15], and increase pen nation angle [16], consequently optimizing muscle hypertrophy and strength [17]. Several [18,19] but not all [20,21] studies reported eccentric training to be superior to traditional strength training for muscle mass, strength, and functional performance gains. In addition, eccentric strength training gains could also be specific to the training modality without functional improvements [22]. It has been reported [23] that 8 weeks of eccentric exercise with an uninjured limb promotes reduced neural activity in the frontal cortex with increased corticospinal and spinal reflex excitability, likely resulting in larger acute and chronic strength gains and muscle activity in the untrained (injured) limb [24]. Taken all together, eccentric-oriented training seems to be a promising tool to beneficially remodel both peripheral and central neural activity [25], enhance neuromuscular control, and likely reduce the incidence of injury the effects of eccentric-oriented training protocols have been studied sparsely in the ACL-reconstructed population, with contradictory study findings. Lepley et al. [26,27] reported that 6 weeks of eccentric training produced large gains in quadriceps strength but not sagittal plane knee kinematics in early-stage non-athletic ACL patients.

**Friedman-Bette et al.'s [28]** study results showed that a 12-week eccentric training program (24 sessions in total) leads to superior quadriceps hypertrophy than conventional strength training in a sample of 37 recreational athletes. Finally, an 8-week eccentric bicycle training program was found to be like concentric training in improving knee flexion angle, strength, and patient reported outcomes in early-stage ACL patients [30]. Even less data, considering eccentric-oriented training effectiveness, is available when mid- and last-stage ACL-rehab periods are targeted.

**Kami et al.** [31] examined the effects of eccentric training, plyometric training, and eccentric/plyometric training on dynamic balance, the Lysholm knee scale, and the single leg hop test in 40 elite female athletes following ACL reconstruction.

**AIM OF THE STUDY:**

The aim of the study is to find out the effectiveness of Eccentric oriented strength training versus plyometric training for post Acl reconstruction on return to sports in football players

**OBJECTIVES OF THE STUDY:**

The objective of the study is to evaluate the effectiveness of Eccentric oriented strength training versus plyometric training for post acl reconstruction on return to sports in football players

- To find the effectiveness of Eccentric oriented strength training for post Acl reconstruction on return to sports in football players
- To find the effectiveness of plyometric training for post Acl reconstruction on return to sports in football players
- To comparing effectiveness of Eccentric oriented strength training versus plyometric training for post Acl reconstruction on return to sports in football players

**BACKGROUND OF THE STUDY**

An effective post-injury training program is essential to regain performance and fulfill criteria for return to sport for team sport athletes following anterior cruciate ligament (ACL) reconstruction. The aim of this study was to compare the effects of 8 weeks of eccentric-oriented strength training vs. Plyometric training during the late-stage ACL-rehab phase on leg strength and vertical and horizontal jumping performance in professional team sport athletes. The standard method to treat physically active patients with anterior cruciate ligament (ACL) rupture is ligament reconstruction surgery. The rehabilitation training program is very important to improve functional performance in recreational athletes following ACL reconstruction.

**Granacher, U.; et al.** The Effects of Eccentric and Plyometric Training Programs and Their

Combination on Stability and the Functional Performance in the Post-ACL-Surgical Rehabilitation Period of Elite Female Athletes. Front. Physiol. 2021,

**Lepley et al.** [26,27] reported that 6 weeks of eccentric training produced large gains in quadriceps strength but not sagittal plane knee kinematics in early-stage non-athletic ACL patients.

**NEED OF THE STUDY**

Despite the benefits of both training methods, there is still limited evidence comparing the **relative effectiveness of eccentric-oriented strength training versus plyometric training** in facilitating safe and efficient return to sport in football players following ACL reconstruction. Some studies suggest that eccentric-based programs produce greater improvements in strength and hop performance, while others indicate that combining eccentric and plyometric exercises may lead to better functional outcomes and psychological readiness for return to sport.

**METHODOLOGY**

- Study design : Experimental study
- Study type : comparative study
- Sampling method : Random Sampling

- Simple size : 30
- Study duration : 8 weeks
- Study setting : Rv physiotherapy rehabilitation centre & ishari velan mission hospital

**INCLUSION CRITERIA**

- Age group is between 18 to 30 years
- Both males and females included
- Female athletes who performed systematic sports practice
- On average, athletes exercised between six and eight times per Week
- including competition.
- Athletes with non-contact ACL injury during sporting activity

(training and/or competition).

**EXCLUSION CRITERIA**

- Recreational athlete or untrained individual
- athletes with less than five training sessions per week
- ACL injury caused by contact
- Athletes who were operated with techniques other than the bone patellar-tendon, bone graft (BPTB), or who were operated by different surgeons and rehabilitated by several physical therapists
- Athletes with a history of muscle or joint injuries
- Athletes who had already followed a pre-operative rehabilitation program
- Athletes with complications after surgery

**OUTCOME MEASURES**

I. Y balance test
II. Lysholm knee scale
III. Vertical jump test

**Y- BALANCE TEST**

- **Setup:** The subject stands barefoot on a single leg on the central plate of the YBT kit, with their toes behind the red starting line.
- **Practice:** Perform 4–6 practice trials in each direction for both limbs.
- **Testing Order:** Perform three trials for each direction: Right Anterior (ANT), Left ANT, Right Posteromedial (PM), Left PM, Right Posterolateral (PL), and Left PL.
- **Movement:** While maintaining a single-leg stance, push the indicator with the toes as far as possible, lightly touching it.
- **Return:** Return to the starting position without touching the ground for balance or lifting the standing heel.
- **Measurement:** Record the distance where the box was pushed.
- **Calculation:** The best of the three successful trials is recorded.
- **Normalized Score: sum of 3 directions divided by 3 times the limb length then multiply by hundred**

**LYSHOLM KNEE SCORING**: The 100-point scale is weighed across eight categories:

- **Instability (25 points):** Giving way sensation.
- **Pain (25 points):** Severity and frequency.
- **Locking (15 points):** Catching or locking sensations.
- **Stair Climbing (10 points):** Difficulty level.
- **Swelling (10 points):** Oedema.
- **Support (5 points):** Use of canes or crutches.
- **Limp (5 points):** Walking impairment.
- **Squatting (5 points):** Ability to squat.

**VERTICAL JUMP**

- **Position:** Stand roughly an elbow's width away from the wall.
- **Movement:** Use a countermovement (dip) to bend the knees and swing the arms, followed immediately by a maximum vertical jump.
- **Marking:** Reach up at the peak of the jump to touch the highest possible flag on the Vertec or mark the wall with chalk.
- **Landing:** Land on both feet, preferably in the same spot, without taking extra steps.
- **Trials:** Perform three to five trials to get the highest possible score.

**PROCEDURE**

The training period was 8 weeks long, with training occurring 6 days per week for Participants in both groups. As a core of the rehabilitation protocol, two to three strengths
Training sessions were conducted per week (15 training sessions in total), with eccentric oriented vs. Plyometric training for both groups, respectively. Both experimental groups conducted the same number of sets and Repetitions per set during the study period for each strength training session. The only difference was exercise selection, with Eccentric oriented exercises and plyometric training.

**Group A (ECCENTRIC TRAINING)**

**I.NORDIC HAMSTRING CURLS**

The Nordic hamstring curl is a Highly effective, knee dominant exercise focusing on eccentric strength to build muscle, increase speed and prevent injuries.
**Technique**: kneel on a pad, anchor your ankles (under a barbel, couch or partner), and. Keep your body in a straight line from to head. Lower yourself slowly (3-5 seconds) until you cannot hold, then use your hands to catch yourself and push back up.
**Progression**: beginners should start with "rocking" (partial leans), then move to 3-4 sets of 3-5 reps of slow negatives (lowering phase) before attempting full Repetitions.

**II.COPENHAGEN ECCENTRIC**

**Technique**: lie on your side with your top leg supported on a bench or by a partner (knee or ankle) and your forearm on the found for support.

**Movement**: lift your body into a straight side plank line. slowly lower your bottom leg (and hips) toward the floor (eccentric phase) and raise them back up (concentric phase).

### III.ECCENTRIC SWISS BALL CURL

To focus on the eccentric phase, you must control the ball as it rolls away from your body

**Starting position:** lie on your back supine) with your heels and lower calves resting on top of the Swiss ball. Place your arms at your sides for stability

**The bridge:** squeeze your gluteus and lift your hips until your body forms a straight line from your shoulders to your heels

**The curl:** pull the ball toward your gluteus by bending your knees.

**The eccentric phase:** slowly straighten your legs to roll back to starting position. This phase should ideally take 3 to 5 seconds to maximize hamstring engagement

### IV.QUARICEPS ECCENTRIC LEG EXTENSION

Focus on strengthening by slowing the lowering phase (3- 5 seconds) of a leg extension, increasing time under tension to build muscle and enhance knee stability

**Machine setup:** align the knee with the machine hinge and place the pad just above the ankle.

**Execution:** Raise the weight using two legs, then lower it slowly using only the affected leg to maximize eccentric load

**Tempo:** Use a 1- second upward phase and a 3-5 second downward (eccentric) phase

### GROUP - B (PLYOMETRICS)

### I. STANDING VERTICAL HOP

**standing Initial Setup:** Stand with feet shoulder-width apart, knees slightly bent, and core engaged.

**The Loading Phase (Eccentric):** Perform a quick squat (about 45 degrees, or a quarter squat) by pushing hips back while simultaneously swinging arms back to build momentum.

**The Jump (Concentric):** Explode upward, extending ankles, knees, and hips simultaneously (triple extension). Drive arms forcefully overhead.

**Landing:** Land softly on the balls of your feet, transitioning to heels, while maintaining a half-squat position to absorb force and prevent injury

### II.DEPTH JUMPS

**Starting Position:** Stand on a stable box or platform with feet shoulder-width apart.

**Drop:** Step (do not jump) forward off the box.

**The Landing:** Land on the balls of both feet simultaneously. Aim for a “soft” landing by slightly bending your knees and hips to absorb the force.

**The Exploding Phase:** Immediately upon contact, jump straight up as high as possible, using a vigorous arm swing for momentum.

FIGURE 12 DEPTH JUMPS

## III.TWO FOOTJUMP FORWARD AND BACKWARD

Two-foot forward and backward jumps are plyometric exercises designed to improve lower body power, coordination, and ankle stability by jumping back and forth over a line or obstacle. Start with feet hip-width apart, knees slightly bent, and use your arms for momentum to jump forward, landing softly on the balls of your feet before immediately reversing the motion.

**Starting Position:** Stand with feet together, knees slightly bent, and a engaged core.

**Execution:** Jump forward, landing softly with knees slightly bent to absorb impact. Immediately jump backward to the starting spot.

**Safety:** Land on the balls of your feet and keep knees aligned with your hips and ankles.

**Progression:** For more challenges, try to increase the speed, jump over a higher obstacle, or use a jump rope.

## IV.LATERAL TWO FOOT JUMPS

A lateral two-foot jump (also known as a double-leg lateral line jump or lateral hop) is a plyometric exercise where you jump sideways from one6 spot to another, taking off and landing on both feet simultaneously. It is primarily used to build lower-body power, lateral explosiveness, and joint stability.

**Stance:** Stand with your feet together or shoulder-width apart, knees slightly bent.

**Loading:** Bend your hips and knees to “load” the muscles, swinging your arms back for momentum.

**Take off:** Push through both feet at the same time, swinging your arms forward and jumping sideways.

**Landing:** Land softly on the balls of both feet with knees and hips slightly bent to absorb impact.

**Exercise protocol**

**Eccentric oriented strength training**

| Exercises | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week | 7th week | 8th week |
|---|---|---|---|---|---|---|---|---|
| Nordic hamstring curl | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Copenhagen eccentric | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |
| Eccentric Swiss ball curl | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |
| Quadriceps eccentric leg extension | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |

**Plyometric training**

| Exercises | 1st week | 2nd week | 3rd week | 4th week | 5th week | 6th week | 7th week | 8th week |
|---|---|---|---|---|---|---|---|---|
| Standing Vertical hop | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |
| Depth jumps | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |
| Two foot forward and backward | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |
| Lateral two-foot jumps | 2S×8R | 2S×10R | 3S×8R | 2S×8R | 3S×8R | 3S×10R | 3S×8R | 2S×8R |

## STATISTICAL ANALYSIS

### I. METHODOLOGY

**Descriptive Statistics**

- Mean & Standard deviation for Continuous variables, namely VERTICAL JUMP (VJ) Test, LYSHOLM KNEE SCORING (LKS), and Y BALANCE TEST (YBT) scores

**Inferential Statistics**

- Intra Group Analysis (or within-group analysis) – Paired Samples t-test
- Inter Group Analysis (or between-group analysis) – Independent Samples t-test

**Outcome Measure:**

- VERTICAL JUMP (VJ)
- LYSHOLM KNEE SCORING (LKS)
- Y BALANCE TEST (YBT)

**Treatment Groups:**

- GROUP A: ECCENTRIC EXERCISE
- GROUP B: PLYOMETRIC TRAINING

## II. ANALYSIS

### 1. Descriptive Statistics

### 1.1 Descriptive Statistics for Group A

| Descriptive Statistics - Group A | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Count** | **Min** | **Max** | **Mean** | **SD** |
| **VJ_PRE** | 15.00 | 37.00 | 53.00 | 44.67 | 4.85 |
| **VJ_POST** | 15.00 | 40.00 | 55.00 | 47.73 | 4.99 |
| **LKS_PRE** | 15.00 | 55.00 | 72.00 | 63.27 | 5.13 |
| **LKS_POST** | 15.00 | 59.00 | 77.00 | 68.00 | 5.29 |
| **YBT_PRE** | 15.00 | 74.90 | 95.80 | 85.07 | 5.39 |
| **YBT_POST** | 15.00 | 77.80 | 98.30 | 87.71 | 5.45 |

**GROUP B: PLYOMETRIC TRAINING**

### 1.2 Descriptive Statistics for Group B

| Descriptive Statistics - Group B | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Count** | **Min** | **Max** | **Mean** | **SD** |
| **VJ_PRE** | 15.00 | 37.00 | 54.00 | 44.73 | 5.59 |
| **VJ_POST** | 15.00 | 44.00 | 61.00 | 51.93 | 5.59 |
| **LKS_PRE** | 15.00 | 55.00 | 73.00 | 63.40 | 5.70 |
| **LKS_POST** | 15.00 | 65.00 | 84.00 | 74.40 | 5.83 |
| **YBT_PRE** | 15.00 | 77.00 | 94.00 | 83.32 | 4.54 |
| **YBT_POST** | 15.00 | 87.20 | 105.60 | 91.73 | 4.73 |

The descriptive statistics of both groups indicate improvement in all outcome measures following the intervention. In Group A (eccentric exercise), the mean Vertical Jump score increased from 44.67 (SD = 4.85) pre-intervention to 47.73 (SD = 4.99) post-intervention. Similarly, the Lysholm Knee Score improved from 63.27 (SD = 5.13) to 68.00 (SD = 5.29), and the Y Balance Test scores increased from 85.07 (SD = 5.39) to 87.71 (SD = 5.45). In Group B (plyometric training), greater improvements were observed, with the Vertical Jump increasing from 44.73 (SD = 5.59) to 51.93 (SD = 5.59), the Lysholm Knee Score from 63.40 (SD = 5.70) to 74.40 (SD = 5.83), and the Y Balance Test from 83.32 (SD = 4.54) to 91.73 (SD = 4.73). Overall, both interventions were effective in enhancing performance and functional outcomes, with plyometric training demonstrating comparatively higher mean improvements across all variables.

### 2. Inferential Statistics

### 2.1 Intra-Group Analysis (or Within-Group Analysis)

### 2.1.1 Paired Sample t-test for VERTICAL JUMP (VJ) in Group A

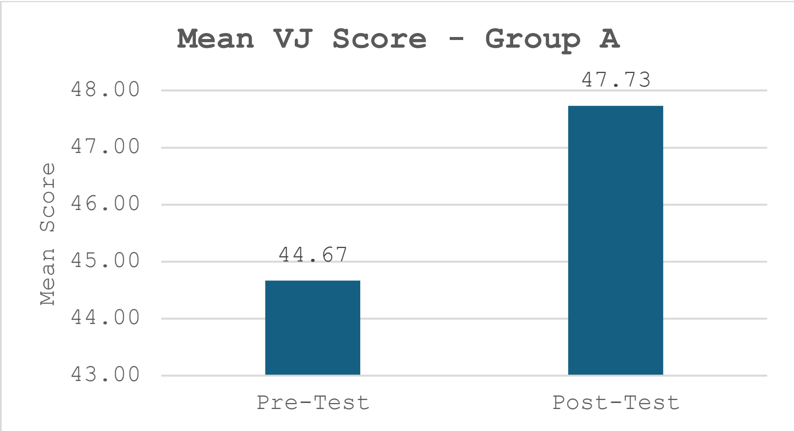
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **Vertical Jum**p scores in Group A (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **Vertical Jump** score from pre to post-test in Group A (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for VJ Score - Group A | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 44.67 | 47.73 | 14.87 | 0.000 |
| SD | 4.85 | 4.99 | | |




Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = 14.87$, $p = 0.000 < 0.05$). In addition, the mean Vertical Jump (VJ) score in Group A increased from 44.67 (SD = 4.85) in the pre-test to 47.73 (SD = 4.99) in the post-test. This indicates a statistically significant improvement in vertical jump performance following the intervention. Hence, the evidence is sufficient to conclude that eccentric-oriented strength training (Group A) is significantly effective in improving vertical jump performance among post ACL reconstruction football players.

### 2.1.2 Paired Sample t-test for LYSHOLM KNEE SCORING (LKS) in Group A

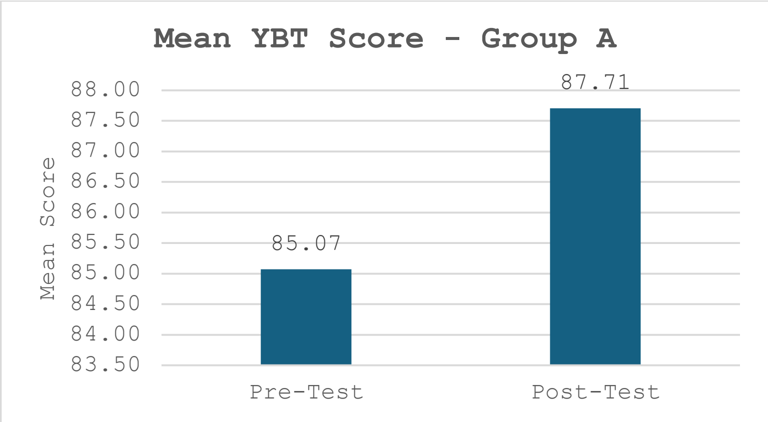
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **LYSHOLM KNEE SCORING** scores in Group A (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **LYSHOLM KNEE SCORING** score from pre to post-test in Group A (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for LKS Score - Group A | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 63.27 | 68.00 | 26.05 | 0.000 |
| SD | 5.13 | 5.29 | | |




Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = 3.52$, $p = 0.002 < 0.05$). In addition, the mean Y Balance Test (YBT) score in Group A increased from 85.07 (SD = 5.39) in the pre-test to 87.71 (SD = 5.45) in the post-test. This indicates a statistically significant improvement in dynamic balance following the intervention. Hence, the evidence is sufficient to conclude that eccentric-oriented strength training (Group A) is significantly effective in improving balance among post ACL reconstruction football players.

### 2.1.3 Paired Sample t-test for Y BALANCE TEST in Group A

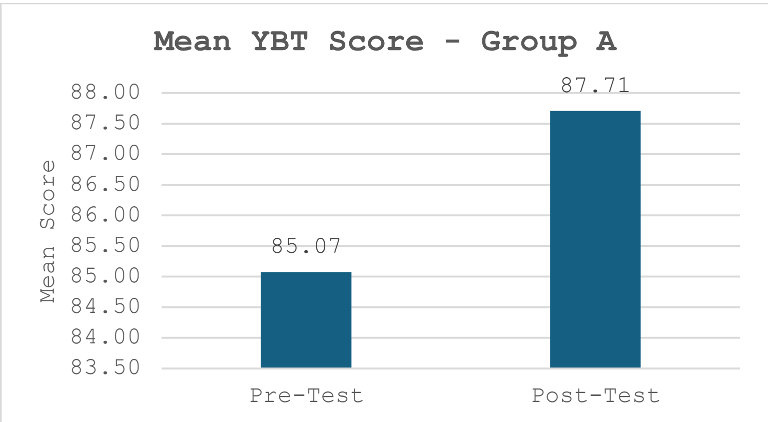
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **Y BALANCE TEST** scores in Group A (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **Y BALANCE TEST** score from pre to post-test in Group A (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for YBT Score - Group A | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 85.07 | 87.71 | 3.52 | 0.002 |
| SD | 5.39 | 5.45 | | |


Mean YBT Score - Group A
88.00
87.50
87.00
86.50
86.00
85.50
85.00
84.50
84.00
83.50
Mean Score
87.71
85.07
Pre-Test
Post-Test

Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = 3.52$, $p = 0.002 < 0.05$). In addition, the mean Y Balance Test (YBT) score in Group A increased from 85.07 (SD = 5.39) in the pre-test to 87.71 (SD = 5.45) in the post-test. This indicates a statistically significant improvement in dynamic balance following the intervention. Hence, the evidence is sufficient to conclude that eccentric-oriented strength training (Group A) is significantly effective in improving balance among post ACL reconstruction football players.

### 2.1.4 Paired Sample t-test for VERTICAL JUMP (VJ) in Group B

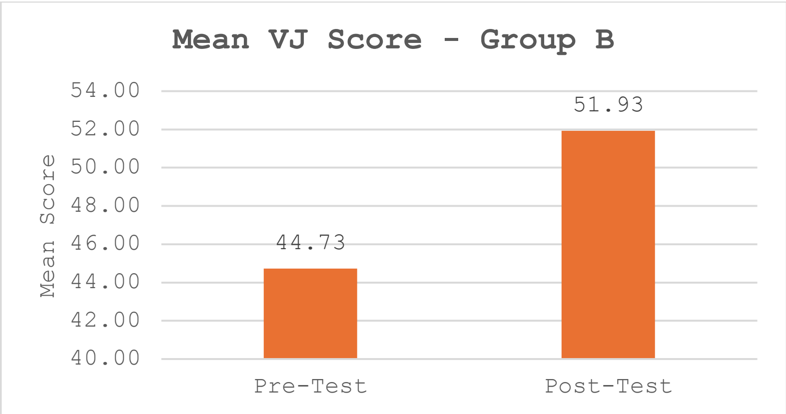
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **Vertical Jum**p scores in Group B (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **Vertical Jump** score from pre to post-test in Group B (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for VJ Score - Group B | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 44.73 | 51.93 | 9.21 | 0.000 |
| SD | 5.59 | 5.59 | | |




Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = 9.21$, $p = 0.000 < 0.05$). In addition, the mean Vertical Jump (VJ) score in Group B increased from 44.73 (SD = 5.59) in the pre-test to 51.93 (SD = 5.59) in the post-test. This indicates a statistically significant improvement in vertical jump performance following the intervention. Hence, the evidence is sufficient to conclude that Plyometric Training (Group B) is significantly effective in improving vertical jump performance among post ACL reconstruction football players

### 2.1.5 Paired Sample t-test for LYSHOLM KNEE SCORING (LKS) in Group B

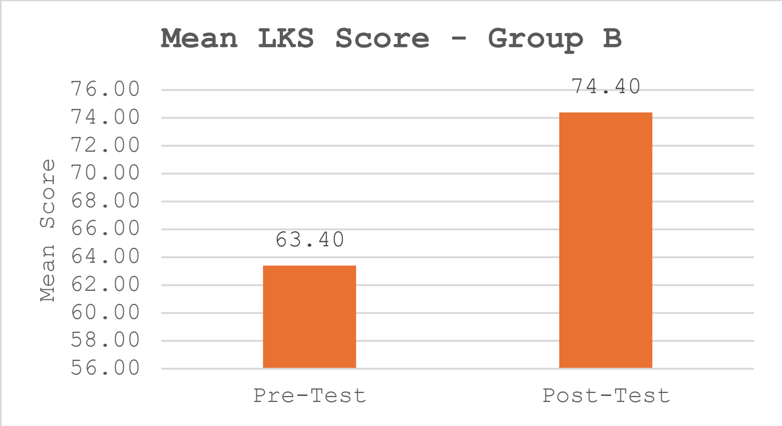
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **LYSHOLM KNEE SCORING** scores in Group B (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **LYSHOLM KNEE SCORING** score from pre to post-test in Group B (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for LKS Score - Group B | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 63.40 | 74.40 | 18.05 | 0.000 |
| SD | 5.70 | 5.83 | | |




Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance (t = 18.05, p = 0.000 < 0.05). In addition, the mean Lysholm Knee Score (LKS) in Group B increased from 63.40 (SD = 5.70) in the pre-test to 74.40 (SD = 5.83) in the post-test. This indicates a statistically significant improvement in knee function following the intervention. Hence, the evidence is sufficient to conclude that plyometric training (Group B) is significantly effective in improving knee functional outcomes among post ACL reconstruction football players.

### 2.1.6 Paired Sample t-test for Y BALANCE TEST in Group B

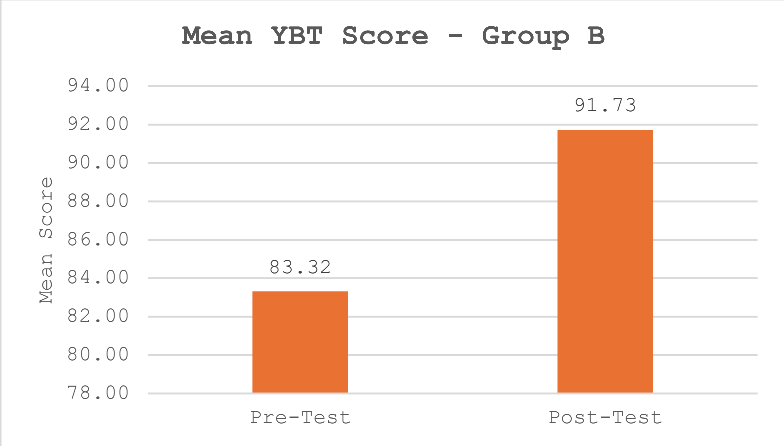
Null hypothesis, $H_0$: There is no significant difference between pre- and post-test **Y BALANCE TEST** scores in Group B (i.e., $\mu_d = 0$)

Alternate hypothesis, $H_1$: There is significant **improvement** in **Y BALANCE TEST** score from pre to post-test in Group B (i.e., $\mu_d > 0$)

where d = difference between pre- and post-test scores and $\mu_d$ = population mean of the difference 'd'

**Paired t-test Output:**

| Paired-Samples t-test for YBT Score - Group B | | | | |
|---|---|---|---|---|
| | **Pre-Test** | **Post-Test** | **t-stat** | **P-value** |
| Mean | 83.32 | 91.73 | 12.87 | 0.000 |
| SD | 4.54 | 4.73 | | |




Since the p-value obtained from the paired t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = 12.87$, $p = 0.000 < 0.05$). In addition, the mean Y Balance Test (YBT) score in Group B increased from 83.32 (SD = 4.54) in the pre-test to 91.73 (SD = 4.73) in the post-test. This indicates a statistically significant improvement in dynamic balance following the intervention. Hence, the evidence is sufficient to conclude that plyometric training (Group B) is significantly effective in improving balance among post ACL reconstruction football players

**2.2 Inter-Group Analysis (or Between Group Analysis):**

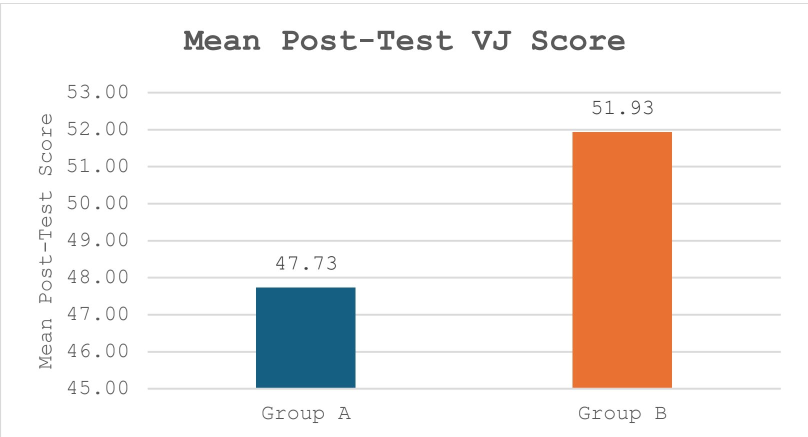
**2.2.1 Independent Samples t-test to compare Group A and Group B in terms of Post-test Scores of VERTICAL JUMPS**

Null hypothesis, $H_0$: There is no significant difference between Group A and Group B in terms of mean post-test scores of **VERTICAL JUMPS**

Alternate hypothesis, $H_1$: There is significant difference between Group A and Group B in terms of mean post-test scores of **VERTICAL JUMPS**

**Output of Independent Samples t-test:**

| Independent Samples t-test for Post-Test VJ Score | | | | |
|---|---|---|---|---|
| | **Group A** | **Group B** | **t-stat** | **P-value** |
| Mean | 47.73 | 51.93 | -2.17 | 0.039 |
| SD | 4.99 | 5.59 | | |



Since the p-value obtained from the independent samples t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = -2.17$, $p = 0.039 < 0.05$), indicating a statistically significant difference in vertical jump performance between the two groups after the intervention. In addition, the mean post-test VJ score of Group A (47.73) is lower than that of Group B (51.93). Hence, the evidence is sufficient to conclude that plyometric training (**Group B**) is **more effective** than eccentric-oriented strength training (Group A) in improving vertical jump performance among post ACL reconstruction football players.

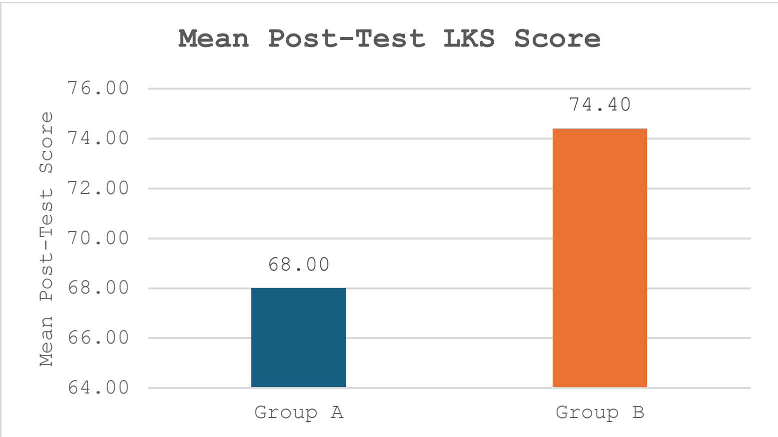
### 2.2.2 Independent Samples t-test to compare Group A and Group B in terms of Post-test Scores of LYSHOLM KNEE SCORING

Null hypothesis, $H_0$: There is no significant difference between Group A and Group B in terms of mean post-test scores of LYSHOLM KNEE SCORING

Alternate hypothesis, $H_1$: There is significant difference between Group A and Group B in terms of mean post-test scores of LYSHOLM KNEE SCORING

**Output of Independent Samples t-test:**

| Independent Samples t-test for Post-Test LKS Score | | | | |
|---|---|---|---|---|
| | **Group A** | **Group B** | **t-stat** | **P-value** |
| Mean | 68.00 | 74.40 | -3.15 | 0.004 |
| SD | 5.29 | 5.83 | | |




Since the p-value obtained from the independent samples t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = -3.15$, $p = 0.004 < 0.05$), indicating a statistically significant difference in knee functional outcomes between the two groups after the intervention. In addition, the mean post-test Lysholm Knee Score (LKS) of Group A (68.00) is lower than that of Group B (74.40). Hence, the evidence is sufficient to conclude that plyometric training (Group B) is more effective than eccentric-oriented strength training (Group A) in improving knee function among post ACL reconstruction football players.

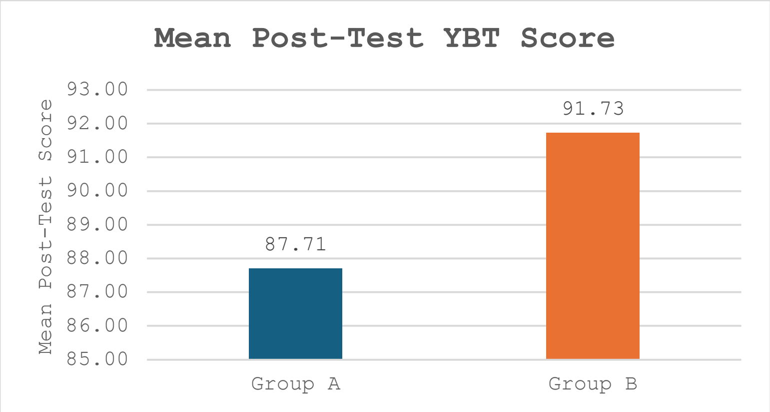
### 2.2.3 Independent Samples t-test to compare Group A and Group B in terms of Post-test Scores of Y BALANCE TEST (YBT)

Null hypothesis, $H_0$: There is no significant difference between Group A and Group B in terms of mean post-test scores of YBT

Alternate hypothesis, $H_1$: There is significant difference between Group A and Group B in terms of mean post-test scores of YBT

**Output of Independent Samples t-test:**

| Independent Samples t-test for Post-Test YBT Score | | | | |
|---|---|---|---|---|
| | **Group A** | **Group B** | **t-stat** | **P-value** |
| Mean | 87.71 | 91.73 | -2.16 | 0.039 |
| SD | 5.45 | 4.73 | | |




Since the p-value obtained from the independent samples t-test is less than 0.05, the null hypothesis is rejected at the 5% level of significance ($t = -2.16$, $p = 0.039 < 0.05$), indicating a statistically significant difference in balance performance between the two groups after the intervention. In addition, the mean post-test Y Balance Test (YBT) score of Group A (87.71) is lower than that of Group B (91.73). Hence, the evidence is sufficient to conclude that plyometric training (Group B) is more effective than eccentric-oriented strength training (Group A) in improving balance among post ACL reconstruction football players.

**RESULTS**

According to the results of Intra-Group and Inter-Group Analysis, comparison of the mean values of GROUP-A and GROUP-B for Vertical Jump (VJ) scores revealed that both groups demonstrated statistically significant improvement following the intervention. However, the post-test mean value was higher in GROUP-B (51.93) than in GROUP-A (47.73), indicating that Plyometric Training was more effective than Eccentric-Oriented Strength Training in improving vertical jump performance among post ACL reconstruction football players at $p < 0.05$. Hence, the null hypothesis is rejected.

Similarly, comparison of the mean values of GROUP-A and GROUP-B for Lysholm Knee Score (LKS) showed significant improvement in both groups following the intervention. However, the post-test mean-value of GROUP-B (74.40) was higher than that of GROUP-A (68.00), indicating that Plyometric Training was more effective than Eccentric-Oriented Strength Training in improving knee functional outcomes among post ACL reconstruction football players at $p < 0.05$. Hence, the null hypothesis is rejected.

Also, the comparison of the mean values of GROUP-A and GROUP-B for Y Balance Test (YBT) scores showed significant improvement in both groups following the intervention. However, the post-test mean-value of GROUP-B (91.73) was higher than that of GROUP-A (87.71), indicating that Plyometric Training was more effective than Eccentric-Oriented Strength Training in improving dynamic balance among post ACL reconstruction football players at $p < 0.05$. Hence, the null hypothesis is rejected.

The Intra-Group Analysis explicitly showed that comparison of the pre-test and post-test mean values within GROUP-A and GROUP-B revealed statistically significant improvements in Vertical Jump, Lysholm Knee

Score, and Y Balance Test scores in both groups at $p < 0.05$. Although both interventions were effective, GROUP-B showed greater improvement than GROUP-A, suggesting that Plyometric Training is more beneficial for improving return-to-sport performance among post ACL reconstruction football players.

## DISCUSSION

The present experimental study was conducted to evaluate and compare the effectiveness of eccentric-oriented strength training and plyometric training on return-to-sport performance in football players following anterior cruciate ligament (ACL) reconstruction. The results of this study demonstrated that both interventions led to statistically significant improvements in functional performance outcomes, including Vertical Jump, Lysholm Knee Score, and Y-Balance Test scores within each group ($p < 0.05$). However, when comparing between groups, plyometric training (Group B) was found to be more effective than eccentric-oriented strength training (Group A) in enhancing return-to-sport performance.

### Effectiveness of Eccentric-Oriented Strength Training

Eccentric training has long been recognized as a fundamental component of post-ACL reconstruction rehabilitation. It focuses on controlled lengthening of muscles under load, which is essential for improving muscle strength, tendon stiffness, and neuromuscular control. In the present study, Group A showed significant improvements across all outcome measures, indicating that eccentric training contributed positively to restoring lower limb function.

The improvements in Vertical Jump performance in this group can be attributed to increased muscle strength, particularly in the quadriceps and hamstrings, which play a vital role in force production. Similarly, the enhancement in Lysholm Knee Scores suggests improved knee stability, reduced pain, and better functional capacity. The gains observed in the Y-Balance Test further indicate improved proprioception and postural control, which are crucial for preventing re-injury.

Eccentric training is especially important in the early to mid-stages of rehabilitation, as it prepares the musculotendinous unit to tolerate higher loads and improves the ability to decelerate movements, which is critical in football-related activities such as landing and cutting.

### Effectiveness of Plyometric Training

Plyometric training, which emphasizes explosive movements involving the stretch-shortening cycle, demonstrated superior outcomes in this study. Group B exhibited greater improvements in all measured variables compared to Group A. This suggests that plyometric exercises are more effective in enhancing performance parameters directly related to return-to-sport readiness.

The significant improvement in Vertical Jump in Group B reflects enhanced muscular power and explosive strength. Plyometric exercises such as jump training, bounding, and hopping mimic the dynamic and high-intensity movements required in football, thereby improving functional performance more effectively.

In terms of the Lysholm Knee Score, the greater improvement in Group B indicates enhanced knee function, stability, and confidence during movement. Plyometric training challenges the neuromuscular system under dynamic conditions, which likely contributed to better functional outcomes and reduced perception of instability.

The Y-Balance Test results further support the superiority of plyometric training, as this form of exercise improves dynamic balance, coordination, and neuromuscular control. These factors are essential for football players, who frequently perform rapid directional changes and must maintain stability under unpredictable conditions.

**Comparison Between the Two Interventions**

While both interventions were effective, the greater improvements observed in the plyometric training group can be explained by the principle of specificity. Plyometric exercises closely replicate sport-specific demands, particularly in football, where explosive power, agility, and rapid neuromuscular responses are essential.

Eccentric training primarily enhances strength and control, forming a necessary foundation for rehabilitation. However, it may not sufficiently address the high-velocity, sport-specific movements required for return to competitive play. In contrast, plyometric training bridges the gap between rehabilitation and sport performance by integrating strength with speed and coordination.

Therefore, although eccentric training is crucial in the rehabilitation continuum, plyometric training appears to be more beneficial during the later stages when the goal is to restore full athletic performance and ensure a safe return to sport.

**Stojanovi´c, M.D.M.; Andri´c, N.; Miki´c, M. et al.23** Effects of Eccentric-Oriented Strength Training On Return to Sport Criteria in Late-Stage Anterior Cruciate Ligament (ACL)-Reconstructed Professional Team Sport Players. They proved that  Therefore, eccentric-oriented strength training appears to be a potent tool to produce improvements in return-to-sport performance outcomes for Professional team sport athletes in late-stage ACL rehabilitation.

**Kasmi S, Zouhal H, Hammami R,Clark CCT, Hackney AC et al.21** The Effects of eccentric and plyometric training programs and Their combination of stability and functional performance in the Post-ACL-surgical rehabilitation conclusion, combined eccentric/ plyometric training seems to represent the most effective training method as it exerts positive effects on both stability and functional performance in the post-ACL-surgical rehabilitation

According  to these two studies I have taken in both articles which I including effectiveness of Eccentric oriented strength training versus plyometric training for post acl reconstruction on return to sports in football players, In Group A 15 and Group-B 15 number of patients for them (8 weeks of training) of eccentric training and plyometric training in this topic both interventions were effective but comparing eccentric training and plyometric training than plyometric training is more effective than eccentric-oriented strength training in improving strength and sports specific activities in football players after acl reconstruction in return-to-sport performance.

## CONCLUSION

Based on the results of the intra-group analyses, it can be concluded that both eccentric-oriented strength training and plyometric training were effective in improving vertical jump performance, knee functional outcomes, and dynamic balance among post ACL reconstruction football players. However, inter-group comparisons showed that plyometric training (Group B) was significantly more effective than eccentric-oriented strength training (Group A) in improving vertical jump height, Lysholm Knee Score, and Y Balance Test performance, as evidenced by better post-test outcomes in Group B.

On the whole, the findings suggest that while both intervention procedures are beneficial, Plyometric Training (Group B) produces greater improvements in power, knee function, and balance compared to Eccentric-Oriented Strength Training (Group A) among post ACL reconstruction football players, thereby facilitating a better return to sports performance.

**REFERENCES**

1. Gornitzky, A.L.; Lott, A.; Yellin, J.L.; Fabricant, P.D.; Lawrence, J.T.; Ganley, T.J. Sport-Specific Yearly Risk and Incidence of Anterior Cruciate Ligament Tears in High School Athletes. Am. J. Sport. Med. 2016, 44, 2716–2723. [CrossRef]

2. Sanborn, R.M.; Badger, G.J.; Proffen, B.; Sant, N.; Barnett, S.; Fleming, B.C.; Kramer, D.E.; Micheli, L.J.; Yen, Y.-M.; Murray, M.M.; et al. Psychological Readiness to Return to Sport at 6 Months Is Higher After Bridge-Enhanced ACL Restoration Than Autograft ACL Reconstruction: Results of a Prospective Randomized Clinical Trial. Ortho. J. Sport. Med. 2022, 10,232596712110705. [CrossRef] [PubMed]

3. Davies, W.T.; Myer, G.D.; Read, P.J. Is It Time We Better Understood the Tests We Are Using for Return to Sport Decision Making Following ACL Reconstruction? A Critical Review of the Hop Tests. Sport. Med. 2020, 50, 485–495. [CrossRef] [PubMed]

4. Mastroeni, L.; Read, P.; Bishop, C.; Turner, A. Strength and Power Training in Rehabilitation: Underpinning Principles and Practical Strategies to Return Athletes to High Performance. Sport. Med. 2019, 50, 239–252. [CrossRef] [PubMed]

5. Kyritsis, P.; Bahr, R.; Landreau, P.; Miladi, R.; Wit vrouw, E. Likelihood of ACL Graft Rupture: Not Meeting Six Clinical Discharge Criteria Before Return to Sport Is Associated with a Four Times Greater Risk of Rupture. Br. J. Sport. Med. 2016,

6. Powell, C.; Jensen, J.; Johnson, S. Functional Performance Measures Used for Return-to-Sport Criteria in Youth Following Lower-Extremity Injury. J. Sport Rehabil. 2018, 27, 581–590. [CrossRef]

7. . Kotsifaki, A.; Van Rossom, S.; Whiteley, R.; Korakakis, V.; Bahr, R.; Sideris, V.; Jonkers, I. Single Leg Vertical Jump Performance Identifies Knee Function Deficits at Return to Sport after ACL Reconstruction in Male Athletes. Br. J. Sport. Med. 2022, 56, 490–498. [CrossRef]

8. Greenberg, E.M.; Greenberg, E.T.; Albaugh, J.; Storey, E.; Ganley, T.J. Rehabilitation Practice Patterns Following Anterior Cruciate Ligament Reconstruction: A Survey of Physical Therapists. J. Orthop. Sport. Phys. Ther. 2018, 48, 801–811. [CrossRef]

9. 9. Kora kakis, V.; Kotsifaki, A.; Kora kaki, A.; Karana Sios, S.; Whiteley, R. Current Perspectives and Clinical Practice of Physiotherapists on Assessment, Rehabilitation, and Return to Sport Criteria after Anterior Cruciate Ligament Injury and Reconstruction. An Online Survey of 538 Physiotherapists. Phys. Ther. Sport 2021, 52, 103–114. [CrossRef]

10. Kotsifaki, R.; Kora kakis, V.; King, E.; Barbosa, O.; Maree, D.; Pantouveris, M.; Bjerregaard, A.; Luoma Joki, J.; Wilhelmsen, J.; Whiteley, R. Aspetar Clinical Practice Guideline on Rehabilitation after Anterior Cruciate Ligament Reconstruction. Br. J. Sport. Med. 2023, 57, 500–514. [CrossRef]

11. Kinikli, G. I., Yüksel, I., Baltaci, G., and Atay, O. A. (2014). The effect of progressive Eccentric and concentric training on functional performance after autogenous Hamstring anterior cruciate ligament reconstruction: A randomized controlled Study. Acta. Orthop. Traumatol. Turc. 48, 283–289. Doi: 10.3944/aott.2014.13.0111

12. Padua, D. A., DiStefano, L. J., Hewett, T. E., Garrett, W. E., Marshall, S. W.,golden, G. M., et al. (2018). National athletic trainers' association position Statement: Prevention of anterior cruciate ligament injury. J. Athl. Train 53,5–19.

13. Tegner, Y., and Lysholm, J. (1985). Rating systems in the evaluation of knee Ligament injuries. Clin Orthop Relat Res. 198, 43–49.

14. Yoo, J. H., Lim, B. O., Ha, M., Lee, S. W., Oh, S. J., Lee, Y. S., et al. (2010).A meta-analysis of the effect of neuromuscular training on the prevention Of the anterior cruciate ligament injury in female athletes. Knee. Surg. Sport Traumatol. Arthrosc. 18, 824–830.

15. Diermeier T, Rothrauff BB, Engebretsen L, Lynch AD, Ayeni OR, Paterno MV, et al. Treatment after anterior cruciate ligament injury: Panther symposium ACL treatment consensus group. Knee Surg Sports Traumatol Arthrosc 2020;28:2390-402.

16. Buckthorpe M, GokelerA, Herrington L, Hughes M, GrassiA, Wadey R, Et al. Optimising the early-stage rehabilitation process post-ACL Reconstruction. Sports Med 2024;54:49-72.
17. Irarrázaval S, Albers M, Chao T, Fu FH. Gross arthroscopic, andRadiographic anatomies of the anterior cruciate ligament: foundations for anterior cruciate ligament surgery. Clin Sports Med.2017;36:9---23,.
18. Weber W, Weber EF. Mechanik der menschlichen Gehwerkzeuge: Eine anatomisch-physiologische Untersuchung. Göttingen: Dieterich; 1836,.1837
19. Siebold R. Flat ACL anatomy: fact no fiction. Knee Surg Sports Traumatol Arthrosc. 2015;23:3133---5,.
20. Smigielski R, Zdanowicz U, Drwiega ̧ M, Ciszek B, Williams A. The Anatomy of the anterior cruciate ligament and its relevance To the technique of reconstruction. Bone Joint J. 2016;98-B:1020---6,.
21. Cone SG, Howe D, Fisher MB. Size and shape of the Human anterior cruciate ligament and the impact of sex and Skeletal growth: a systematic review. JBJS Rev.2019;7:.
22. Hassebrock JD, Gulbrandsen MT, Asprey WL, Makovicka JL, Chhabra A. Knee ligament anatomy and biomechanics. Sports Med Arthrosc Rev. 2020;
23. Buckthorpe M, GokelerA, Herrington L, Hughes M, GrassiA, Wadey R, Et al. Optimising the early-stage rehabilitation process post-ACL Reconstruction. Sports Med 2024; 54:49 72.
24. Buckthorpe M. Recommendations for movement re-training after ACL Reconstruction. Sports Med 2021; 51:1601 18.
25. Gokeler A, Benjaminse A, Hewett TE, Paterno MV, Ford KR, Otten E, et al. Feedback techniques to target functional deficits Following anterior cruciate ligament reconstruction: Implications For motor control and reduction of second injury risk. Sports Med 2013; 43:1065 74.
26. Myer GD, Ford KR, Hewett TE. Rationale and Clinical Techniques For anterior cruciate ligament injury prevention among female athletes. J Athl Train 2004; 39:352 64.
27. Nelson C, Rajan L, Day J, Hinton R, Bodendorfer BM. Postoperative Rehabilitation of anterior cruciate ligament reconstruction: A systematic Review. Sports Med Arthrosc Rev 2021;