ISOINERTIAL TRAINING FOR ECCENTRIC STRENGTHENING IN ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION SURGERIES: AN EXPERIMENTAL TRIAL

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Physiotherapy

By

Som Gupta

Registration Number: 41800812

Supervised By

Dr. Ramesh Chandra Patra (UID-19500)

Associate Professor, Department of Physiotherapy

School of Allied Medical Sciences

LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled "Isoinertial Training for Eccentric Strengthening in Anterior Cruciate Ligament Reconstruction Surgeries: An Experimental Trial" in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Ramesh Chandra Patra**, working as Associate Professor, in the Department of Physiotherapy, School of Allied Medical Sciences of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of other investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

Name of the scholar: Som Gupta
Registration No.: 41800812
Department/school: Physiotherapy
Lovely Professional University,
Punjab, India

CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled “Isoinertial Training for Eccentric Strengthening in Anterior Cruciate Ligament Reconstruction Surgeries: An Experimental Trial” submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Physiotherapy, School of Allied Medical Sciences of Lovely Professional University, is a research work carried out by **Som Gupta**, Registration No. 41800812, is bonafide record of his original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

Name of supervisor: Dr. Ramesh Chandra Patra
Designation: Associate Professor
Department/school: Physiotherapy
University: Lovely Professional University

ABSTRACT

Background and Purpose: Patients undergoing ACL reconstruction often experience challenges such as limited range of motion caused by swelling and stiffness post-surgery, along with muscle weakness, often leads to poorer functional outcomes scores and decreased activity levels. Previous researches indicated that flywheel resistance training can enhance eccentric muscle loading and strength. With limited research on the combined effects of isoinertial training and conventional rehabilitation, the study aims to investigate their impact on muscle power, endurance, isometric strength, balance and on knee related quality of life and function in postoperative ACL reconstruction patients.

Methodology: A total of 96 out of 130 screened patients aged 18-45 years, 3 weeks post-op patients were included as per selection criteria and randomly divided into groups. Group A consisted of 47 patients (n=47) which were administered Isoinertial Eccentric Strength Training with Conventional Rehabilitation Protocol whereas 49 patients in group B (n=49) received conventional rehabilitation protocol only over 6 weeks. The patients were assessed for muscle power, endurance, isometric strength and balance using flywheel ergometer (D11 Plus; Desmotec, Biella, Italy); knee related quality of life using Knee injury and Osteoarthritis Outcome Score (KOOS), knee related function using Cincinnati knee rating System (CKRS) and pain and function outcome of knee using Oxford Knee Score (OKS) of the patients respectively before and after the 6 weeks of interventions.

Results: The study demonstrated statistically significant improvements in Muscle Power (both concentric and eccentric), Isometric strength, and Balance in both Groups A and B ($p < 0.05$). Notably, while there was no significant difference in muscle endurance within Group B, the comparison between the two groups showed no statistical significance in the improvement of mean values for Muscle Power (concentric), Isometric strength, and Balance ($p > 0.05$). However, a significant improvement in mean values of muscle power (eccentric) was observed in Group A ($p < 0.05$). Likewise, significant improvements seen in Muscle power, Strength, Balance, and knee-related outcome scores in both dominant and non-dominant sides within Group A subjects after a 6-week interval. However, no significant improvement was suggested within Group B in Endurance parameter only. The study demonstrated statistically significant improvements in the score of KOOS, CKRS and OKS in both the groups A and B ($p < 0.05$). However, the comparison between the two groups showed no statistical significance in the difference in improvement of mean values of KOOS, CKRS and OKS ($p > 0.05$).

Conclusion: It is concluded that there is effectiveness of isoinertial training combined with conventional rehabilitation and conventional rehabilitation only in enhancing Muscle Power (concentric and eccentric), Isometric strength, and Balance. The isoinertial protocol, however, showed improvement in Endurance, unlike the conventional rehabilitation group. Notably, no significant difference was found in Isometric strength and Balance between the two intervention programs. In terms of operated dominant side, the Group A showed substantial improvement in Endurance with respect to Group B while other parameters improved for the both groups. The analysis further highlighted the effectiveness of isoinertial training in enhancing power during the eccentric phase. Further, in terms of knee-related quality of life, function and pain, while both protocols demonstrated effectiveness, neither proved superior to the other.

Keywords: ACL reconstruction, Isoinertial training, Conventional Rehabilitation, Knee related quality of life

ACKNOWLEDGEMENT

The undertaking of this experimental trial was driven by the pressing need to enhance postoperative rehabilitation outcomes for patients undergoing anterior cruciate ligament (ACL) reconstruction. Recognizing the significant challenges faced by these patients, including limited range of motion and muscle weakness, I was motivated to explore the potential benefits of combining isoinertial training with conventional rehabilitation protocols. This study aimed to provide a comprehensive evaluation of these interventions to improve muscle power, endurance, isometric strength, balance, and overall knee-related quality of life.

My sincere Gratitude to **Lord Almighty**, my parents **Dr. Roshan Lal Gupta** and **Mrs. Usha Kiran Gupta**, wife **Mrs. Khushboo Gupta**, daughter **Samaira Gupta**, son **Ridhav Gupta**, other family members and friends, for their unwavering support and encouragement throughout my years of study. This accomplishment would not have been possible without them.

I am also grateful to **Mr. Ashok Mittal**, Honorable Chancellor of Lovely Professional University, **Mrs. Rashmi Mittal**, Worthy Pro-Chancellor, and **Dr. Monica Gulati**, Senior Dean, LFAMS, for providing all the facilities to carry out the project work.

I am deeply grateful to my advisor, **Dr. Ramesh Chandra Patra** for his continuous support, patience and immense knowledge. His guidance and encouragement were instrumental in the successful completion of this research and writing of this thesis.

A special thanks goes to **Dr. Sanjeev Mahajan** for his unconditional and patient support throughout my study. Your encouragement and assistance have been critical in helping me navigate the complexities of my research.

Lastly, I am thankful to the patients who participated in this study; their commitment and cooperation were crucial to the research process.

Date:

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 BACKGROUND

The stability of the knee joint and its movements are coordinated by the anterior cruciate ligament (ACL). Mostly, this is what stops the tibia from bunching forward on top of the femur. Therefore, an injury to the ACL can lead to extensive knee damage and might also contribute to the premature onset of osteoarthritis in the joint (Gerami MH et al., 2022). ACL is a collagenous tissue from the knee joint extending from the lateral femoral condyle to the tibial articular surface. Posterior bundles — tight on extension. Anteromedial fibres — Tight on flexion. The ACL is innervated proprioceptively by the posterior articular nerve and is considered a branch of the tibial nerve. Damage to the ACL disrupts this proprioceptive feedback and is thought to result in loss of motor control at both the spinal and supraspinal systems. The primary role of the ACL is to resist excessive anterior translation of the tibia, particularly during flexion. It also helps stabilize the knee in full extension against varus/valgus stress and rotation, particularly via the posterolateral bundle. The force on the ACL is highest in: -The final 30 degrees of extension -Valgus, Hyperextension, and Internal rotation forces (Sepúlveda F et al. 2017).

Especially popular among those who engage in physical activities, such as athletes, ACL ruptures often arise when you bend your knees and suddenly stop or extend them a bit too far. After such injuries, patients often suffer from repeated episodes of pain, instability, and functional limitations. ACL injuries in the big picture of incidence mean productivity loss to society and its continuously increasing costs. In turn, ACL reconstruction surgery has been the case for how a stable knee is lost and is best restored. The high success rates of this procedure are such that patients can return to their pre-injury activities with little risk of relapse. It also protects the meniscus from further damage, which in turn delays the early development of osteoarthritis. ACL reconstruction is a procedure that aims to replace the ligament using a graft from tendons. But it is important to remember that the tendinous structure and content of these are somewhat lacking in proteoglycans and collagen distribution compared with that of the native ligament (Gerami MH et al., 2022).

ItaiGans et al. conducted the study. When ItaiGans et al. (2018) analyzed data from the NCAA Injury Surveillance Program (ISP) from 2004 to 2014, they reported that of a total of 350,416 athlete-exposures (AEs), there were 1105 ACL ruptures, with 126 classified as recurrent. Mark V. Paterno et al. examined in their study those anterior cruciate ligament (ACL) injuries reported to the Gala registry's parent organization, noting approximately 200,000 annual cases only in the United States and up to 90 % of patients undergoing ACL reconstruction (ACLR) (Mark V. Paterno et al., 2015). ACL injuries are most commonly attributed to roadside accidents, in which they account for 38.8% of cases, along with injuries from sports (33.3%) or falls (16.5%). These rates are derived from a previously performed retrospective observational analysis. As to Joshi et al. In 2022, football was the most common example of ACL injuries, while two-wheeler accidents were mainly responsible for RTAs. Seventy to eighty percent of ACL injuries occur with noncontact mechanisms such as landing from a jump or pivoting, but contact mechanisms can also cause these injuries. This places the females into the "point of no return," (extended hip and knee, inturned lower limb, pronating foot).

ACL injuries have multifactorial causes, with neuromuscular control and landing biomechanics identified as modifiable risk factors, and other established non-modifiable risks. Neglecting these factors increases the likelihood of initial injury or reinjury. Football accounts for most knee injuries, and non-contact mechanisms are more prevalent. Female athletes may be at greater risk due to landing mechanics, such as increased valgus angulation and knee extension, as supported by video analyses showing greater valgus positioning during abrupt directional changes, alongside decreased mobility and endurance in hips and knees.

Other anatomical factors increasing the odds of injury included ankle laxity (AOR, 1.94), impingement on the notch, a smaller femoral notch width (AOR, 3.19), body mass index in men (AOR, 4.46), ACL volume in young women (AOR, >5% larger or smaller volume) and joint hypermobility (5 times greater risk of noncontact injury).

There is a strong correlation between ACL injuries and activities such as football, especially among men, and basketball in girls. Hormonal imbalances can diminish coordination, particularly during the ovulatory stage of the menstrual cycle. OCP may have a minimal effect on females. Estrogens may influence tissue strength and flexibility, particularly in ligaments, but there is limited support for this role, and the question remains controversial. Furthermore, reduced injury risk in women has also been associated with differences in collagen production, specifically linked to the COL5A1 gene.

Patients with ACL injuries may have guarded gait patterns that can include quadriceps avoidance and have difficulty with active knee extension. Attention should also be paid to varus malalignment of the knee, which does not represent a contraindication for performing ACL reconstruction, as this situation increases the risk of ACL re-tear and can lead to additional procedures, such as realignment osteotomy, performed at the time of ACL reconstruction. The deformed knee and the involved knee are often swollen with joint line tenderness, especially if associated with meniscal injuries. The knee may become locked, with an inability to move the knee, possibly indicative of a meniscal tear or where pain originates from non-articular structures such as the meniscus and ligamentous tissues.

ACL injury often to bring impairments and disabilities reduces the quality of life a lot and worsens physical functioning. Knee instability is a common consequence of ACL injury, and it can affect all of your activities that require weight-bearing, pivoting or sudden changes in direction, leading to falls and possible future injuries. After an ACL injury there is also frequent muscle weakness, especially of the quadriceps and hamstring muscles, from disuse atrophy and protective guarding. This weakness leads to reduced knee stability and abnormal movement patterns. Similarly, the knee may become somewhat immovable with ACL injury (due to swelling and pain); limited in extension range of motion, further leading to the loss of mobility in functional activities. ACL individuals frequently employ adaptive gait strategies to decrease knee load at the expense of altered joint biomechanics and decreased function.

The psychological element, involving strains such as fear of re-injury and anxiety above an ACL harm, can have an impact on any therapy's progress. Moreover, untreated or inadequately rehabilitated ACL injuries can also raise the risk of joint degradation and osteoarthritis in the involved knee as time passes, further intensifying disabilities. Restoring athletic performance to pre-injury levels might prove to be a bit of a challenge for these human specimens, though: The tissue is scarred into place, leaving the joint as flexible and pliant as an oak tree. In addition, ACL injury predisposes to associated damage such as meniscal tears and cartilage disruption that can compound the problem in return to function and long-term outcomes. Treatment focused on overcoming these impairments and disabilities with high-quality, specialized rehabilitation programs is vital for maximizing recovery and restoring function in patients with ACL injuries.

The Lachman is one modality in which you can assess the integrity of the ACL. Nonetheless, clinical testing, including the anterior drawer sign and pivot shift test, can help in providing information about instability. The primary diagnostic with the highest sensitivity is the Lachman test, which involves assessing the amount of anterior tibial translation on a fixed femur by an examiner. Positive results suggest an ACL rupture; the severity is graded by the distance of the translation (R. Eberl 2019). The pivot shift test represents the functional, dynamic instability of an ACL-deficient knee by internally rotating the tibia (Kim SJ et al., 1995), and the anterior drawer test checks for translation of the tibia anteriorly with the patient lying supine on an examination table with knees flexed to 90 degrees (Kim SJ et al., 1995). This tests the integrity of ACL by measuring the heel reaction to downward stress on the quadriceps, known as the Lever sign test (Lelli et al., 2016). Anterior laxity can be quantified with the KT-1000, which is an especially useful assessment of ACL integrity.

For ACL damage, MRI is a common tool used to diagnose the injury, even though it can typically be palpated upon clinical assessment. MRI is the most commonly used test with a sensitivity of 86% and specificity of 95% for ACL disease. Significantly, even partial and full tears, as well as continual injuries, are identified in knee arthroscopy. Arthrography is rarely used for the first diagnostic step, even though it is considered the gold standard due to its high specificity (95% to 100%) and sensitivity (92% to 100%), given that this technique has an invasive nature and requires anaesthesia. MRI has a sensitivity of 97 % and specificity of 100%, rendering it highly effective in confirming the viva diagnosis whilst assessing any associated injuries. Typical MRI signs of ACL injury are primary features such as edema, increased ACL signal intensity on T2-weighted or proton density imaging, irregularity or absence of ACL fibres, and altered course of the ACL (Atik OŞ et al., 2015; Wu F et al., 2022; Xu B et al., 2018).

ACL injury trial manifestations contained bone marrow edema, particularly in the tibia and femur, Segond fracture, accompanying medial collateral ligament injury with a nutrient foramen of 1 mm or more, and anteroposterior tibial translation relative to the femur of at least 7 mm. Anteroposterior (AP), skyline or merchant, lateral, and sunrise views radiographs can rule out bony fractures or other osseous injury, but are most likely not diagnostic for ACL problems. They may additionally show evidence of joint effusion or more specific findings such as a Segond fracture (Shaikh H 2017), arcuate sign (Kushare I 2021), the deep sulcus terminalis sign, or a deep lateral sulcus sign. Despite its limited role in diagnosing ACL tears, computed tomography (CT) can provide information on the overall bone stock for revision cases and identify areas of bone loss secondary to tunnel widening or osteolysis at high sensitivity and specificity.

A patient-centered ACL management strategy where both surgical and non-surgical treatments are considered appropriate has been recommended (Diermeier et al., 2020). Considerations regarding the ideal treatment concept. Complicating factors such as age of the patient, activity level, participation in sports, and health status of other knee supporting structures that affect the recommended desired treatment for ROM should also be discussed. During the acute phase, patients are often treated with "RICE" therapy, which stands for rest, ice, compression, and elevation of the injured knee. Patients should limit their activities and avoid weight-bearing. And they may have to use a wheelchair or crutches to move about. Treatment might vary depending on the discretion of the treating physicians, but OTC drugs such as NSAIDs are commonly used in pain management.

Non-surgical management is typically the more appropriate approach for patients with a low-grade ACL laxity, especially those who are less active or participate in sports without cutting and pivoting (Giummarra et al., 2022). These people usually have physiotherapy and life style interventions for management of symptoms. Partial ACL tears could also be feasible for non-operative treatments. Most patients will be medically managed in the acute phase initially, before being referred to a 12 week structured physiotherapy program. The aim of Physiotherapy advancement is to target Key muscle groups- Quadriceps, Hamstrings, Hip abductors and core muscles along (Return with full range of motion). On the other hand, non operative treatment may put such patients at risk for continued severe “giving way” episodes that can increase meniscal and articular cartilage damage, particularly in individuals who participate in activities involving heavy loading and/or side to side sports. The available studies examined the repair and reconstruction of the ruptured ACL for the operative management of ACL injury. In the meantime, ACL repair is generally recommended for complete ACL tears in younger active individuals or older and active patients over 40 (Pang L et al., 2022). The principle of restoration is to restore subsequently anatomical ACL stability, which lowers the risk of more meniscal or chondral injuries. The benefits of preoperative rehabilitation include improved chances for full range of motion and reduced risks of post-surgical complications. At a population level, activity limitation can be challenging in this group of patients, but reconstruction may also be indicated in paediatric cases. In addition, even partial ACL ruptures associated with functional instability may be repaired. Some are functional, some psychological, and some demographic variables contribute to the return to sports after rehabilitation.

The surgical techniques to enhance the delicious (Prime Archive) reconstruction of torn ACL by (Acronym: arthroscopy:lio>) ijnbf Graft bed can be prepared by two methods; in 1st method all remains of native ACL are cleared (preferred if primary reconstruction) and 2nd method is to keep stump which guides tunnel placement and systemically enhances healing. Single-bundle reconstructions are performed in addition to the double bundles, though the former is done more often. The femoral tunnel can be drilled either transtibially or via a tibia independent method, while the tibial tunnel must be positioned with respect to certain anatomical landmarks; The ORIF of SC is an open surgery with multiple potential surgical approaches based on the position and orientation of the graft in comminuted or segmental fracture types. The critical sections are graft placement followed by fixation which can be interference screw, cortical (washers posts), screws, buttons or staples fixation [10] Reoperation rates after ACL reconstruction have decreased; however, there has been a resurgence in the use of ACL repair techniques — particularly in children, he noted. These include bridge-enhanced ACL repair (BEAR), internal brace ligament augmentation (IBLA), and dynamic intra-ligamentary stabilisation (DIS) [22]. Failed primary surgery often necessitates revision of ACL reconstruction, with reasons that include understanding the cause of re-rupture; evaluating neglected concomitant injuries; and selection of second-time grafts like quadriceps tendon, hamstrings, or allografts. Autograft harvest is another variable that influences cost, with some studies suggesting that the cost of ligament substitution may be higher if hamstring autografts result in hamstring weakness and longer recovery times (Sim K et al., 2022).

Both intra- and postoperative ACL issues can be problematic in their management (Heard WM et al., 2013;Musahl V et al., 2022). These may include graft tunnel mismatch with the suture limbs tensioned, leading to tibial bone plug prominence if the graft is longer than the combined length of the femoral and tibial tunnels. Malpositioning of the tunnels, especially on the femoral side, may result in residual ROTATIONAL INSTABILITY (de Padua et al., 2021). A further complication that must be considered is the risk of posterior wall blowout, which can sometimes be addressed by means of appropriate tunnel drilling. Examples of other possible complications include graft failure from causes including hardware breakage or poor fixation. Self-missed diagnoses of associated ligamentous injuries or bony malalignment may also result.

Infection and septic arthritis, though rare, are of paramount concern. Contamination during surgery or dropping grafts on the floor are risk factors, which can be controlled by soaking the cornea in antibiotics. Most cases of infection present clinically within 2 to 14 days postoperatively and are managed by incision and drainage in conjunction with an appropriate antibiotic. In the postoperative setting stiffness and arthrofibrosis are prevalent complications that result from preoperative loss of range of motion. Avoidance by using preoperative physiotherapy and cryotherapy and treatment of stiffness with aggressive postoperative physiotherapy. The other drawbacks were infrapatellar contracture syndrome, tunnel osteolysis, patellar tendon rupture, patella fracture, complex regional pain syndrome, and long term osteoarthritis (Wang LJ et al., 2020) as well as saphenous nerve irritation and cyclops lesion formation (Noailles T et al., 2019). Management of each type of complication is critical for a successful patient outcome.

Over the years, multiple studies have been done on ACL surgery outcomes and rehab. Most research seems to be focused on the appreciation of injury prevention and balance perturbation training (Bulow A et al., 2021). Perturbation training, often using dynamic sport-specific proprioceptive tasks, is commonly included in the late stages of ACL rehabilitation after surgery to reduce the likelihood of re-injury and possibly correct how the initial injury occurred.

Another said that the rehabilitation ideas of the ACL replacer are becoming rapidly evolved. A literature review from 2005 showed that knee braces after ACL reconstruction with additional perturbation training programs have important function in non-operative, preoperative and postoperative rehabilitation plays. They also studied criteria based progression in the latter stages of ACL repair rehabilitation (including return to sports). Ultimately, the study concluded that well-designed and properly conducted RCTs with standardized reporting are required to be done using appropriate outcome measures and durations of follow up. Therefore, the literature indicates the necessity of a strong randomised control trial in rehabilitation with validated outcome measures and over prolonged a period (Lorenz D et.) Many studies have shown that eccentric overloading training has a good effect on the recovery of ACL repair.

As do concentric conditions, however, eccentric muscle activation is essential for functional, daily activities and sports. ~ This makes eccentric & concentric exercise and testing all the more important. The availability of active dynamometers has made it possible to isokinetically measure the capacity of muscles to develop tension under eccentric conditions of muscle action. Several of the isokinetic features have been well scrutinized. There is also limited research on isokinetic eccentric exercise.

There is clear evidence that a muscle group is capable of generating a greater moment eccentrically (while being stretched) at a given constant joint velocity than when the same muscle group generates force during an isometric or concentric action. Actually, the max moment with 3 parameters is different as eccentric > isometric > concentric (Herzog W, 2018). It is not clear what is driving this increased force during the eccentric phase of an isokinetic contraction, but it was theorized that the heightened activation may be influenced by what Grabiner. Also the mechanism for cross bridge detachment is different during eccentric activations compared to concentric actions [35]. Because with the eccentric activations, we are not requiring any energy for cross bridge detachment and we have more force generation by the cross-bridges. Eccentric activity might therefore explain the higher tension produced at a given velocity. The muscle works in the opposite direction of work, and consequently the contractile parts are less activated than in normal conditions**. It is signified by the lesser electromyography (EMG) activity of muscles as opposed to concentric activities (Barker L et al., 2024). Thus, many individuals have proposed that fewer motor units are recruited when the muscle is working eccentrically compared to concentrically. The additional cost at which performed during the eccentric parts is generated by its elastic elements. Performing eccentric work before a concentric effort better increases the tension produced by the eventual focus on increasing force generation. We hypothesize that this can be explained by the elastic elements influencing muscle force, which is likely related to utilization of elastic energy during lengthening of the muscle. In the work by Griffin et al. (1993), knee and elbow flexors and extensors were evaluated equally for both eccentric and concentric conditions (300 eliminations/sec and 1200 eliminations/sec; two maximal reps). There was no significant difference between the moment-velocity relationship for males or females. The average eccentric moment of the upper and lower extremities was similar as speed increased. The velocity of the movements is also an important factor, and muscle groups have been shown to vary in eccentric compared with concentric strength (Griffin et al., 1993). During most normal functional tasks, such as elevation of the arm or rising from a chair, contraction velocity exceeds that achieved under most laboratory conditions. Furthermore, Westing and Seger reported that the gravity-uncorrected quadriceps eccentric moment was significantly lower than the corrected ($P < 0.001$), while the hamstrings gravity-uncorrected moment was significantly higher than the corrected ($P = 0.036$). There was no effect on concentric moments. Nonetheless, Westing SH et al. (1989) found no effect of increasing angular velocity on the gravity-corrected peak isokinetic eccentric quadriceps moment during any portion of gait, nor did we observe changes in either quadriceps or hamstrings peak gravity-corrected moment with increasing angular velocity during eccentric tests. Considerable research has focused on the use of isokinetic exercise for both assessing and treating muscular and ligamentous injuries. The ability to accurately measure the moment generated and the ideal muscle loading during joint movement makes isokinetic devices a clinical tool in the physical rehabilitation area. Using this device for training is also recommended for muscular strength recovery after acute soft injuries (Pelegrinelli AR, et al., 2018). In this paper [7, 8, 14–16], most of the research in terms of isokinetic concentric training was focused towards rehabilitation settings. Our literature search identified a small number of isokinetic eccentric training clinical studies. Although some studies did find differences of clinical significance in moment production between healthy vs. injured or various populations with dysfunction [12, 13]. A study by Shirakura et al. revealed that, in comparison between 30 patients with ACL and 19 patients with PCL injury, isokinetic maximum moments for the eccentric and concentric maneuvers were less on the injured compared to the non-injured knees (Shirakura K et al., 1992). Subjects then warmed up with 5 isokinetic eccentric-concentric cycles of the knee extensors at 600 /sec. Conclusion: The differences in eccentric and concentric moments were found to be significant on both sides. This was seen in ACL-injured individuals at extension angles less than 45° and in those with PCL injury at flexion angles less than 36° (Shirakura K et al., 1992). Jonhagen reported that healthy control athletes had significantly higher values for eccentric moments of the knee extensors and flexors at all velocities than those obtained in our study on athletes with hamstring injuries. There are Concentric moment deficits only at slow angular velocities (Jonhagen S, 1994).

Isokinetic Eccentric Exercise Programs in Rehabilitation

Some previous studies had applied isokinetic eccentric exercise in pathological joint or neuromuscular conditions. According to Stanish et al. (1986), it was also demonstrated that eccentric exercise was highly efficient in patients with chronic tendinitis. Stretch, followed by eccentric activations coupled with ice proved effective in a rehabilitation programme for individuals with this dynamic dysfunction. It was recommended that strength training be activity-specific to help prepare the tendon for its proposed task (Stanish WD et al. 1986). Jensen and Fabio also examined an 8-week programme of isokinetic eccentric exercise plus home stretch-training, but found no superiority in strength improvements with respect to those who only did home stretching (Jensen K et al., 1989). In addition, isokinetic exercise should be individualized to the specific injury and phase of rehabilitation and be periodically combined with monitoring other variables such as flexibility, proprioception, functional ability and physiological parameters of the injured person. Several studies have proposed that; eccentric training may also serve for the purpose of rehabilitation of musculoskeletal injuries and diseases [1, 2]. Eccentric training, which is associated with less muscle damage and greater increase in strength compared to concentric training, may also be a useful tactic for patients with limited exercise capacity, given the reduction in maximal oxygen uptake during negative work. This mode of training might in addition enable patients to use energy more economically and, consequently, to do more work using less energy expenditure and associated fatigue.

1.2 RESEARCH GAP

As per the literature review, many rehabilitation protocols were proposed to such patients who had undergone anterior cruciate ligament reconstruction surgery. Isoinertial concentric-eccentric maximal exercise sessions were effective in protecting subjects from clinical signs of muscle damage and DOMS after training, and they are now gaining importance as rehabilitation steps for several post-surgical rehabilitative protocols. But the treatment method itself is not enough to provide the comprehensive benefits. During the search, it was found that very few cases were implemented as combination therapy and there is lack of combined effects on Isoinertial training for eccentric strengthening after Anterior Cruciate Ligament reconstruction surgeries.

1.3 NEED OF THE STUDY

The study is pertinent given the important role that eccentric muscle function appears to play in human movement (particularly high force fast stretch-shortening cycle (SSC) tasks, essential for most athletic performance such as jumping and sprinting). Although chronic eccentric training has shown promise for increasing leg spring stiffness and SSC performance, there is a lack of information surrounding the direct relationship between high force locomotive activities in trained athlete and eccentric muscle activity. Conversely, chronic eccentric training studies frequently exclude resistance-trained athletes adhering to a more ecologically valid physical preparation program, limiting the external validity of observations. Furthermore, the place of isoinertial eccentric overload strength training in post-ACL reconstruction rehabilitation programs needs to be clarified and a reference intervention should be described. Hence, it is imperative to elucidate the role of eccentric muscle function in athletic performance and design evidence-based treatments for post-ACL reconstruction rehabilitation programs.

1.4 RESEARCH QUESTION

- Whether the Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol will increase the Muscle Power, Endurance

Isometric strength, Balance, knee related QoL and function of patients undergoing reconstruction surgery on ACL?

1.5 RESEARCH OBJECTIVES

1.5.1 Primary objectives

1. To assess the impact of Isoinertial eccentric training on Endurance, Muscular Power and Isometric strength in patients undergoing ACL reconstruction surgery when combined to traditional rehabilitation regimen.

2. To evaluate the effects on Muscular Power, Endurance, and Isometric strength of Isoinertial eccentric strengthening vs traditional rehabilitation routine in patients who have had anterior cruciate ligament (ACL) reconstruction surgery.

1.5.2 Secondary objectives

1. To assess how well Isoinertial eccentric strengthening works in conjunction with traditional rehabilitation protocols for patients who have undergone reconstructive surgery on their ACL, with regard to knee injury, knee related QoL, and Balance.

2. To evaluate the impact of Isoinertial eccentric strengthening in conjunction with conventional rehabilitation protocol versus conventional rehabilitation protocol alone in patients who have undergone reconstruction surgery on the ACL, with respect to Balance, knee injury, knee related QoL.

1.6 HYPOTHESIS

1.6.1 Alternate Hypothesis

$H_1$1 = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Muscle Power.

$H_1$2 = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on muscle Endurance.

$H_1 3$ = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Isometric strength.

$H_1 4$ = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Balance.

$H_1 5$ = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on knee related QoL and function.

$H_1 6$ = There is statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on pain and function outcome of knee.

$H_1 7$: There is statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on Muscle Power.

$H_1 8$: There is statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on muscle Endurance.

$H_1 9$: There is statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on Isometric strength.

$H_1 10$: There is statistically significant effect of conventional rehabilitation protocol in only patients with ACL reconstruction surgeries on Balance.

$H_1 11$: There is statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on knee related QoL and function.

$H_1 12$: There is statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on pain and function of knee.

1.6.2 Null Hypothesis

$H_0$1: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Muscle Power.

$H_0$2: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on muscle Endurance.

$H_0$3: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Isometric strength.

$H_0$4: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on Balance.

$H_0$5: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on knee related QoL and function.

$H_0$6: There is no statistically significant effect of Isoinertial eccentric strengthening in combination with conventional rehabilitation protocol in patients with ACL reconstruction surgeries on pain and function outcome of knee.

$H_0$7: There is no statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on Muscle Power.

$H_0$8: There is no statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on muscle Endurance.

$H_0$9: There is no statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on Isometric strength.

$H_0$10: There is no statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on Balance.

$H_0$11: There is no significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on knee related QoL and function.

$H_0$12: There is no statistically significant effect of conventional rehabilitation protocol only in patients with ACL reconstruction surgeries on pain and function of knee.

CHAPTER-II

LITERATURE REVIEW

This section outlines the research conducted to identify relevant literature and highlights the number of articles retrieved from various databases on the topic. 757 articles were reviewed, out of which the following articles were found to be directly relevant and included in this study. The articles were retrieved from various academic databases, including PubMed, Scopus, CINAHL, and Google Scholar, ensuring a comprehensive review of the available literature. The literature provides a comprehensive review of published, applicable studies authored by distinct researchers on the subject under investigation. It consolidates data within the specified domain, facilitating the identification of information, details, and methods pertinent to the study.

This chapter presents literature review that has been explained under following headings:

- Literature review on applied anatomy, biomechanics, patho-mechanics of ACL Injury
- Literature review on epidemiology, assessment strategies, surgical management programs in case of ACL Injury
- Literature review on Physiotherapy Management in Post-operated ACLR patients

2.1 APPLIED ANATOMY OF KNEE JOINT

Adjustment of the hinge joint is known as the knee, which permits rotation and flexion as well as maintaining control and stability when loaded in diverse ways (Simon et al., 2000). It consists of two major joints, namely, the femorotibial joint and the patellofemoral joint. The stability of the knee joint is supported by the bony construction of the femur, tibia, and patella in combination with the static and dynamic constraints provided by the ligaments, the joint capsule, and surrounding muscles. The structural design of the bones partially determines the range of motion permitted by the joint. The femorotibial joint, the largest joint in the body, consists of two condyloid articulations. The medial and lateral femoral condyles articulate with their respective plateaus of the tibia. Interposed between these structures are menisci, which facilitate knee rotation (Meister et al., 2000).

The femoral condyles have a cam-like structure. The medial condyle extends farther distally in the AP projection and has a wider radius of curvature than the lateral condyle. The lateral projection’s terminal sulcus and popliteus insertion groove identify the lateral condyle, which extends anteriorly in relation to the medial condyle. A convex, circular lateral plateau and a concave oval-shaped medial plateau are separated by the intercondylar eminence on the proximal tibia. The knee’s AP orientation and valgus alignment are influenced by this discrepancy. On the tibia, the medial condyle of the femur can spin in three different directions and translate somewhat in the AP direction. On the other hand, the lateral femur is free to translate AP at a transverse axis, and most often near full extension, but has free AP translation. The 3-degree lateral tilt of the tibial plateau with respect to the joint line, added to the posterior slope of 9 degrees, provides an overall valgus, posterior-inferior tilt of 10 to 12 degrees in most knees (Fineberg et al., 2000).

2.2 BIOMECHANICS OF KNEE JOINT

The biomechanics of the knee joint involves a complex interaction between its anatomical structures and the forces acting on it, enabling a range of movements essential for daily activities and athletic performance (Lack et al., 2014). The menisci, two C-shaped cartilaginous structures, act as shock absorbers and improve weight distribution. The knee primarily performs flexion and extension, but it also allows for a small degree of internal and external rotation, especially when the knee is flexed. The forces acting on the knee joint include compressive forces during weight-bearing activities, shear forces during dynamic movements like twisting, and tensile forces that are resisted by ligaments like the ACL and PCL.

The knee functions as part of the kinetic chain, meaning its movements influence and are influenced by other joints like the hip and ankle. In a closed chain kinetic exercise (such as squatting), the foot is fixed, providing stability to the knee, while in an open kinetic chain (such as leg extensions), the foot is free, allowing for isolated muscle activation. The quadriceps and hamstrings play key roles in controlling knee movements, with the quadriceps extending the knee and stabilizing it during weight-bearing activities, while the hamstrings assist in knee flexion and control the speed of knee extension. The biomechanics of the knee are critical not only for movement but also for stability and shock absorption (Goh et al., 1995). When any component of the knee joint, such as muscles, ligaments, or cartilage, is compromised, it can lead to path-mechanical issues like knee osteoarthritis or ligament injuries, affecting its function. Understanding the biomechanics of the knee is essential for injury prevention, rehabilitation, and optimizing performance in both clinical and athletic settings (Lack et al., 2014).

2.3 PATHO-MECHANICS OF KNEE JOINT

Because the patellofemoral joint is a shallow and nonconformist one, it requires the functioning of all static and dynamic soft-tissue stabilizers (Grelsamer & Klein, 1998). The static stabilizers- Patellar tendon and joint capsule and ligamentous structures. The normal restraint is approximately 60 per cent in the restraint provided at 20 degrees of flexion of the knee (Powers et al, 1996) MPFL or that ligament structure, which leads from the adductor tubercle to the medial border of the patella, offers about 60 per cent of the entire restraint. The medial secondary restraints are the medial meniscopatellar ligament, originating from the anterior menisci and the inferior third of the patella, in combination with the medial retinaculum, stabilizing distally to form a complete medial collateral ligament and medial patellar tendon. Counterclockwise, there is some lateral support from the iliotibial band (ITB), joint capsule, lateral patellofemoral ligament and lateral retinaculum. Superficially, it connects the ITB to the patella and quadriceps expansion;deeply, it interdigitates caudally with the vastus lateralis and rostrally at least in part with the patellofemoral ligament and perhaps also the patellotibial ligament. The bony stability at knee flexion angles less than 20-30 degrees is very minimal and the joint relies primarily on the medial and lateral retinaculum and joint capsule.

\Dynamically, the stability of the patellofemoral joint is maintained by the quadriceps, the pes anserine muscle group, and the biceps femoris. The vastus medialis oblique (VMO) is particularly significant in patellar alignment due to its oblique orientation, which provides a medial stabilizing force (Desio et al., 1998). The VMO attaches to the mid-patella, MPFL, and adductor magnus tendon, while the rectus femoris inserts on the superior anterior aspect of the patella. These dynamic and static structures work together to ensure the alignment and stability of the patellofemoral joint, particularly during movement.

2.4 EPIDEMIOLOGY OF ACL INJURY

Recurrent Ruptures are common injuries. This data was reported in an epidemiology study on injuries across 25 NCAA sports. The researcher identified NCAA ISP athletes who had an acute, primary, or recurrent ACL rupture between 2004 and 2014. There were 1105 ACL injuries reported from 350,416 athlete-exposures (AEs), and of those, 126 were classified as repeat injuries. Male footballers had the highest reinjury rate of the ACL, followed by female gymnasts and football players. Surprisingly, female soccer players were significantly more likely to have recurrent ACL ruptures than their male counterparts, suggesting of AD for sex (e.g., RR = 3.2; CI = 1.4–7.5). Overall, males had a higher rate of recurrent ACL ruptures than females, but the rate was reduced for both sexes over time (Gans et al., 2018). The findings support the idea that athletes who present higher risk factors for relapse of ACL injuries after surgery need to be identified in order to establish targeted injury prevention programmes.

More than 200,000 ACL injuries occur in the US annually, with as many as 90% of patients undergoing an ACL reconstruction (ACLR). The popularity of surgery is not paralleled by results, as the literature suggests that for many patients outcomes are less than optimal. Up to 50% of athletes fail to return to their pre-injury level after ACLR and a significant percentage develops knee osteoarthritis within 5-10 years. Because of the high rate of poor outcomes following primary ACLR, much recent attention has been focused on preventing second ACL injuries (Paterno 2015). Conclusions, prevention was effective in reducing primary ACL injury rates (Lenhart et al.)

This was a retrospective descriptive study to describe the prevalence pattern of ACL injuries and our patient demographics that occurred in Nepal at the tertiary trauma unit. With 237 randomised participants, two-thirds of whom were young men aged between 15 and 30, the trial ran from February 2018 to January 2020. RTAs accounted for 38.8% of all ACL injuries, followed by sports-related injuries (33.3%)

and falls (16.5%). Only two-wheelers were the most common mode of transport, leading to RTA, and football was responsible for most ACL injuries. Moreover, patients under 30 had a significantly higher incidence of sports-related injuries (62%) compared to their elder counterparts, and individuals over 30 years dominated with RTAs/-MVCs. Among students, sports accounted for the majority of ACLs and among office workers RTAs [Joshi et al., 2022]. The findings emphasize the importance of RTAs as a leading cause of ACL injuries in Nepal, which is different from Western countries, where sports-related injuries are more common.

A study was conducted in 2016 by PGIMER Chandigarh, to document types and patterns of prevalent knee Injuries among Indian Athletes and related demographic factors. Methods of the study: Halladay and colleagues analyzed complete data for 363 athletes (77%) out of a total of 465 athletes with sports-related knee injuries that were prospectively referenced over five years. Some of such sports are: soccer (30.6%), which was closely followed by kabaddi (20.9%), among others, as the analysis of data revealed. Competitive injuries were the most frequently recorded noncontact mechanisms (64.4%) and surpassed the practice/training injuries ($p<0.001$). The most prevalent injury was the ACL (314 injuries often in combination with the meniscus injuries). The proportion of athletes returning to sport with respect to therapy was 39.8 percent, and the average turnaround time to reemerge back to sport was 8.84 months. BMI, level of competition by the athlete, and management had an imminent relationship with the return to sport (John et al., 2016). The importance of the topic to athletes' careers really stuck with us, and suggested that not only do knee injuries appear to be a principal player in altering the course of an athlete's career, but also future research ideas should perhaps focus more on prevention strategies and emerging good quality epidemiological study designs tailored toward informing injury prevention policy across ALL levels of athletic involvement.

2.5 ASSESSMENT STRATEGIES FOR ACL INJURY

The NACOX project sought the purpose of understanding the therapeutic decision-making process involving anterior cruciate ligament (ACL) damage based on the viewpoints of patients, orthopaedic surgeons and physiotherapists. The results were received from 101 patients, orthopaedic surgeons, and physiotherapists who were requested to fill in the Shared Decision-Making Process (SDMP) questionnaire along with their decision on the use of ACL reconstruction surgery (ACLR) or non-reconstruction (non-ACLR) treatment. The four big questions touched on the following areas: knowledgeable patient, to be listened to, engagement and collaboration. Results indicated extraordinarily high satisfaction levels of patients based on the aspects of being heard and being in agreement with the treatment decision, as 75-98 per cent stated they are having their needs met in such aspects. Compared to those in the ACLR group, the non-ACLR group of patients showed reduced satisfaction with the information provided by orthopaedic surgeons as well as with their participation in the process of decision making (Mason-Bish, 2019). This lays stress on the significance of better communication and patient participation in the non-ACLR decision-making process.

2.6 POST-SURGICAL OUTCOME IN ACL RECONSTRUCTION

Two studies assessed extractors and reviewers for a review managing postoperative pain after anterior cruciate ligament reconstructions (ACLR) – an everyday musculoskeletal sports medicine procedure that carries out annually around 130,000 arthroscopic surgeries (Ioanna et al., 2021). Conclusion: Although the clinical outcomes of ACLR are excellent, persistent pain is still a primary postoperative complaint, which leads to delayed patient discharge as well as increased health care expenditure. Historically, traditional pain management approaches had moved from the era of opioid monotherapy to one focused on multimodal approaches, including nerve blocks, local anesthetic injections, NSAIDs, ketamine, tranexamic acid (TXA), sedatives and adjuncts such as gabapentin and corticosteroids. These medications are often used together to decrease postoperative pain, narcotic use and subsequent delayed discharge (Bolia et al., 2021). Objective: The aim of this review was to examine and summarize the extant literature for pharmacologic approaches to postoperative pain following ACL reconstruction, specifically focusing on individual opioids and other pharmaceutical agents (as monotherapy or part of a multimodal regimen).

A different research is regarding the safety and functional outcome of arthroscopic anterior cruciate ligament (ACL) reconstructive surgery with Sironix titanium button vs. polyetheretherketone (PEEK) button. Thirty-one patients who underwent primary systematic ACL reconstruction between August 2022 and January 2023 in a tertiary hospital were enrolled in this study. An assortment of functional outcomes measured with the IKDC questionnaire, TAS, Lysholm score, QoL subscale of KOOS and SANE have been reported. Side effects related to the device were also noted. The outcomes post-surgery such as IKDC, TAS, Lysholm score, QoL subscale of KOOS and SANE score, showed significant improvement in the scores, with mean scores increased. Noteworthy, there were no reported negative device effects demonstrating the safety and efficacy of Sironix knee implant devices in ACL reconstruction as well as meniscus repair surgery. The study concluded that it is so safe and effective to use Sironix knee implants for ACL restoration surgeries (Kumar et al., 2016).

2.7 PHYSIOTHERAPY MANAGEMENT FOLLOWING ACL REPAIR

That the muscles become resistant to very powerful eccentric lengthening contractions, something that can help them heal and work better (over obstacles). Muscle contract eccentrically to adequate the accumulation of elastic recoil energy for a concentric contraction (shortening contraction) and get ready to discharge energy in assisted deceleration. In nature, the work required to lengthen muscle fibers is minimal, however, the muscular forces that are generated during this stretch can be significant enough to improve body performance (Lastayo et al., 2009). In the past, muscle damage response had been attributed primarily to high-force eccentric contractions. In this clinical commentary we investigate the ability of the muscle-tendon system to remodel in response to increasing eccentric muscle strains, and discuss functional and anatomical consequences. Injury to the muscle-tendon is not a necessary response! Instead, the tendon adapts to higher pressures as a larger muscle matures and alters spring properties improve the power. Thus, the reviews are both basic and clinical results. The authors investigated the type of structural changes that occur and how these changes contribute to musculoskeletal flexibility, enhancement in sporting performance and the prevention of musculoskeletal injuries.

Conclusion: Eccentric isokinetic training improved sagittal and coronal knee kinematics during locomotion in subjects nine months after ACL surgery.

Background complete evaluation of the knee kinematics after anterior cruciate ligament (ACL) surgery is needed to determine the effectiveness of rehabilitation programs. The other parameter flexion/extension of knees has been studied a number of times and the valgus and varus values were not accounted. The frontal plane movement of the knee also needs to be studied due to the problem of stability in the joints involved in the restoration of ACL. An isokinetic dynamometer was used to examine the knee extensor torque and goniometry was utilized nine months following ACL repair to measure flexion/extension and valgus/varus of a walking motion measured by angular changes and velocity. After training the eccentric isokinetic quadriceps in five subjects, three months later the analysis was carried out again. Ten healthy controls were also taken to measure the gait pattern. The gait was enhanced with a vast change in knee extensor torque and flexion/extension range of motion after training. The reconstructed ACL knee however recorded the unexpected increase in valgus, peaking during the swing phase of movement and this may have adverse consequences to the knee. Nevertheless, crosstalk has the potential to lead to over reporting of the valgus angles (Coury et al., 2006). Therefore, the quantity of the increased valgus together with the mechanisms and the functional and clinical consequences have to be elucidated prior to the stance that eccentric training after reconstruction of ACL tends to be recommended widely.

2.7.1 Rehabilitation Exercises

Studies have highlighted the adverse effects of knee immobilization following anterior cruciate ligament (ACL) reconstruction, yet there remains a limited understanding of the optimal level of activity required for effective rehabilitation without compromising graft integrity or articular cartilage health. A study was carried out using a randomized controlled trial in order to understand the effects of accelerated and nonaccelerated rehabilitation on anterior-posterior knee laxity, clinical outcomes, patient satisfaction, functional performance, and synovial fluid levels of cartilage metabolism. Twenty-five patients underwent reconstruction of the ACL through a bone-patellar tendon-bone graft and were randomly divided into any of the two protocols of rehabilitation. Surgery assessments were performed and assessments taken after 3, 6, 12, and 24 months. The results of the two-year follow-up showed that there are no significant differences between the two groups when it comes to anterior knee laxity, clinical examination, patient satisfaction, activity level, and functional outcomes or biomarker reaction. Both types of rehabilitation surpassed the anterior knee laxity by similar margins (2.2 mm versus 1.8 mm compared to the uninjured knee) and yielded no superior advantages associated with one over the other. Notably, markers of cartilage metabolism, such as collagen synthesis and aggrecan turnover, remained elevated in both groups even after a year of healing, raising concerns about prolonged cartilage remodeling. These findings suggest that both accelerated and nonaccelerated rehabilitation protocols can be used interchangeably without compromising clinical outcomes; however, the long-term implications of persistently elevated cartilage biomarkers warrant further investigation (Beynnon et al., 2005).

The debate surrounding the efficacy and safety of open kinetic chain (OKC) versus closed kinetic chain (CKC) exercises in ACL rehabilitation has led to numerous studies examining their biomechanical effects, impact on graft healing, knee function, and patient satisfaction. CKC exercises are often preferred due to their ability to reduce anterior shear forces on the tibia, increase tibiofemoral compressive forces, and enhance muscle co-contraction, which may protect the reconstructed graft and aid in functional restoration. In contrast, OKC exercises, particularly at higher resistance levels, have been associated with increased ACL strain but are also beneficial for isolated quadriceps strengthening, which is crucial for knee stability and functional performance (Braden C. Fleming, Heidi Oksendahl, 2004).

Biomechanical studies indicate that CKC exercises, such as squats and leg presses, generate lower anterior shear forces compared to OKC exercises like knee extensions. Additionally, CKC exercises improve tibiofemoral stability, reduce patellofemoral compressive forces near extension, and facilitate better neuromuscular control. However, in vivo strain data suggest that while CKC exercises minimize ACL strain, they do not completely eliminate it when the knee is near extension (around 30°). Furthermore, weight-bearing compressive loads applied to the tibiofemoral joint do not necessarily "shield" the ligament from strain, as previously thought (Braden C. Fleming, Heidi Oksendahl, 2004).

Clinical trials comparing OKC and CKC rehabilitation protocols have yielded mixed results. Some studies suggest that OKC exercises may contribute to increased joint laxity and patellofemoral discomfort, whereas others report no significant differences in knee stability, patient satisfaction, or functional outcomes between the two exercise types. Additionally, research comparing CKC-based rehabilitation with a combined CKC-OKC protocol suggests that incorporating OKC exercises may lead to better functional recovery and an earlier return to sports without compromising knee stability (Braden C. Fleming, Heidi Oksendahl, 2004).

The current evidence supports the integration of both OKC and CKC exercises in ACL rehabilitation, as neither appears to have a detrimental effect on graft healing, knee function, or patient satisfaction when appropriately controlled. While biomechanical studies highlight differences in knee loading patterns, direct ACL strain measurements suggest that these differences may not be clinically significant. Given the task-specific nature of muscle strengthening, a combination of OKC and CKC exercises may be necessary to fully restore function in ACL-reconstructed patients. However, further randomized controlled trials are needed to determine the optimal timing and progression of these exercises in rehabilitation protocols.

2.7.2 Electrotherapy in ACL Rehabilitation

ACL injuries are among the most common ligamentous traumas, particularly in athletes, often resulting in significant pain and functional impairment. Postoperative rehabilitation is crucial for restoring knee function, reducing pain, and regaining range of motion (ROM). Transcutaneous electrical nerve stimulation (TENS) has been brought into consideration as a non-invasive, cost-effective, and conservative use of pain management in the initial phase of ACL rehabilitation. However, its efficacy in improving functional outcomes beyond exercise alone remains unclear.

A randomized single-blind clinical trial investigating the role of high-frequency TENS in the first phase of ACL rehabilitation (0–4 weeks) examined its impact on pain relief, knee function, and ROM recovery (Forogh et al., 2019). The study included 70 male athletes who underwent ACL reconstruction, divided into two groups: one receiving semi-supervised exercise plus TENS, and the other performing exercise alone. The intervention lasted for four weeks, with outcomes assessed using the Visual Analog Scale (VAS) for pain, the International Knee Documentation Committee (IKDC) questionnaire for knee function, and knee flexion ROM measurements at baseline, four weeks, and 14 weeks post-surgery. The results demonstrated significant improvements in pain reduction, knee function, and ROM in both groups over time. However, no significant additional benefits were observed in the TENS group compared to the exercise-only group, indicating that TENS did not enhance rehabilitation outcomes beyond the effects of structured exercise alone. Mixed ANOVA analysis revealed no significant interaction effects between time and group allocation on outcome measures. The findings suggest that while pain management is a critical component of ACL rehabilitation, the addition of TENS to an early-phase exercise protocol does not provide additional functional or analgesic benefits. Rehabilitation programs should continue to prioritize evidence-based interventions such as progressive exercise therapy, neuromuscular re-education, and manual therapy to optimize recovery. Further research is warranted to determine whether variations in TENS parameters, treatment duration, or patient populations could influence its effectiveness in ACL rehabilitation (Forogh et al., 2019).

Neuromuscular electrical stimulation (NMES) has been explored as a potential adjunct to traditional rehabilitation programs following anterior cruciate ligament reconstruction (ACLR). However, the effectiveness of NMES in enhancing quadriceps strength, functional performance, and self-reported function remains a subject of debate. This systematic literature review evaluates the available randomized controlled trials (RCTs) assessing the impact of NMES in ACLR recovery (Kim et al., 2010).

Electronic databases were comprehensively searched from 1966 to October 2008, and eight RCTs were found that fulfilled the inclusion criteria. The quality of studies in terms of methodology, estimated by the Physiotherapy Evidence Database (PEDro) Scale, gave 4/10 scores on average, which is moderate in quality. The findings highlight variability in NMES effectiveness, particularly concerning quadriceps strength. Seven studies reported effect sizes ranging from −0.74 to 3.81 for isometric or isokinetic torque at approximately six weeks postoperatively. It is notable that 6 out of 11 comparisons were statistically significant, meaning that the NMES treatment had improved the scores with statistical significance in comparison with one another. Conversely, NMES was found to have a limited effect on measurements of functional performance. The effect sizes in one study were 0.07 and 0.64 at 6 weeks post-operation, but all three comparisons failed to attain the required statistical significance. There was a possibility of self-reported functional outcomes, though. In one study, effect size was noted at 12 to 16 weeks after surgery as 0.66 and 0.72, which was statistically significant, thus showing the NMES value in the situations of perceived functions. The review highlights NMES as an added benefit to rehabilitation regimens, especially in building the strength of the quadriceps. Nevertheless, there is no clear indication of its effects on functional performance and patient-reported outcomes. Moreover, differences in NMES parameters and techniques of delivery among the studies emphasize the necessity to have unified protocols and additional quality studies to improve clinical usage of the technique, which is used in rehabilitation after ACLR (Kim et al., 2010).

High Tone Power Therapy (HiToP) is a novel electrical stimulation technique, yet its effectiveness in the patients enduring anterior cruciate ligament reconstruction (ACLR) remains largely unexplored. Given the lack of scientific reports explicitly evaluating HiToP in post-ACLR rehabilitation, this study aimed to assess its impact on quadriceps muscle strength, joint function, and overall recovery (Ogrodzka-Ciechanowicz et al., 2021).

A randomized controlled trial was conducted with 35 male patients, aged 21–50, who had undergone ACL reconstruction (Ogrodzka-Ciechanowicz et al., 2021). Participants were assessed prior to surgery and again six months postoperatively. They were erratically dispersed to either an experimental group (n=17), receiving HiToP alongside rehabilitation, or a control group (n=18), undergoing standard rehabilitation without HiToP. Rehabilitation spanned six months, with key outcome measures including muscle strength torque, range of motion (ROM), knee and thigh circumference, the Lysholm knee scoring scale, and the visual analog scale (VAS) for pain. The findings revealed statistically significant improvements in muscle torque, knee circumference, thigh circumference, and knee extension ROM in the experimental group compared to the control group. These results indicate that HiToP contributed to muscle strength enhancement, reduction in joint effusion, and improved joint mobility. However, pain reduction, as measured by the VAS scale, showed no statistically significant difference between the groups, suggesting that HiToP does not provide additional pain relief benefits in ACLR patients. In conclusion, this study supports the integration of HiToP in post-ACLR rehabilitation, highlighting its role in accelerating muscle recovery, reducing swelling, and improving joint function. However, its analgesic effects remain inconclusive, warranting further research to clarify its role in pain management (Ogrodzka-Ciechanowicz et al., 2021).

2.7.3 Eccentric ergometry

Eccentric cycling will be used to give a progressively greater negative-work exercise regimen early after ACL-R. This paper proposes that the negative work can enhance the gains in quadriceps and strength gain. A 26-year-old recreational athlete who was very active tore her ACL in January 2004 and again in February 2005 during skiing. This case was initially undergone arthroscopically supported ACL-R using a twice ring semitendinosus gracilis auto graft, then after that rupturing of the ACL graft, this poor patient underwent the interference with a patellar tendon autograft. Within three weeks of surgery, a progressive negative-work training programme was started with an eccentric ergometer. The patient completed 31 sessions of 5-30 minutes of training in accordance with the ACL-R over 12 weeks and 33 of the same frequency and duration after the revision. During the 12 weeks of training, quadriceps improved by 28 percent and 14 percent with the use of ACL-R. With the correction, quadriceps volume had been restored to its preoperative levels (2 percent reduction on the involved side and 2 percent increase on the uninvolved side). The average strength of quadriceps was enhanced to 15 weeks after the ACL-R, 20 (involved) and 14 (uninvolved) percent. After the ACL revision, the quadriceps strength was greater than that was ever recorded. This case study showed that eccentric ergometry done negatively and done in a slow and slow manner is both safe and effective in the initial stages after ACL -R (Gerber et al., 2006). Ecstatic training can ameliorate the fatigue of muscle rapprochement and strength that generally befall after ACL reconstruction. The outcomes of this case indicate a future study that requires priming work interventions in the early negative work interventions after ACL-R.

The short-term efficacy and safety of adding a progressive negative work-out exercise programme − including a steady decline in ergometric concentric (ECC)-generated eccentric (ECC) - to the initial part of an ACL- R. During ACL-R, a ramp and eccentric (ECC) ergometry-based progressive negative work exercise programme was randomly assigned to 32 patients one week after surgery and compared to a 12-week standard (TRAD) exercise programme. The level of discomfort in knees, pains in thighs, knee effusion and knee stability was measured at pre-operative level and data measured after 3 weeks, 15 weeks, and 26 weeks after operation. The effect was measured via determining the negative work output in the 12-week training programme, the functional ability (i.e., measures of the quadriceps peak torque, hopping distance, self-reported functional ability, and activity level) before the ACL-R surgery and the same aspects established after ACL-R surgery. There were also no relevant group differences when it comes to discomfort in knee and thigh, effusion, or knee and thigh stability related to any measurement in time between surgery. The adverse labour output augmented gradually in the course of training, nevertheless, the knee and thigh discomfort was not too high either. The interaction effect of group by time was significant in the quadriceps peak torque, the jump distance and the intensity of activity (P.02). ECC group measured a large gain within the quadriceps power and the hop length as compared to the TRAD group (P <.01). Activity level in the ECC group was reduced as compared to the level of activities reduction in the TRAD group (P =.02) (Gerber et al., 2006). Following the ACLR, it was implied safely negative work with the assistance of an ECC intervention. The negative work exercise ensured the desirable short term outcomes of strength, performance, and activity level after the surgery.

Eccentric training exercises and eccentric training with static stretching exercises have been used in the management of patellar tendinopathy. Group A (n 1622) was subjected to eccentric patellar tendon as well as static stretching exercises with quadriceps and hamstrings, whereas Group B (n 1621) was subjected to eccentric tendon training only. Each patient was managed five times in a week, and this lasted for a period of four weeks. The VISA-P score was applied to assess pain and the outcome of the functioning at the baseline, post-therapy (week 4), and week 24 of the study. Treatment would cause an improvement in the VISA-P scores in each of the two groups (P<0.0005, paired t-test). The change in the difference in VISA-P score between the groups was notably altered after the termination of the treatment (14; 10-18) and after the six-month follow-up (19;13-24). Eccentric training and static stretching exercises were the largest done (P<0.0005, one-way ANOVA) (Dimitrios et al., 2012). Combined with eccentric training, as compared to eccentric training, body eccentric training helps in relieving pain and improving the results of people diagnosed with patellar tendinopathy at the end of their treatment and after follow-up.

This decided to examine the clinical effectiveness of eccentric strengthening in improving the quadriceps strength following anterior cruciate ligament reconstructive surgery. The main objectives of this research were to safely fatigue or overload the quadriceps muscle after having undergone anterior cruciate ligament (ACL) replacement to ensure the quadriceps muscular weakness is kept low and this may take too long after the period of recovery. Although clinicians and researchers have tried their best to increase ACL rehabilitation strategies, there is no universal effective way of ACL rehabilitation to regain pre-injury quadriceps strength. Force producing capacity is the greatest in a muscle when an external force over equals its own as it elongates. Consequently, eccentric strengthening is better placed to enhance the muscle strength through the attraction of stressing the tissue than concentric strengthening. Conventional thinking has been to avoid high-intensity eccentric resistance training of the ACL-reconstructed limb during the early phase of recovery because hard exercise may cause injury to the ACL graft or the surrounding articular cartilage or the soft-tissue tissues. Nevertheless, the modern study implies that it is possible to start with low loads and considerably increment them slowly using eccentric training of the affected limb and safely increase muscle volume and strength in patients with rebuilt ACL (Lepley & Palmieri-Smith, 2013). Consequently, eccentric strengthening could be an option to avoid the normal concentric exercise, to enhance quadriceps strength after ACL surgery.

Reductions in muscle strength and power due to age can have a significant detrimental effect on the functional performance of older people. It was ascertained that exercise training is a considerable stimulus that can increase strength and power.

Nonetheless, it utilises the necessity of additional studies regarding the optimum way that training-related adaptations can be optimised, and the availability of training strategies. The strength and power can be developed and maintained with the traditional (TR) method involving the use of gravity-dependent free weights or weight machines, and yet there are limitations in relation to consistent muscle tension and high levels of muscle activation during the lowering (eccentric) phases of the lift. Certain amounts of eccentric overload (EO) Exercise could, however, surmount these limitations, and it has been found that EO exercise is able to bring significant change in both young and older individuals. In practice, the manufacturing processes of EO are very limited. The appendage of the whole body flywheel training systems provides a true method of producing EO, and the said method could be applied to elderly individuals seeking to augment outcomes of training. We can say that EO training is a worthwhile addition to the training tools of the older individual (Kowalchuk & Butcher, 2019). Flywheel training is a viable form of attaining EO, gaining strength and power, combating age-defying adaptations, and enhancing overall QoL among elderly individuals. Decreased strength and power of muscles related to age can pose a serious impairment to the functional outcome of older individuals.

A work based training (ENT) iOS change of direction (COD), sprint and jumping task, and intervention in muscle mass and football players of semi-professional soccer, 40 male soccer subjects were engaged in an eight week single day presence exercise of 48 squats repetitions to maximize the ENT either via flywheel device (inertia=0.11kg m -2) or weight exercising (80 percent1RM) control group. Agility T-test, 20+20 m shuttle, 10 m and 30 m sprint, squat jump (SJ), countermovement jump (CMJ), lean mass, Quadriceps strength, and Hamstring strength, Hamstrings to Quadriceps ratio have been the parameters (Coratella et al., 2019). Improved braking capabilities, which are a determinant in COD performance, could have occurred through repeated bad behavior in ENT. In-season ENT on semi-professional soccer players may be needed to enhance COD and lessen negative-specific adjustments in muscular intensities and hamstring-to-quadriceps proportions.

Results of the standing long jump (SLJ), countermovement jump (CMJ), and 5 m sprint acceleration in response to eccentric overload (EOL) contraction versus weightlifting (TW). Crossover research design of ten male subjects. During a single visit, in a random order and with 1-minute intervals after each other, the subjects performed EOL or TW half squat exercise (3 sets of 6 repetitions), SLJ (Special Long Jump), and CMJ tests as well as 5 m sprint Element Tocometer™. The evidence strength was quantified by the Bayes factor (BF10). Overall, EOL and TW workouts do not greatly enhance 5 m sprint performance, yet SLJ and CMJ are. With both methods, it was found that the PAP time frame lasted between three and seven minutes (Beato, McErlain-Naylor et al., 2020). The results of this investigation provide no differences between EOL and TW exercises with respect to eliciting a PAP response.

Similar to a previous study [21], we have already reported the molecular adaptations promoted by flywheel-based iso-inertial resistance training in eight resistance-trained men. T0 refers to pre-exercise, and muscle biopsies were performed at t0 and following exercise at unitary time points of 2 h, 24 h, and 48 h post-exercise. Participants completed a flywheel resistance exercise composed of five sets of ten maximal squats using a flywheel device. After 2 h of exercise, the mRNA expression for inflammation-related genes (MCP-1, TNF-α, IL-6) was significantly increased in both peripheral blood mononuclear cells and muscle tissue. Also, at this time, the production of extracellular vesicles in circulation, as well as EV-encapsulated mRNA levels, increased. By 2 hours post-exercise, however, mRNA expression of genes in muscle growth/remodeling decreased. IL-6 and muscle creatine kinase showed a significant increase in plasma concentrations at all time points measured, while IGF-1 increased only after 24 h post-exercise (Annibalini et al., 2019). Altogether, these data suggest that a single session of flywheel training induces changes in local and systemic markers related to late structural remodelling and functional adaptation to skeletal muscle, even in resistance-trained individuals.

A study carried out by others reported the different eccentric overload (EOL) exercise volumes on the performance of CMJ and LJ. These soccer players are male participants (n = 13) of the university. This study was conducted through a crossover design following a familiarisation session. The CMJ and LJ performances were recorded when control (no PAP) was applied. Three randomised-order experimental procedures were to be conducted: 1, 2, or 3 sets of 6 repetitions of flywheel EOL half-squats (inertia = 0.029 kg2). The repeated measure design was implemented to test the performance of CMJ and LJ 3 and 6 minutes following each experimental condition. As this study revealed, the multiset EOL exercise was superior to the single set. In order to produce the effects of PAP on CMJ and LJ performance in male university football players, two or more sets of EOL flywheel half squats are required (Beato et al., 2019). Between much less than 3 minutes (<3 minutes) and around 6 minutes of rest intervals are necessary to get the full PAP treatment effects of every massive amount of EOL exercise. Nonetheless, additional studies are required to find out the most successful EOL regimes to respond to PAP. The PAP was examined in terms of the time course and the size in different situations.

Researcher contrasted isokinetic quadriceps and hamstring torque performance enhancement (PAPE) resulting from exercise after an isokinetic flywheel (FW)- squat vs. isokinetic FW-deadlift exercise with a no-exercise control. In this randomised, crossover study, 15 male athletes were involved. Three repetitions were performed with three repetitions in each of the three protocols, with a total of six repetitions, as well as an inertial load of 0.029 kg · m2. Some of the measurements covered by the study included isokinetic quadriceps (knee extension), hamstrings (knee flexion), concentric peak torque (60o/s), eccentric peak torque (-60o/s) measured 5minutes following experimental condition or control. It was discovered that a substantial condition (PAPE) effect (f = 4.067, p = 0.008) on isokinetic hamstring eccentric peak torque after FW-squat and FW-dead existed, but no notable differences were ascertained in quadriceps and hamstrings peak torque concentrations. The difference of FW-squat versus control was large (14 Nm; 95% CI: 2, 28; d = 0.75, moderate; p = 0.033), and FW-deadlift versus control was also large (13 Nm; 95% CI: 1, 25; d = 0.68, moderate; p = 0.038). This research study determined that FW- squat and FW-deadlift exercises are capable of yielding PAPE of isokinetic hamstring eccentric torque (Martín-Rivera et al., 2022). The issue is that these findings can be applied by practitioners to inform strength and power training during complex training sessions involving flywheel-based exercise prior to a sport-specific task.

The interventions, including post-activation potentiation (PAP) regimens, enhance the effects of flywheel eccentric overload exercises. We undertook a search in the electronic databases PubMed, Scopus, and the Institute for Scientific Information Web of Knowledge. Results: Seven studies were identified for the following results: Practitioners can implement different inertia intensities (e.g., 0.03–0.11 kg·m2) depending on the sport-specific performances they want to enhance [76,83]. Second, the PAP time frame following EOL exercise seems to be in line with classic PAP research, where acute fatigue dominates on the early portion of the recovery period (e.g., 30 s) and PAP dominates on others (e.g., 3 and 6 minutes). Third, EOL activities have high force and power output requirements, and thus 3 sets appear to be a rational approach for the conditioning activity (e.g., half-squat or lunge). This would theoretically reduce the transient tiredness of the muscles and, in turn, allow for greater potentiation than what you may induce with more volume. Fourth, athletes should undergo experience with EOL exercise prior to using it as a PAP tool in a training program (3 or 4 familiarization sessions). Lastly, the common flywheel devices allow for effective, practical ways of inducing PAP prior to competitions (Beato, de Keijzer, et al., 2020). Previous Post-activation potentiation EOL exercise is used to elicit PAP responses and improve performance in a wide range of sports.

The EOL exercise affected Post-activation potentiation of performance and isokinetic muscular strength of lower limbs during testing of countermovement jump (CMJ). Randomly conducted crossover studies which included 18 active males with mean SD of 6 age of 20.2 6 1.4 years and body mass of 71.6 6 8kg and the height of 178 6 7 cm. Lastly, the available evidence shows that an EOL bout consisting of the PAP raises height, peak power, impulse, and peak force during CMJ as well as quadriceps and hamstring isokinetic strength in sport-playing male participants (Raya-Gonzalez et al., 2021). Further, it was determined that the desirable timing between 3 and 9 minutes was that of PAP.

According to Raya-González et al. (2021) not only due the Strength training is an important method, which is method for increasing performance as well as protecting against injuries in team sports. Accordingly, a plurality of approaches have been adopted; nevertheless, because of the accruing advantages ascribed to strength training regimens with emphasis on eccentric contraction (6), the usage of flywheel (FW) devices has increased in this regard within typical periodization strategies for team sports. A cross-sectional study: 31 male soccer players, 21 ±6.4 years; body mass: 77.0±5.2 kg EOL exercises were performed by subjects and then, a 4-min rest period was given to dominant-leg (5-m shuttle test of COD-D) followed by non-dominant leg (5 m shuttle test of COD-ND) shuttle tests. Tensiomyography (TMG): Muscle contractile, contraction time (Tc), time delay (Td), displacement of the muscle belly (Dm) of vastus lateralis, vastus medialis and rectus femoris was measured. In a study of football players, the COD-5mD and COD-5mND performances 4 minutes after performing EOL workouts (INC, EXT, and SQU) induced a significant positive PAP response in this investigation (Beato, Stiff et al., 2021).

Next, the EOL exercise in turn impacted vertical and horizontal jump performance and change of direction (COD) performance. A crossover study was carried out in a study of 12 healthy male individuals who were physically active. The subjects were made to complete three sets of six maximum-power EOL half squats on a flywheel ergometer. The nature of post-activation potentiation in the medium (MEOL) and high inertia in the experiment condition (H-EOL) with the use of EOL exercise was studied. Long jump (LJ) was logged at 30 seconds, 3, and 6 minutes after each EOL session, and it was contrasted with the baseline (control). It was done in a similar manner to the measurement of the height of the countermovement jump (CMJ), peak power, and 5-m COD test (COD-5m). The current findings observe that PAP on an EOL (M-EOL or H-EOL) enhances LJ, CMJ height, CMJ peak power, and COD-5m among men athletes (Beato, McErlain-Naylor, et al., 2020). In the case of the two EOL situations, the increases in PAP effect took place between 3 and 6 minutes, which is the best interval. However, the effects of PAP on M-EOL and H-EOL are analogous in exercises of LJ, CMJ, and COD-5m.

The study of the flywheel strength training and the traditional strength training on the fitness attributes was carried. Thirty-six highly trained junior basketball players (n = 36; 17.58 0.50 years) were recruited and assigned to three groups, Flywheel group

(FST; n = 12), Traditional Strength Training (TST; n = 12), and Control (CON; n = 12). During research, teams were engaged in five practices of basketball and one actual game once a week. The intervention period lasted eight weeks, involved a 1-2 d/w equivalent volume of work on flywheel (0.075 kg. m2) of inertia during FST and the use of free weights (weight, 80% 1 RM) during TST. An 8 weeks exposure of flywheel training procedure (1-2 sets per week) with maximal concentric effort reveals larger improvements in CMJ, 5 m speed, and direction alteration capacity compared to tovel loaded classic weightlifting machine subjects when examined in well trained adolescent basketball players (Stojanovic et al., 2021). It is feasible that coaches and trainers will be suggested to utilize flywheel training to develop power-based performance characteristics of young basketball players.

Subjects were tested for post-activation performance enhancement (PAPE) both as differences between baseline jumps and those before change of direction drills in vertical and horizontal ground reaction force parameters following flywheel squat exercise using two different flywheel inertias. In a counterbalanced mixed design, male athletes completed one control trial, consisting of CMJ and SBJ followed by 505 COD, before performing six minutes of three rounds of sort repetitions of half squats with a flywheel (inertias: 0.029 kg. m2 and 0.061 kg. m2). All trials elicited a peak directional force, power and rate of force development. McErlain-Naylor & Beato (2021) also reported an elevation in CMJ BF10 = 3.65, moderate; = 0.93; CI: 0.11, 1.88 and increased CMJ peak vertical force was observed with the lower inertia flywheel (BF10 = 33.5, very strong; = 1.66; CI: 0.67, 2.70). There was no effect of the vertical squat exercises on any outcome measure for the SBJ (ground reaction forces) or horizontal COD (inertias). Therefore, the kinetic and kinematic model (pre-load stimulus) with the respective sports-specific task (e.g. flywheel squat to CMJ) must be established by researchers and practitioners.

Fifteen healthy males performed six flywheel half-squats at maximal effort and 0.029, 0.061, 0.089, and 0.121 kg.m2. The rate of movement and power were measured via 3D motion capture and a built-in transducer. Concentric and eccentric velocity, mean concentric and mean eccentric velocities, and the ratio of peak eccentric to peak concentric power decreased (peak concentric, 2 = 37.9; $p < 0.001$; peak eccentric 2 =

24.9; $p < 0.001$; mean concentric $F(3) = 52.7$; $p < 0.001$; mean eccentric 2 = 16.8; $p < 0.001$;) and the ratio of peak eccentric Flywheel inertia did not have any significant influence in the ratio of eccentric and concentric peak or mean velocities and the peak concentric or eccentric power. The subject-specific relationship of inertia peak concentric velocity had the strongest fit of any measured subject-specific relationship (median linear R2 = 0.95, median logarithmic R2 = 0.97) (McErlain-Naylor & Beato, 2021). The results indicate that to prescribe and monitor flywheel squat intensities should be performed with reference to velocity as opposed to power, along with individual linear relationships between inertia and maximum concentric velocity.

The current evidence suggests that strength training, such as classic resistance, eccentric, and flywheel training, may be a viable strategy for reducing injury risk in football players. Training programmes possessing multiple components (e.g., the combination of strength, balance, and plyometrics) with the incorporation of strength measures are effective at preventing noncontact injuries amongst female footballers. Moreover, the recent evidence is in favor of eccentric training in sport practice as it allows the athlete to get different physiological responses in contrast to the other forms of resistance exercises. It is believed that Nordic hamstring exercise, specifically, is good to help hamstring injuries in the case of football players (Beato & Drust, 2021). In addition, flywheel training possesses special training features and advantages because concentric and eccentric contractions can be combined, and this aspect may be critical in preventing injuries.

A study of data simulation that sought the reproduction and the analysis of past research study on body mass, vertical jump performance, and sprint performance. The means of 1000 simulated data sets in each condition were averaged and the influences of different parameters on the corresponding correlations between jump momentum and sprint momentum studied. Jump take-offs are most strongly correlated with sprint momentum where there is a relatively large within-individuals body mass variability and relatively small within-individuals variability in jump height. This is mostly due to the fact that there is greater emphasis on the body mass under such conditions. Although jump height and sprint velocity had a weak negative correlation ($r = -0.30$), the correlation was very strong (r 0.76). It was found that jump momentum was not significantly better at predicting sprint momentum ($p < 0.05$) than body mass in any of the environments under investigation. Moreover, it is advisable not to consider between-individual correlations to use them when making conclusions at a within-individual level (predictions, measuring the consequences of a longitudinal training intervention, etc.) (McErlain-Naylor & Beato, 2022). Any reason behind calculation and/or tracking of jump take-off momentum is advised to be differentiated as to its predictive capacity of sprint momentum. In fact, the body mass may be the better indicator of sprint momentum.

Both concentric and eccentric peak power and the ratio of eccentric to concentric peak power were influenced by flywheel moment during unilateral leg curl flywheel and hip extension exercises. Inter-session reliability was established in peak power between the two activities. A group of 20 amateur men soccer players, came to five visits, each consisting of three times eight repetitions of leg curl or hip extension based on the three moments of inertia (unilateral). During the unilateral leg curl, no difference between any moment of inertia measured at any level of power was different ($p = 0.479$) and all peak powers were higher eccentric than concentric ($p < 0.001$). Significant differences in moments of inertia were found in all the tests of unilateral hip extension ($p < 0.05$). In particular, the lowest moment of inertia yielded the highest concentric peak power ($p = 0.022$), no differences were present between the lowest and the middle inertia ($p = 0.391$) and the highest moment of inertia yielded the highest eccentric peak power ($p = 0.036$). The measures of peak power indicated a fair to excellent reliability and the eccentric:concentric ratio indicated poor to moderate reliability of both workouts. Specific moments of inertia can induce large eccentric demands of the knee flexors when using unilateral leg curls, though moments of inertia needed to induce eccentric-overload in peak power during hip extensions are much higher (De Keijzer, Gonzalez, et al., 2022). Correlation of inertia-power may vary with exercises. These concentric and eccentric measures in terms of peak power should be maintained to aid in training but eccentric:concentric ratio should not be utilised.

A comprehensive search was carried out in PubMed/MEDLINE, SPORTDiscus, and Web of Science, and these tasks were conducted in accordance with the recommended reporting items of systematic reviews and meta-analyses statement. A total of 52 meta-analyses were obtained, with 14 of them meeting the inclusion criteria. These articles were published during the period 2009 to 2020, and a total of 178 primary investigations with 4,784 people were considered. Nine meta-analyses were characterized as the high-quality ones, and the range of their scores was 81 to 88%. The rest of the meta-analysis was classified under moderate quality with a range of 63-75%. Regarding the umbrella review, it is suggested that at least 10 sets per muscle group for each week should be practiced, eccentric contractions should be prioritized, and very slow repetitions (not less than 10 s) should be avoided. The practice might include blood flow restriction approaches to some participants (Bernárdez-Vazquez et al., 2022). Moreover, this theory does not seem to support other factors like the order of exercise, time of the day, and form of periodization directly affecting the level of muscle mass development. Such findings can be used to design and set up a resistance training programme in order to maximise muscle growth.

Fifty-one practitioners took an electronic questionnaire. There were four topics of Likert statements: strength and performance, post-activation performance enhancement and methodological concerns, chronic strength, chronic performance, and injury prevention. Three generic questions were then asked, which gave greater information on the flywheel training application. Most subjects mentioned > 2 years of experience with flywheel training with respect to the programming. Nearly all participants concurred that familiarisation is needed. It is felt among the practitioners that flywheel training may enhance athletic performance and strength and reduce the risk of non-contact injury outcomes. The majority of the practitioners suggest two weekly meetings in the pre- and during-seasons. During Flywheel exercises, most of their routines consist of squats; however, these exercises also include a variety of exercises, which include the lunge, hip hinge, and open kinetic chain routine. The majority of the practitioners are unsure of the differences between the flywheel and traditional resistance training devices and results, the feasibility of the flywheel devices, and evidence-based recommendations (De Keijzer, McErlain-Naylor, et al., 2022). This analysis illuminates the views and application of flywheel training in professional football, with a special spotlight on its perceived effectiveness in strength and injury prevention.

Match performance measures after injury depend on the severity of the injury in professional soccer players. This paper has analyzed the injuries that occurred to 201 professional soccer players in the Spanish LaLiga 201. They were all categorized into minor (loss 4 to 7 days), moderate (loss 8 to 28 days), and major (loss 28 or more days). The Mediacoach 1862 video tracking system was used to collect time and external factors that influence demand and compare them before and after injury and return to play. The variables examined were: (up to m min-1): relative distance moved (RD; complete distance covered•(min-1), distance moved walking (0-6 km h-1), distance moved jogging (6-12 km h-1), distance moved running (12-18 km h-1), distance moved at intense running (18-21 km h-1), distance moved at high-speed running (21-24 km h-1), sprinting (> 24 km h-1). Elimination of substantial playing time after moderate and significant injuries. Finally (Raya-Gonzalez, Castillo, et al., 2022), the study proves that high loading is necessary when reconditioning programmes are performed and after implementing the strategy of applying strategies that permit maximum speed levels when returning to play.

In addition to this, another Studies were retrieved in electronic databases (PubMed, SPORTDiscus and Web of Science) on the basis of preferred reporting items for systematic reviews and meta-analysis statement criteria. The methodological quality of the seven reviewed studies varied between 10 to 19 (good to exceptional) points with mean of 14 points (good). These researches were held between 2004 and 2019, and 100 women took part in these works. The duration of training was 5 to 24 weeks, with volume as 1 to 4 sets, 7 to 12 repetitions and the frequency was once to thrice per week. The existing evidence shows that flywheel training is a safe and time-efficient method to develop better physical outcomes in young and older girls (Raya-Gonzalez et al., 2021). It is based on this fact that practitioners may be convinced more easily to prescribe flywheels training as a favorable source of preventing accidents or falls as well as a potent head start in physical reconstruction.

A procedural research study in the classic concentric-eccentric (TRAD) resistance training enrolled sixty women randomly into unilateral volume-equivalent training groups of CONC, ECC, or TRAD knee extension training or control (n=515 in each group). Isokinetic concentric and eccentric as well as isometric torque measures were determined before training, after an 8-week intervention period, as well as after a subsequent 8-week detraining period. Lean mass of the thigh was also examined by dual X-ray absorptiometry, and vastus lateralis thickness, pennation angle, and fascicle length using ultrasound. Concentric and isometric torque increased in a similar manner ($p < 0.05$) in all groups, whereas eccentric torque increased to a greater extent in ECC than in CONC (+13.1%, effect size (ES): 0.71 [0.041.38]) and TRAD (+12.6%, ES: 0.60 [0.121.08]). Lean mass of the thighs increased in ECC (+ 6.1 percent, ES: 0.47 [0.27-0.67]) and TRAD (+ 3.1 percent, ES: 0.33 [0.01-0.65]). The thickness of the vastuslateralis and pennation angle also increased similarly ($p < 0.05$) in the two groups, but fascicle elongation occurred in ECC (+9.7%, ES: 0.92 [0.14-1.65]) and TRAD (+7.1%, ES: 0.64 [0.03-1.25]). All groups gained the same concentric torque after detraining ($p < 0.05$). ECC and TRAD had similar eccentric torque (p, 0.05); ECC was superior to TRAD (addition +17.9%, ES: 0.61 [0.21-1.21]). Similar isometric torque was presented when taking the origin (p, 0.05), yet ECC was more successful than CONC (+14.2%, ES: 0.71 [0.04-1.38]) and TRAD (+13.8%, ES: 0.65 [0.10-1.20]) (Coratella et al., 2022). Only thigh lean mass and vastuslateralis fascicle length were maintained with ECC only ($p < 0.05$), but pennation angle was maintained in all groups ($p < 0.05$), and thickness was maintained in CONC and ECC. To avoid the loss of adaptations to resistance training, it is necessary to include the eccentric period in the training process.

One literature review on FW training reflects findings from research, as well as applications for practitioners. This meta-analysis has found that speed on the treadmill does indeed increase with Flywheel training. With the specific examples given, analysis also shows that lag relationships exist between FW resistance and normalised vertical jump height. However, it has not yet been confirmed whether this is quite as applicable across different types of resistance training programs. There is no way to conclude that FW training is superior, scientifically speaking, to standard resistance training methods (Raya-González, Pulido et al., 2012). In addition, discrepancies between populations and sexes still have to be carefully studied before firm conclusions can be drawn. Among senior male international hockey athletes, the game accelerations and decelerations were recorded. Twenty-four players' routines over ten actual games were researched. Participants were outfitted with a distinct GPS unit (STATSports APEX), which worked at ten Hz. With the game data, all efforts at acceleration or deceleration were tracked down (Cunniffe et. al., 2012). More information was extracted about the effort, including the distance, size of each effort, and also how long it lasted, plus what time intervals between them. 71 % of the acceleration events (61% decelerations) occurred between 3 and 3.99 m.s-1. In deceleration efforts of more than 5m.s-1 (11% of efforts), there were still fewer acceleration efforts (6%) than deceleration ones. 54 % of acceleration efforts had a distance under 2-7 meters, while 93 % of deceleration efforts were ≤5m. Defenders made less distance per acceleration effort (6.20m) than midfielders (7.59m) and forwards (7.54m), with no significant difference in force. The characteristics described by this investigation could be used to help plan and analyse the progress of international hockey players. In training, athletes must have opportunities for accelerations and decelerations of match-level form. These conclusions can also be used alongside data on workout participation to help ensure that training techniques allow participants to experience forces of similar magnitude and distance as they would in actual games.

They have also been analysed into four categories based on their acceleration and deceleration information, i.e. training drill variables (to be manipulated like the number of players in small-sided games), training exercise variables (such as different drills like the small games or the circuit training), player positions (position specific requirements), and the training schedule (presented or delivered during the training sessions in the form of microcycles, form of training sections in the season or as the whole season). The macro-analysis will respond to the complete-text publications that include 42 research reports. The amateurs, youth, semi-professional, professional, and elite were the levels of the players. All the positions on the field were implemented along with the goalkeepers. Six various global positioning system brands were used, with most of them measuring data at a speed of 10 Hz. In other articles, several levels and magnitudes were applied (Silva et al., 2022). In every one of the four categories, instances of lower, as well as deceleration intensity, were more frequent than instances of greater ones.

The training with the flywheel has beneficial effects on the sprint performance, but there is some inconsistency in the gains shown by the elite athletes (e.g., soccer players). Both AMSTAR 2 and GRADE were used to determine the quality of the methodology of the eleven reviews that were included. The two papers are systematic reviews, 6 systematic reviews and meta-analyses, and 3 narrative reviews. The two papers are systematic reviews, 6 systematic reviews and meta-analyses, and 3 narrative reviews. Although the provided assessment offers an opportunity to state the high effectiveness of flywheel training in sports people and healthy individuals, it appears that the umbrella review demonstrates the cases of methodological disparities and study exaggeration (38 studies were retrieved). The possible advantage of introducing flywheel post-activation performance enhancement programmes has been revealed to raise the strength and physical abilities of healthy individuals and sports patients. Any available reviews feature flywheel training as an inviting alternative to conventional resistance training in the context of increasing the muscle strength, power, and jump capabilities of the untrained and trained people (De Keijzer, Gonzalez, et al., 2022). Similarly, reviews indicate that flywheel training would lead to improvement in change of direction performance, with little conclusion drawn since few investigations have been conducted.

Bianchi M et al (2022) have explored the impact of a combined jump and sprint training programme (2 per week over 6 weeks) on the sprinting, change of directions (COD), and jumping performance in semiprofessional soccer players. The subjects of this randomised controlled trial were 20 footballers (20, 2 years old on average, body mass is 74.3 5.9 kg). A sample of 20 was randomly assigned to two groups: training (TG, n = 10) and control (CG, n = 10). A physical test that was done included sprint 10 m, sprint 30 m, 505-COD test, and a standing long jump (LJ) that was conducted before and after 6 weeks of training. The mixed jump and sprint training two times per week was the only difference in training of the two groups. The difference between the TG and the control group was statistically significant after 6 weeks of training (in sprint 10 m $p = 0.015$, 02 = 0.295, big), sprint 30 m $p < 0.001$, 02 = 0.599, large), 505-COD p = 0.026, 02 = 0.154, large), as well as LJ (p = 0.025, 02 = 0.0 The statistics prove that combined sprint and jump training, when carried out twice a week for 6 weeks, besides regular team training, can bring about enhancement in specific physical performance in male soccer players. The present study has demonstrated that a progressive training dose (volume increment of 10% after 3 weeks of training) can be a suitable progression and that a combination of 64- 70 jumps and 675- 738 m of sprinting can be beneficial in sprint, COD, and jump performance.

In addition, inertial load was tested in association with mean concentric linear velocity (MCLV) in flywheel squats at different intensities. The report involved 25 physically active men (their age is 26.5 +/- 2.9, their height is 179.5 +/- 4.2 cm, their weight is 81.6 +/- 8.6 kg). After familiarisation, the participants were tested twice using the flywheel progressive load before inertial to determine the load velocity profile and reliability of the flywheel. All the participants performed 5 sets of 6 repetitions of the flywheel squat routine with different amounts of inertial resistance (0.047, 0.104, 0.161, 0.245, 0.321 kg·m ²) in a randomised and counterbalanced order on each test day. The means of MCLV and RPE/load were compared. Regulation of MCLV during flywheel exercise has been provided as a valid approach to quantification of load and personalizing flywheel training prescription (Martin-Rivera et al., 2022). In addition, RPE responses have exerted a close connection with load and speed. Consequently, RPE has been provided as a promising and consistent alternative to using flywheel training.

The concentric-eccentric mechanical output ratios freestyle of the flywheel squat exercise at different loads and other factors were also analyzed. Twenty physically active men (22.9 2.2 years; height: 1.8 0.1 m; weight: 79.6 8.2 kg) underwent a five moments of inertia loading test. Angular speed was measured by a rotary encoder, and vertical force is acquired using the force plates. Mean and peak values for all variables (angular speed, angular acceleration, power, vertical force and torque) were separately calculated at each concentric or eccentric movement together in order to compare the load applied. Thus, they checked the potential changes in Load x Phase (concentric and eccentric) and Load x Variable. Statistical tests of significance were performed at $p < 0.05$ level. There was a meaningful Load x Phase interaction in mean angular speed, peak vertical force, peak angular acceleration, peak power and at peak torque (Muñoz-Lopez et al., 2023). Values of eccentric overload were actually higher for variables that were speed derived (angular speed, angular acceleration and power). Finally, speed-specific variables of lighter loads are more associated with eccentric overload and can be used to track the flywheel training responses.

A systematic overview studied how flywheel training has a long-term or lasting impact on the physical capabilities of the football players. They stated the areas on which they would further research to come up with guidelines on how it could be applied. Electronic databases (PubMed and SPORTDiscus) were searched in regard to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA). There were eleven studies that fit the inclusion criteria and are thus admitted. The methodological quality of identified studies was between 10 and 18 points, and the mean score on the PEDro scale was 15. The duration of the training was 6-27weeks, and 1-6 sets and 6-10 reps, and the frequency was 1-2 times per week. This exhaustive review concluded that even an assortment of flywheel training programs has the ability to successfully boost strength, power, leap, and change of directions in male footballers of different levels. Flywheel training activities enhance the physical capabilities of football players at different angles (Allen et al., 2023). However, the literature available brings conflicting results when it comes to changes in sprint speed and acceleration capacity in football players induced by flywheel training.

A questionnaire was administered to 73 therapists regarding the use and attitudes of flywheel training (pre-conditions, technology use, barriers & limitations, upper- vs. lower extremity activities). Most therapists (47/73) used or intended to use flywheel training with their athletes and expected that familiarisation would occur earlier than training. The remaining many were unconvinced, although over half agreed that flywheel training might improve muscle strength (27/52) and muscle recovery (40/52) outcomes as compared to other modalities (De Keijzer et al., 2023). Long-term implementation to the point of 1 year training adherence would still be limited (22/52), but it seems that flywheel training would mostly be used in treatment (40/52) or later course of recovery (37/52). Therapists would use both power outputs (30/52) more than velocity outputs to assess progress, and no one would ever use these. Although the exercises a therapist may prescribe will differ, some of the most common include a unilateral leg curl, rotation exercise, and squat.

Flywheel (isoinertial) resistance training has long been recognized as an effective strength training method in sports, yet its implementation by therapists in this field remains relatively unexplored. This study was done to investigate how sports therapists currently apply and perceive flywheel resistance training. A survey was conducted with 73 therapists, 52 of whom completed the questionnaire, covering aspects such as prerequisites, technology use, barriers, and types of exercises involved. The results showed that a considerable number of therapists (47 out of 73) either utilize or intend to adopt flywheel training, highlighting the necessity of familiarization prior to implementation. While more than half of the respondents expressed confidence in flywheel training's ability to improve strength (27/52) and support muscular prehabilitation (40/52), many still had reservations. Therapists predominantly preferred to integrate flywheel training into prehabilitation (40/52) or later stages of rehabilitation (37/52). When it came to tracking progress, power outputs were favored (30/52) over velocity metrics. The most frequently prescribed exercises included squats, rotational movements, and unilateral leg curls, while therapists were less inclined to recommend lateral squats and unilateral hip extensions (De Keijzer et al., 2023). Major obstacles identified included equipment costs, spatial requirements, the availability of evidence, and scheduling conflicts. This study provides valuable insights into how sports therapists perceive and apply flywheel training, which could help shape future practices and research in this area.

The research involved testing 469 athletes from five distinct sports disciplines, along with physical education students. The findings revealed that FvP outcomes during the eccentric phase of the FW squat significantly differed among athletes from various sports. However, only the slope variable showed differences during the concentric phase. Contrary to the researchers' expectations, there were no statistically significant correlations found between the FvP outcomes from FW squats and the results of CMJ or CoD tests. This suggests that the FvP outcomes derived from FW squats may not possess external validity, indicating that they cannot be reliably used to predict athletes' performance in jumping and agility tasks. The paper also discusses potential reasons for the pronounced differences observed in the eccentric FvP outcomes across sports, as well as the lack of correlation between FvP measures and the functional tests used in the study (Spudić et al., 2024).

Emerging evidence supports integration of flywheel resistance training within various sports programs due to its reported benefits in neuromuscular function, strength, and task-specific performance enhancements. The first aim of the study was to involve the internationally well-known specialists in developing the set of definitions and regulations on the introduction of the flywheel resistance training technology in the sporting context. The consensus process involves 19 experts of various countries as 16 of them attended the consensus meeting on May 18, 2023, whereas three of them sent their recommendations through emails. Before the meeting, there was the formation of evidence summaries that had to address key areas of priority. The five steps that were undertaken in the consensus process were a systematic review of the existing reviews, updating the most current umbrella review on the subject, preliminary consultations with members of the research group, the recommendations as per the consensus meeting, and the finalization of the consensus statements. The systematic scanning brought nine concerned articles, and their quality was evaluated by AMSTAR 2 and GRADE requirements. A recommendation/statement that would fall between 7 and 9 would be considered suitable. Based on the consensus, three statements and seven recommendations on effective use of flywheel resistance training technology were determined with high scores of 7.7 to 8.8 (Beato, Madruga-Parera, et al., 2021). Since the results of this agreement among the experts are so strong, the paper proposes that sports practitioners and researchers can use the elaborate suggestions of the guidelines on the use of flywheel resistance to this technology in sports training.

The research by Sergio Maroto-Izquierdo and his co-workers sought to describe and compare force production and muscle activity in 4 conditions of Flywheel deadlift exercises, bilateral (Bi), unilateral (Uni) assaults, and various loading conditions, vertical (Ver) and horizontal (Hor). A total of 23 team-sport athletes participated in the assessments, which measured exercise kinetics through hand-grip force and analyzed muscle activity using surface electromyography (sEMG) on key muscle groups, including the proximal (BFProx) and medial biceps femoris (BFMed), semitendinosus (ST), and gluteus medius (GM). It was observed that both the mean and the peak forces produced in the Bi + Ver condition were significantly greater ($p < 0.001$) than the other variations, such as Bi + Hor, Uni + Ver, and Uni + Hor. None of the differences were significant between Bi + Hor and Uni + Ver; however, both conditions showed increased ($p < 0.001$) average and peak eccentric forces compared to Uni + Hor. More importantly, eccentric overload was only evident during vertically loaded exercises. In addition, Bi + Ver and Uni + Ver resulted in observed higher ($p < 0.05$) sEMG activity in BFProx and BFMed muscles than Uni + Hor (Maroto-Izquierdo et al., 2024). The Uni + Ver variation yielded the greatest sEMG values of the GM and ST muscles as well. Conclusively, this paper indicates that the vertical adjustments of the flywheel deadlift exercises produced higher levels of muscle force production and sEMG activity than horizontal adjustments. Both Bi + Ver and Uni + Ver training may succeed in increasing the hamstring muscle activity and force production at greater muscle lengths, and Uni + Ver could provide extra advantages in the engagement of the GM and ST muscles.

This chapter reviewed recent advancements in physiotherapy management for post-operative ACLR patients, focusing on the role of flywheel resistance training (FWT) and its application in sports and rehabilitation. Studies highlighted FWT as an effective method to improve strength, power, and hypertrophy, though not superior to traditional resistance training, with further research needed to address population and sex-specific variations (Raya-González et al., 2022; De Keijzer et al., 2022, 2023). Acceleration and deceleration demands in sports were explored by Cunniffe et al. (2022) and Silva et al. (2022), emphasizing the importance of replicating match-specific conditions during training. Research on FWT's effects on performance, including sprinting, jumping, and change of direction (COD), shows promising outcomes, particularly when integrated with regular training programs (Bianchi et al., 2022). Variations in load, movement phases, and eccentric overload were found to significantly influence muscle activation and force production, suggesting tailored approaches for optimal results (Martín-Rivera et al., 2022; Muñoz-López et al., 2023).

Consensus studies underscore the need for standardized guidelines and better implementation strategies to enhance FWT's effectiveness across diverse populations (Beato et al., 2024). Overall, FWT showed potential as a robust tool in physiotherapy, though challenges like cost, accessibility, and methodological inconsistencies require attention.

2.8 THEORIES OF ECCENTRIC TRAINING IN ACL

The emerging study examined the effectiveness of combining neuromuscular electrical stimulation (NMES) and eccentric exercise in restoring quadriceps function post-ACL reconstruction. Thirty-six patients were divided into four groups: NMES & eccentrics (N&E), eccentrics only (E-only), NMES only (N-only), and standard care (STND), with ten healthy controls. Quadriceps activation and strength were assessed pre-surgery, 12 weeks post-surgery, and at return-to-play. Results showed that eccentric exercise (E-only) improved activation better than NMES alone, while both E-only and N&E groups had superior strength recovery. At return-to-play, their strength matched that of healthy individuals, highlighting eccentric training as key in rehabilitation (Lepley et al., 2015).

A case study explored the therapeutic benefits of neuroscience pain education (PNE) combined with eccentric training in a 19-year-old male post-ACL reconstruction. Initially, rehabilitation focused on a basic range of motion and isometric exercises, progressing to eccentric training and PNE sessions from the first to the fourth week. Results indicated significant improvements in quadriceps strength, range of motion, and overall function. The study suggests that integrating PNE with eccentric training may enhance post-surgical recovery, highlighting the need for further clinical investigations to validate its effectiveness in ACL rehabilitation (Tatiya et al., 2021).

This study highlights the benefits of early eccentric resistance training in post-ACL reconstruction rehabilitation. Traditional rehabilitation often fails to prevent long-term muscle atrophy and weakness. However, introducing a 12-week eccentric training program just three weeks post-surgery significantly improved quadriceps and gluteus maximus muscle volume at both 15 weeks and one year. Patients undergoing eccentric training also demonstrated superior quadriceps strength and hopping ability compared to those in standard rehabilitation. These findings suggest that eccentric contractions can be a safe and effective addition to ACL rehabilitation programs, promoting better long-term functional recovery (Gerber et al., 2009).

This review explores the role of eccentric exercise in addressing neuromuscular dysfunction, a key factor in primary and secondary injuries. Despite the use of injury prevention programs, injury rates remain high, and post-injury functionality often falls short of clinical recommendations. By targeting neuromuscular alterations, eccentric exercise offers an alternative to conventional concentric training. The review highlights its effects on muscle morphology, including fiber composition, cross-sectional area, and working range, while also influencing neural mechanisms such as motor neuron recruitment and corticospinal excitability. These findings suggest that eccentric exercise not only enhances muscle structure but also improves neuromuscular control, potentially reducing injury risk and improving rehabilitation outcomes (Lepley et al., 2017).

Another study investigated the effects of deep knee flexion flywheel Bulgarian split squats on quadriceps strength in athletes with ACL reconstruction. Eleven athletes completed 16 training sessions, performing a single set of split squats to exhaustion with a knee extension of 60°. The results showed significant improvements in quadriceps rate of force development (RFD), indicating better muscle activation. While overall maximum voluntary isometric contraction (MVIC) did not show significant change, athletes with weaker quadriceps at baseline experienced greater strength gains. Additionally, the strength imbalance between the reconstructed and healthy limb was reduced after training. This study highlights the potential of eccentric-focused training for improving quadriceps function after ACL reconstruction. Flywheel Bulgarian split squats may help restore strength and reduce asymmetry, supporting better rehabilitation outcomes (Henderson et al., 2022).

This study explored the effects of flywheel resistance training (FWRT) versus traditional resistance training (TRT) on muscle hypertrophy, architecture, and performance in physically active young adults. Over 10 weeks, participants were randomized into FWRT, TRT, or a control group maintaining habitual activity. Both FWRT and TRT led to increased maximal isometric strength and fat-free mass. However, TRT resulted in superior improvements in free weight squat and bench press performance, while FWRT uniquely enhanced muscle fascicle length and cross-sectional area in the distal vastus lateralis. Additionally, FWRT participants showed significant gains in countermovement jump height and broad jump distance, whereas TRT led to greater pennation angle and proximal vastus lateralis hypertrophy. These findings suggest that FWRT offers distinct architectural adaptations that enhance athletic performance, particularly in explosive movements, making it a valuable alternative to traditional resistance training (Banks et al., 2024).

Moreover, the mechanical responses and regional muscle activations of two inertial exercises, flywheel leg-curl and conic-pulley hip-extension on hamstrings, were studied in a single study. Findings indicated that concentric peak and mean power were lower than those of eccentric in the flywheel leg-curl. Conversely, the conic-pulley hip-extension exercise recorded a higher peak power in the eccentric phase and high mean power in the concentric phase. The functional MRI analysis indicated that the flywheel leg-curl stimulated all four hamstring muscles (biceps femoris long head [BFl], biceps femoris short head [BFs], semitendinosus [ST], and semimembranosus [SM]), with the most significant preference of ST as well as the BFs in the internal parts of the muscle. Conversely, the proximal extent of BFl and ST was preferentially activated (selectively) via the conic-pulley hip-extension exercise. These results also indicate that flywheel leg curls result in a more complete hamstring activity and are thus favorable with regard to general strengthening. In contrast, the conic-pulley hip extension is selective in targeting certain areas of muscle, which can be beneficial in injury-specific rehabilitation. All of these differences should be taken into account by physiotherapists and strength coaches when planning training and rehabilitation programs to maximise hamstring activation and the recovery process (Suarez-Arrones et al., 2020).

CHAPTER III

RESEARCH METHODOLOGY

This chapter brings an in-depth coverage of the data collection procedures, study designs and the statistical software involved for analyzing the data.

3.1 ADAPTED RESEARCH PARADIGM

The research model of the current study is designed under a positivist paradigm to confirm the quantitative research (Figure 3.1). Data is gathered through understanding and perception and quantitatively tried via assorted strategies like trial, polls, measurable examination. Analysis of Quantitative approach, the assessment of these connected/related factors is the bed-rock upon which positivism rests to fulfil its intense obligation towards making consciousness of genuine amounts explicitly and advancing the proceeding solidarity of reality (Abraham Kuyper). What is more, positivism is identified as a quantitative method and therefore it identifies a possible research focus manner of the study subject as it was proposed in figure 3.1.

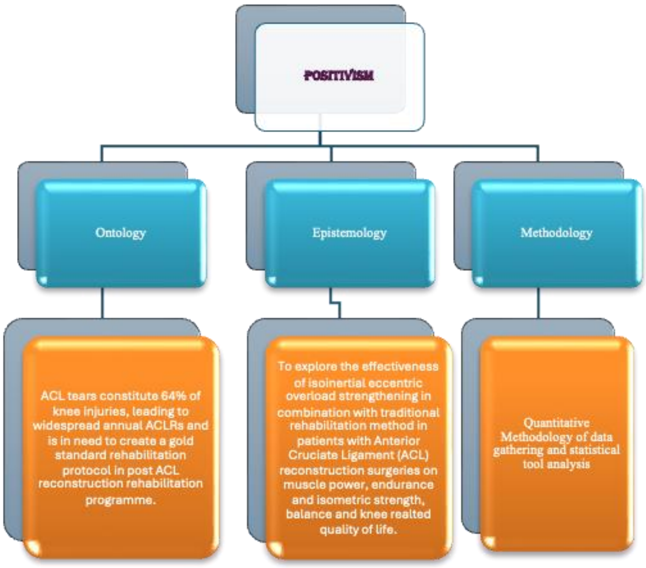


Figure 3. 1 Arguments in favor of the Positivistic paradigm application to research the effectiveness of Isoinertial Eccentric overload strengthening in combination with traditional rehabilitation method in patients with ACL Reconstruction surgeries on Muscle power

3.2 RESEARCH APPROACH

Furthermore, this study effort has been adapted in accordance to the hypotheses generation and conclusion-setting deductive tool.

3.3 STUDY DESIGN

A self-controlled case series using an interventional experimental design in a randomized controlled trial protocol, according to the CONSORT (Consolidated Standards of Reporting Trials) statement [11] on isoinertial eccentric overload (IO) strengthening, combined with traditional rehabilitation in patients who had undergone ACLR.

Description of the study: This study was conducted from July 2020 to September 2023 at the UNI Health Care Centre LPU, Punjab, India, registered with the clinical trials gov. registry (CTRI/2021/09/036933) and was ethically approved by the Institutional Human Ethical Committee. All patients provided informed written and oral consent. Both of human ethical principles have been situated in and around this study keeping the latest Declaration of Helsinki -- 2013 from World Medical Association, Good Clinical Practice standards for Indian Medical Research Council.

3.4 STUDY SETTING

Examined and managed at UNI Health Care Centre, LPU, Punjab, India were only included among the patients with enrolled. The study protocol and operation procedures were conducted in such a way to permit compliance by the patients regarding inclusion/exclusion criteria.

3.5 SAMPLE SIZE DETERMINATION

Calculation by G Power programme Sample size was calculated in the G Power Programme like 95 (15% dropout rate) A (0.05), E 2 =. A sample size was determined by using error of deviation (5), standard deviation (0.25), and statistical power (80%).

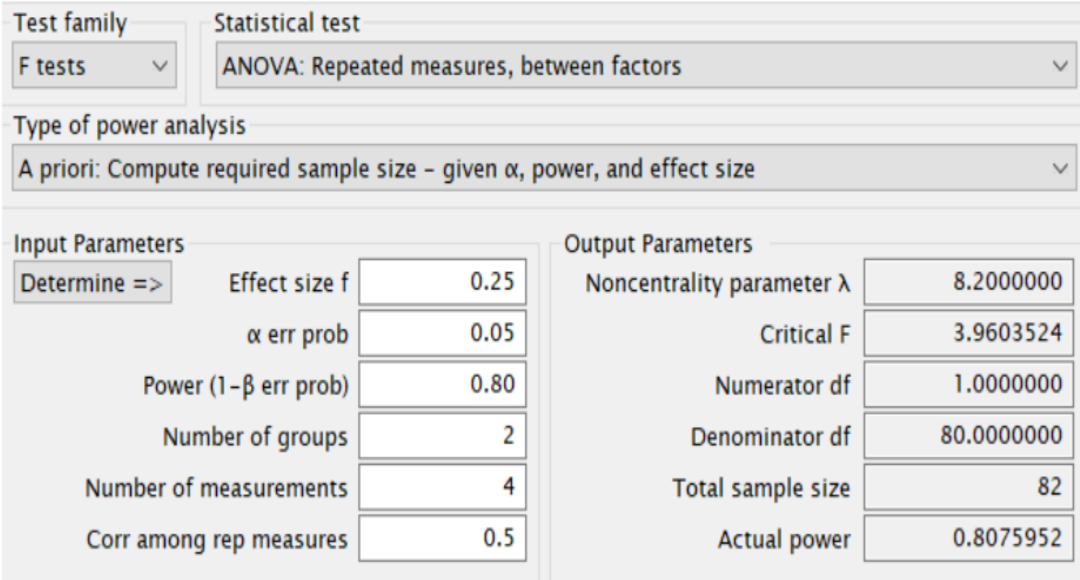


Figure 3.2: Sample size calculation by using G* 3.1 Power Package Software

3.6 POPULATION AND SAMPLING

The 96 sampled patients were randomly chosen into two groups through a strategy of lottery i.e. Group A and Group B according to the determined selection criteria. Conventional Rehabilitation Protocol along with Isoinertial strengthening protocol was used in group A and Conventional Rehabilitation Protocol only was used in group B.

3.7 SELECTION CRITERIA

3.7.1 Inclusion Criteria

The inclusion of clients was based on the standards mentioned below:-

- Patients with age between 18-45 years both male and female.
- ACL reconstruction patients, done by same surgeon using Semi-tendinosis gracilis graft.
- Patients with 3weeks post ACL reconstruction surgery.

3.7.2 Exclusion Criteria

Exclusion of clients was based on the standards mentioned below: -

- History of previous knee surgery.
- Previous ACL Reconstruction surgery.
- Pre-existing physical limitation affecting gait or lower limb activity.
- Patients who are not willing to sign consent form.
- Inability to understand the English, Hindi, Punjabi language.
- Unable to perform isoinertial training.

3.8 SAMPLE SELECTION

The subjects were screened at UNI Health Care Centre, Lovely Professional University. Out of total 130 screened subjects, 96 subjects were enrolled as per the selection criteria of study. These subjects were divided into two groups namely Group A (Experimental group) n= 47 and Group B (Control group) n= 49.

Group A- Experimental group, received additional Isoinertial strengthening protocol along with Conventional rehabilitation protocol while Group B- Control group, received only Conventional rehabilitation protocol.

Subjects were on supportive therapy only, including calcium, multivitamins, and painkillers as needed, with no specific medications prescribed.

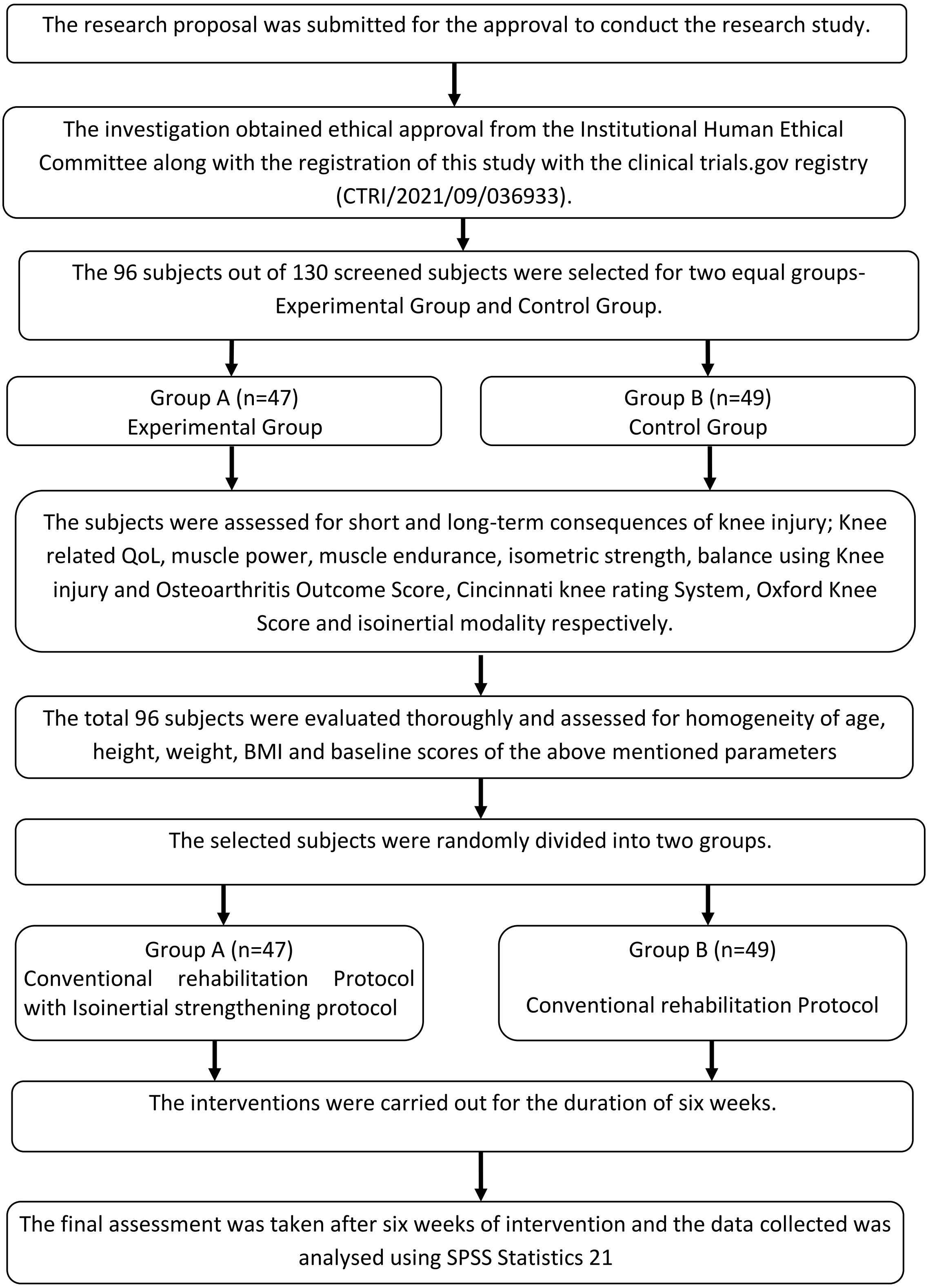


Figure 3.3 CONSORT Flowchart showing the procedure of the study

3.9 STUDY PROCEDURE

A total of 130 patients with subsequent ACL reconstruction surgery had been reviewed upon their reports to UNI Health Care Centre, Lovely Professional University. Out of the patients screened, 96 were included in the current study. Before performing any test, written patient consent was obtained from each screened patient. The included patients were seen for patient-relevant outcomes; Knee related quality of life, pain and function outcome of knee, Muscle Power, muscle Endurance, Isometric strength and Balance using consequences of knee injury and isoinertial modality, and short- and long-term patient-relevant outcomes in a single session. Thereafter, the patients were randomly assigned through a computer generated randomized table similar to coin flipping in two groups: Group A and Group B. The following intervention was given for 6 weeks at 60 minutes duration to both the patient A and patient B, and then, a 2nd assessment was undertaken after six weeks. Hence, each subject in two groups were assessed at a baseline in 1st assessment, before interventional treatment, and 2nd assessment, after six weeks of base line assessment. The changes in outcome variables were noted for all subjects for baseline 1st assessment and 2nd assessment in their respective data collection form. Group B received only standard rehabilitation, but Group A received an isoinertial strengthening regime over and above traditional physiotherapy.

Group A- Experimental Group: Forty seven subjects included in experimental group are given additional Isometric training protocol twice a week for six weeks 30 minutes in combination with conventional rehabilitation Protocol which was administrated daily for six months till phase 2 and half as this is a on going one 30 minutes per day for the rest of days that is Six days/week (Van Grinsven, S et al., 2010).

Using this protocol, the flywheel ergometer D11 Plus (Desmotec, Biella, Italy) was used to test maximum power peak (Ppeak), muscular endurance (work above 90% of Ppeak), total work done during 60 s at maximal power output, balance shift and maximal isometric force. Eccentric overload training was carried out through half squat exercises using a fly-wheel ergometer (D11Plus; Desmotec, Biella, Italy).

Squats and lunges x3x10 each on the flywheel ergometer pressure plate, at 2d/w with a passive 1min in between. All subjects were given global kinematic feedback and a high level of motivation to perform maximal into power zone. The researcher verbally assessed each repeat after it was completed. The concentric phase should be at maximum speed to allow the patients to explode while performing eccentrically controlled until the knee is flexed 90°. Each patient will use the total load as outlined below during experiment EOL: 1 medium disc (diameter 0.240m; mass 1.1kg; inertia 0.008 kg·m2) and 1 large disc (0.285m diameter; mass 1.9 kg). The estimated inertia of this type of ergometer (D11 Plus) is 0.0011 kg•m2 (Beato, Maroto-Izquierdo, et al., 2021).

Table 3. 1 Conventional Rehabilitation Protocol

Phases (Weeks)	Criteria for progression	Details of the Protocol
Phase 1 (Week 1)	–	• Attain range of motion (ROM) of 0–90*, with a focus on achieving complete extension (e.g., by CPM and exercises: heel slides, leg elevation with a cushion under the heel, and patellar mobilization in both directions). • Reduction of pain and inflammation (e.g., via workouts and cryotherapy). • Enhance the way you walk. Try to walk without crutches by day four if the discomfort is tolerable. To walk without crutches, one must have enough neuromuscular control and a non-limping gait pattern. • Strengthen your muscles safely and isotonically with OC (ROM 90*–40*) and CC (ROM 0*–60*) strength workouts without adding extra weight. (SLR, small teams, changing one's own body weight, etc.).
Phase 2 (Week 2 to Week 9)	• Very little edoema (measured with a measuring tape). • Knee pain equals or less than it was a week ago in terms of VAS score. • Using a ROM goniometer, full extension and	• Use cryotherapy following each treatment session to treat discomfort or swelling. • Restoring normal gait pattern with walking activities and walking without crutches from day 4 to day 10.

	90 flexion are achievable. • Enough control over the quadriceps to execute a mini squad 0–30 and SLR in various planes. • Superior patellar mobility in comparison to the ipsilesional side. • The capacity to walk without assistance or with crutches	• Maintain complete extension, 120* flexion from week two, and 130* flexion from week five as you work towards full range of motion, paying close attention to your patellar mobility. • Using isometric and isotonic strength training to target the quadriceps, hamstrings, gastrocnemius, and soleus in order to maximise range of motion for OC and CC motions without increasing weight. Weeks 2, 3, and 4 of the OC exercises are from 90* to 40*; an additional 10* will be added each week as an extension. The CC exercise ranges are 0* to 60* for weeks two through seven, and 0* to 90* for weeks eight. • Commence swimming and ergometer cycling in week three. • Increase from static stability to dynamic stability gradually while beginning neuromuscular training. As surface instability increases and visual input decreases, strive for balancing trust in the vestibular and somatosensory systems. • Begin using a stair-stepping machine in week four. • Take to the outdoors and start riding in week 8. Caution: Take appropriate action if there is ongoing discomfort, inflammation, or restricted range of motion. The possibility of developing arthrofibrosis

		exists (see the orthopaedic surgeon if unsure).
Phase 3 (Week 9 to Week 16)	• Very little discomfort or swelling (measured with a measuring tape and a VAS-score for pain). • ROM goniometer indicates that full extension and at least 130* flexion are feasible. • Normal gait pattern. • Last week's exercises are performed correctly. • Distribute the IKDC survey.	• Maximizing the power and endurance of muscles. For the OC and CC movements, add weights that increase starting in week nine. • Acquiring and preserving all ROM. • Neuromuscular training involves plyometric exercises and a growing focus on dynamic stability that is gradually increased in speed and duration. Work your way gradually up to one-legged leaping from two-legged jumping. Beginning in week 13, make running outside jogging a routine.
Phase 4 (Week 16 to Week 22)	• There is neither knee discomfort nor swelling. • Give the IKDC survey to people once again. • Whole range of motion (ROM) in the knee (goniometer). • The strength of the quadriceps and hamstrings >75 per cent against their opposites sides. The ratio of the hamstring/quadriceps strength is less than 15 percent different when comparing the results to the non-involved side (optional isokinetic testing of the knee flexors and extensors at 180 revolutions/second). • Exercises of previous week are carried out properly.	• Maximizing strength and muscular endurance. • Optimizing neuromuscular control, with special attention on activities related to specialized sports, agility training, and leaping. Different running, turning, and cutting manoeuvres are permitted. To be extended and optimized in both speed and duration.

	• Hop tests >75% compared to the contralateral side.	
-	Criteria for returning to sports • No discomfort or swelling (VAS-score pain, assessing knee pain with a measuring tape). • Knee flexion and extension can be fully extended (ROM-Goniometer). • The quadriceps and hamstring strength on the contralateral side is >85% higher. When comparing the strength of the quadriceps and hamstrings to the opposite side, there is a difference of less than fifteen percent • Hop tests are >85% when compared to the opposite side. • Administer the IKDC survey to people once again. • Exercises from the previous week are performed correctly, and the patient is able to handle maximally fast and prolonged durations of sport-specific activities and agility training.	The patient tolerates maximally prolonged and fast agility training as well as sport-specific exercises performed correctly from the previous week.

Group B- Control Group: In group B, a total of 49 patients were administered conventional rehabilitation Protocol for the total of 6 weeks for 30 minutes daily for six days per week till week 6 of phase2 and half as this is an ongoing study. The details of the interventional program are given in Table 3.1 (Van Grinsven, S et al., 2010)

3.10 OUTCOME MEASURES

3.10.1 Independent Variable

- Isoinertial Training
- Eccentric Overload

3.10.2 Dependent Variables

- Power
- Endurance
- Knee injury and Osteoarthritis Outcome Score (KOOS)
- Isometric Strength
- Cincinnati knee rating System (CKRS) Score
- Balance
- Oxford Knee Score (OKS)

3.11 INSTRUMENTS AND TOOLS FOR DATA COLLECTION

- Knee injury and Osteoarthritis Outcome Score
- Cincinnati knee rating System.
- Oxford Knee Score
- Flywheel Ergometer (D11 Plus; Desmotec, Biella, Italy)

1. Knee injury and Osteoarthritis Outcome Score

Knee Injury and Osteoarthritis Outcome Score (KOOS) is a patient relevant measure questionnaire administered to the care providers to assess the short term, and the long term consequences of knee injury. The five results are symptoms, pain, sport and leisure functions, activities of daily living, and knee-related quality of life that are measured by the self-administered KOOS. The KOOS can be employed as an assessment of the outcome of treatments and expectations of the development of knee injuries since it meets the essential criteria of outcome measures. It has a style of easy usage, takes approximately 10 minutes to do, and it is administered by the patient. The KOOS measures each of the five aspects of the involved five patient-relevant aspects as being: sport and recreation function (five items), pain (nine items), ADL performance (17 things), symptoms (7 items), and quality of life (4 items). There are five possible answers per issue, and Likert scale where the score can go up to 4 (severe problems) and 0 (no difficulty). All the scores are made through adding of all the items in a set.

The scores are then converted into a 0-100 scale with zero representing major knee problems and 100 representing none of the knee problems like orthopaedic scores and overall scores. The percentage scores are represented by the numbers in the range of 0-100. It was stated that the test-retest reliability was very high with intra class correlation values of 0.91 to 0.99 (G. Chamorro-Moriana et al., 2022).

2. Cincinnati knee rating System

This scale was first published by Noyes et al. in 1983 as a scale of outcomes to enable doctors to discover more information about the function and clinical outcomes of patients, after they have undergone knee surgery. This instrument that has experienced numerous modifications is commonly used in determining the final results of Anterior Cruciate Ligament (ACL) repair.

Cincinnati Knee Rating System (CKRS) was rated in 0-100 points ranging sores of Maximum Score 100 points and Minimum Score 0 points. This highest score conveys maximum functioning, stability, and satisfaction and shows no symptoms and knee-related problems. Basically, 100 points is a perfect or near-normal status of the knee. An increase in the CKRS score indicates a greater functional comfort of the knee and a patient. On the other hand, when the score is low, there is more symptomatic irritability and less functioning capacity and a greater risk of problems in knee instability or any other problem. Test-retest reliability was between ICC= 0.82 of the subscale test, and ICC= 0.96 of the subscale test (giving away), (Phatama, K. Y. et al, 2021).

3. **Oxford Knee Score (OKS)**

Oxford Knee Score (OKS) is recognized as a common patient-reported outcome measure _ tool that is employed to assess the knee joint pain and functionality particularly among the patients who have gone through knee replacements. It has 12 questions which are rated on a scale of 0 to 4 points with a maximum score of 48. The scores lower than average reflect intense knee problems, whereas higher score shows the optimal functioning and pain reduction related to knees. The OKS is also comparatively fast in its administration, patients usually spend approximately 10-15 minutes answering it. It has been proven to be reliable and valid in numerous clinical trials which implies that the results that it yields are consistent and accurate and dependant on the actual condition (N. D. Clement, et al., 2022).

4. **Flywheel ergometer (D11 Plus; Desmotec, Biella, Italy)**

The Peak force was determined with the aid of an isoinertial device (D11 full, Biella, Desmotec, Italy) by assessing the lower extremity isometric strength test (ISOMET). A strap was placed on the participant to connect the gadget; one of the ends of the strap was connected to the waistcoat of the participant and the other end was connected to the instrument. The responder would not have been able to move up owing to tightening of the strap. The Desmotec device has two contact panels and they are connected to a computer where the software is located (D.Soft, Biella, Desmotec, Italy). The choirpart does a one-hundred degree bend of which the consequence is the straightening of his knees, also the fact that his body is placed in semi-squat by his presenting of his hands to his hips. During the sign, the person exerts as much pressure as possible at the free point of the plates through maximum voluntary isometric contraction pressure at the plate in 10 seconds. The contact panels measure the force that the participant applies and then inputs the same into the computer. In this way, both the eccentric and concentric muscular power and isometric strength and endurance were measured. In measuring balance, the patient was made to stand in semi-squat, flexion angle of 100 degrees and the plates that were loaded on the platform weighed 10 sec and on becoming loose, the deviation on either side was read and the percentage of the tip was thus measured (Beato, M. et al., 2021).

Figure 3. 4 Patient is performing VMO strengthening exercise in Conventional Rehabilitation Protocol

Figure 3. 5 Patient is performing squatting in Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol.

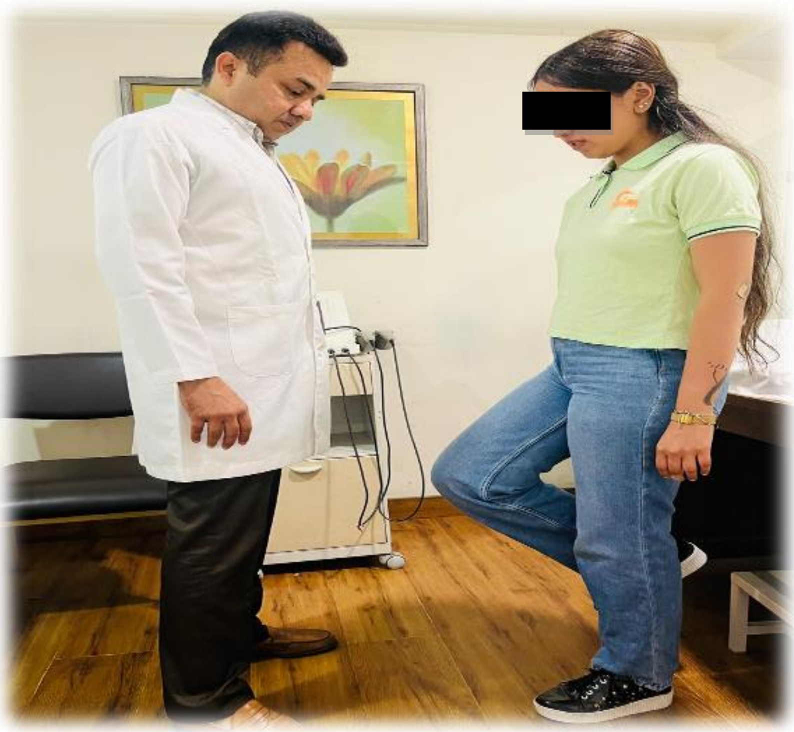


Figure 3. 6 Patient is performing single leg stand in Conventional Rehabilitation

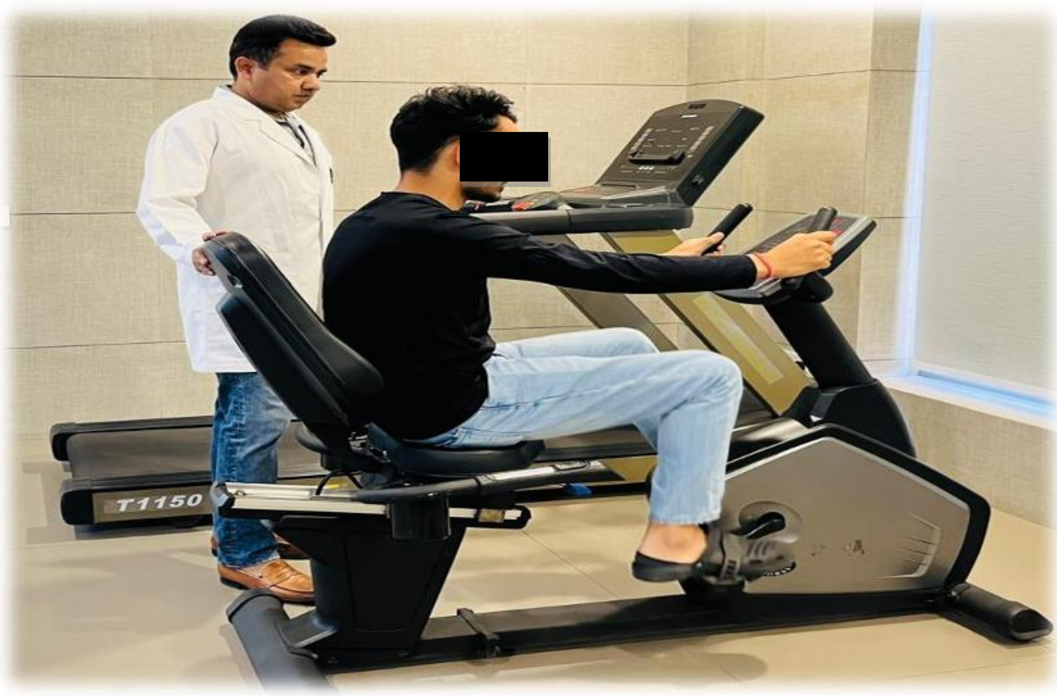


Figure 3. 7 Patient is performing cycling in Conventional Rehabilitation Protocol

Figure 3. 8 Patient is performing side lunges in Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol.

Figure 3. 9 Patient is performing lunges in Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol.

Figure 3. 10 Patient is performing step up and step down exercise Conventional Rehabilitation Protocol.

3.12 STATISTICAL ANALYSIS

The investigation's results have been analyzed using inductive and descriptive statistics along with visually appealing graphs and tables. The paired and independent t-tests, along with their corresponding effect sizes and confidence intervals, are the statistical methods used in this section. SPSS 20 was used for the statistical analysis. The significance threshold for the results was set at 0.05.

3.12.1 Arithmetic Mean ($\bar{X}$)

This formula is derived by adding up every single item and divided the result by the total number of items, yields the value of the whole range of the data provided:

$$\bar{X} = \frac{\Sigma X}{N}$$

Where,

N = Number of subjects X= each subject value

3.12.2 Standard Deviation (SD)

The standard deviation, often represented by the symbol (), which is pronounced as sigma, is the most generally used indicator of a series' dispersion. The square root of the average of squares of deviations, where such deviations for the values of individual items in a series are determined using arithmetic average, is the definition of standard deviation.

The formula used is:

$$SD = \sqrt{\frac{\Sigma(x - \bar{x})^2}{N - 1}}$$

Where, N = Number of subjects X= Variable $\bar{x}$= Mean of x

3.12.3 t-test of Independent Means

The formula for the independent t-test is

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S} \times \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

Where,

$\bar{X}_1$ = Mean of the first sample

$\bar{X}_2$ = Mean of second sample

n_1 = Number of observation in the first sample

n_2 = Number of observation in the second sample

S = Combined standard deviation

3.12.4 t-test for dependent Means

The formula for the paired t-test is

$$t = \frac{\sum D}{\sqrt{\frac{n\sum D^2 - (\sum D)^2}{n-1}}}$$

Where,

D = Difference per paired value

n = Number of samples

To further enhance the statistical interpretation, effect size and 95% confidence intervals (CI) have been calculated. Effect size is quantified using Cohen's d, which measures the magnitude of differences, and confidence intervals provide a range for the true mean difference with a high level of confidence.

CHAPTER IV

RESULTS

CHAPTER OVERVIEW

This chapter provides a thorough explanation of the research's findings in order to paint a clear picture of the conclusions derived from the data analysis.

Baseline Data

In this study, patients participating in this study in group A was 29.94+6.78 years and in group B was 30.20+7.45 years on average. The demography of the patients in terms of age, height, weight, BMI and baseline values of Muscle Power, Endurance, Isometric strength, Balance, Knee injury and Osteoarthritis Outcome Score (KOOS) and Cincinnati knee rating System (CKRS) scores were matched and it was found that the age, height as well as weight, BMI were having statistical non-significant difference, whereas Isometric strength, Endurance and Balance were found to be statistically significant difference except the muscle Endurance which was found to be statistically significant as shown in Table 4.1 using an unpaired t Table 4.2 outlines the comparison of the paired t -test of mean differences between pre and post intervention measures of Muscle Power, Endurance, Isometric strength, Balance, Knee Injury Outcome and Osteoarthritis Score and Knee related Quality of Life in the both individual groups of the post operated patients of having undergone ACL reconstruction surgery. The examination of the findings revealed that there is the statistical enhanced values of Muscle Power (concentric and eccentric) as well as Isometric strength as well as Balance of the both groups A and B ($p < 0.05$). However, considering the aspect of Endurance of muscles, the mean showed no statistical significant difference between the group B at two separate time points (0 week and 6th week) at $p > 0.05$.

In addition, the analysis of the inquiry concerning enhancement of mean values of Muscle Power (concentric), Isometric strength, and Balance demonstrated that no statistically significant difference was revealed between two groups, A and B ($p > 0.05$). The statistically significant effect, however, was witnessed on the third gain of mean value of muscle power (eccentric) in the group A at $p<0.05$ as depicted in Table 4.3 with the use of the unpaired t-test.

The result of the current study has been described under following sections:

4.1 Descriptive Statistics

4.2 Comparison in Muscle Power, Endurance, Isometric strength, Balance, Knee injury and Osteoarthritis Outcome Score, Cincinnati knee rating scores and Oxford knee score at 0 v/s 6 weeks interval within Group A and Group B

4.3 Comparison of improvement in the mean values of Muscle Power, Endurance, Isometric strength, Balance, Knee injury and Osteoarthritis Outcome Score, Cincinnati knee rating scores and Oxford knee score at 0 v/s 6 weeks interval between Group A and Group B

4.1 DESCRIPTIVE STATISTICS

Table 4. 1 Base line demographic characteristics of Study participants.

Demographic Characteristics	**Group A (Mean ± SD) (n=47)**	**Group B (Mean ± SD) (n=49)**	**Group A vs Group B**	
			t value	**p- value**
Age (yrs)	29.94±6.78	30.20±7.45	0.184	0.854
Height (cm)	171.45±5.09	172.31±5.95	0.758	0.449
Weight (kg)	78.38±10.66	78.37±9.97	0.007	0.994
BMI (kg/m2)	26.68±3.57	26.42±3.22	0.380	0.710

Table 4.1 Compares the demographic characteristics of two groups, Group A - and Group B, across several parameters: Age, Height, Weight, and BMI. The

average age for Group A is 29.94 years (±6.78), while Group B has an average age of 30.20 years (±7.45), with no statistically significant difference between them (t = 0.184, p = 0.854). Similarly, there is no significant difference in height, with Group A averaging 171.45 cm (±5.09) and Group B at 172.31 cm (±5.95) (t = 0.758, p = 0.449). Weight averages are also comparable, with Group A at 78.38 kg (±10.66) and Group B at 78.37 kg (±9.97), showing no significant difference (t = 0.007, p = 0.994). BMI scores for both groups are close as well, with Group A at 26.68 (±3.57) and Group B at 26.42 (±3.22), with no statistical significance (t = 0.38, p = 0.71). Overall, none of the demographic characteristics age, height, weight, or BMI show significant differences between Group A and Group B, indicating that the groups are demographically similar.

Table 4. 2 Base line characteristics of Male and Female participants in both Groups

Participants	Male				Female			
	Group A (Mean ± SD) (n=36)	Group B (Mean ± SD) (n=34)	Group A Vs Group B		Group A (Mean ± SD) (n=11)	Group B (Mean ± SD) (n=15)	Group A Vs Group B	
			t value	p value			t value	p value
Age (Yrs)	29.19±6.79	29.71±7.33	0.30	0.76(NS)	32.36±6.44	31.33±7.85	0.36	0.73(NS)
Height (Cm)	172.44±4.79	174.47±4.43	1.84	0.07(NS)	168.18±4.85	167.40±6.17	0.35	0.73(NS)
Weight (Kg)	79.86±8.54	81.09±10.14	0.55	0.59(NS)	73.55±15.28	72.20±6.28	0.31	0.76(NS)
BMI (kg/m2)	26.92±3.23	26.65 ± 3.30	0.34	0.74(NS)	25.90±4.63	25.88±3.08	0.01	0.99(NS)

For male participants, the average age in Group A is 29.19 years (±6.79), while Group B's is 29.71 years (±7.33), with no significant difference (t = 0.30, p = 0.76). Male participants' height shows no significant difference, with Group A at 172.44 cm (±4.79) and Group B at 174.47 cm (±4.43) (t = 1.84, p = 0.07). Likewise, the male participants' weight (Group A: 79.86 kg ± 8.54, Group B: 81.09 kg ± 10.14) and BMI (Group A: 26.92 ± 3.23, Group B: 26.65 ± 3.30) show no significant differences (p > 0.05).

For female participants, Group A has an average age of 32.36 years (±6.44) compared to Group B's 31.33 years (±7.85), with no significant difference (t = 0.36, p = 0.73). Height and weight also remain statistically similar, with Group A females averaging 168.18 cm (±4.85) compared to Group B's 167.40 cm (±6.17) (t = 0.35, p = 0.73), and Group A's weight at 73.55 kg (±15.28) compared to Group B's 72.20 kg (±6.28) (t = 0.31, p = 0.76). The BMI for females is also close, with Group A at 25.90 (±4.63) and Group B at 25.88 (±3.08) (t = 0.01, p = 0.99). Thus, demographic characteristics are consistent between groups for both male and female participants, suggesting demographic homogeneity.

Table 4. 3 Comparison of baseline assessments of both the Groups

Parameters	**Group A (n=47)**	**Group B (n=49)**	**t value**	**p value**
Muscle Power Concentric (W)	79.00±19.35	80.61±25.78	0.345	0.730
Muscle Power Eccentric (W)	85.64±17.80	87.04±17.87	1.72	0.09
Endurance (sec)	10.98±3.28	11.10±2.39	0.211	0.833
Isometric strength (kg)	166.70±33.15	161.30±41.08	0.706	0.481
Balance (%)	6.53±2.74	7.16±2.08	1.28	0.210
KOOS (%)	44.88±4.03	44.34±3.52	0.69	0.490

CKRS	50.77±4.16	50.18±3.63	0.731	0.466
OKS	35.68±4.27	35.31±3.94	0.45	0.66
KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score				

This table 4.3 provides a comparison of physical performance metrics and scores between Group A and Group B, with each parameter showing mean values and standard deviations. For Muscle Power Concentric (measured in watts), Group A has a mean of 79.00 (±19.35), while Group B is at 80.61 (±25.78), with no significant difference (t = 0.345, p = 0.730). Similarly, Muscle Power Eccentric is comparable between groups, with Group A at 85.64 (±17.80) and Group B at 87.04 (±17.87), showing no statistical significance (t = 1.72, p = 0.09). Endurance, measured in seconds, is 10.98 (±3.28) in Group A and 11.10 (±2.39) in Group B, with no significant difference (t = 0.211, p = 0.833).

For Isometric strength (in kg), Group A has a mean of 166.70 (±33.15) compared to 161.30 (±41.08) in Group B, with no significant difference (t = 0.706, p = 0.481). Balance, represented as a percentage, also shows no significant difference between the groups; Group A has an average of 6.53% (±2.74) and Group B 7.16% (±2.08) (t = 1.28, p = 0.21).

In the scoring parameters, KOOS (Knee Injury and Osteoarthritis Outcome Score) averages 44.88 (±4.03) in Group A and 44.34 (±3.52) in Group B, with no significant difference (t = 0.69, p = 0.49). CKRS (Cincinnati Knee Rating Scale) scores are also similar, with Group A at 50.77 (±4.16) and Group B at 50.18 (±3.63), showing no statistical significance (t = 0.731, p = 0.466). Lastly, OKS (Oxford Knee Score) averages are close, with Group A at 35.68 (±4.27) and Group B at 35.31 (±3.94), showing no significant difference (t = 0.45, p = 0.66).

Overall, none of the parameters Muscle Power (Concentric and Eccentric), Endurance, Isometric Strength, Balance, KOOS, CKRS, or OKS show statistically significant differences between Group A and Group B, indicating similar physical performance and outcome scores across the groups.

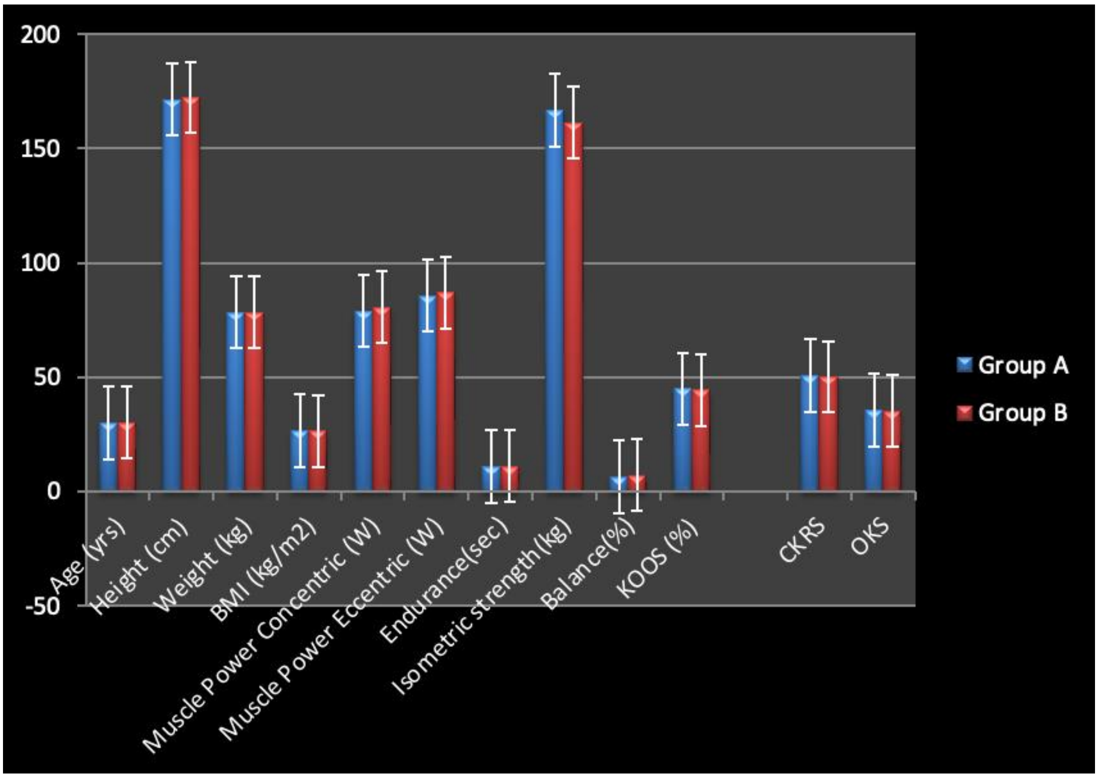


Figure 4. 1 Graphical display of Comparison of Mean value for Age (in years), Height (cm), Weight (kg), BMI (kg/m2) and baseline scores of Muscle Power, Endurance, Isometric Strength, Balance, KOOS, CKRS and OKS between subjects of Group A and Group B

Table 4. 4 Distribution of Males and Females included in the study

Gender	Group A	Group B
Male	36 (77%)	34 (69%)
Female	11 (23%)	15 (31%)

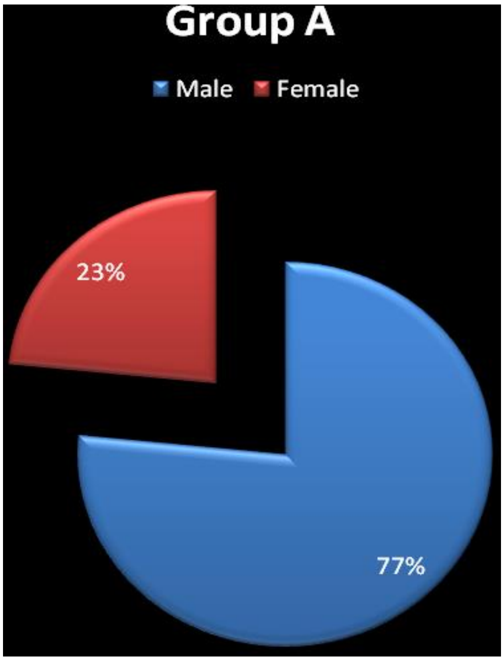


Figure 4. 2 Comparison of Gender distribution among Subjects of Group A

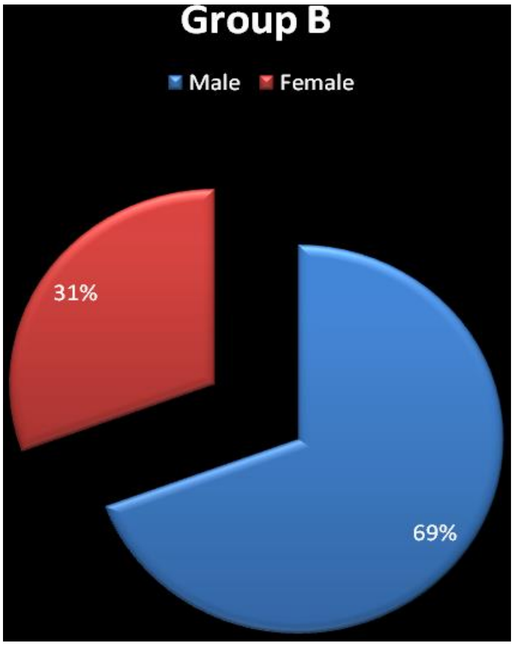


Figure 4. 3 Comparison of Gender distribution among Subjects of Group B

Table 4.5 Distribution of Patients based on Operated Side

Operative Side	Group A	Group B
Dominant Side	29	28
Non-Dominant Side	18	21

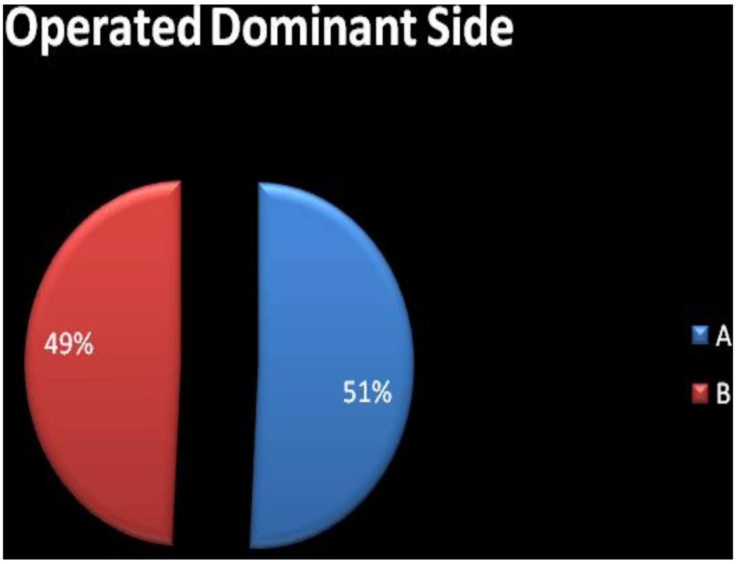


Figure 4. 4 Graphical representation of distribution of patients based on their Operated dominant side.

4.2 COMPARISON OF MEAN VALUES OF OUTCOME MEASURES AT 0 V/S 6 WEEKS INTERVAL WITHIN GROUP A AND GROUP B

Table 4. 6 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group A

Parameters	Week 0 Mean±S.D	Week 6 Mean±S.D	CI Lower	CI Upper	Cohen's d	t value	p value
Muscle Power Concentric (W)	79.00±19.35	173.53±49.91	41	148.06	2.5	16.42	<0.01(S)*
Muscle Power Eccentric (W)	80.79±17.80	178.40±41.96	52.03	143.19	3.03	14.68	<0.01(S)*
Endurance (sec)	10.98±3.28	14.85±3.87	-1.2	8.94	1.08	9.50	<0.01(S)*
Isometric strength (kg)	166.70±33.15	216.34±36.60	0.26	99.02	1.42	17.12	<0.01(S)*
Balance (%)	6.53±2.74	3.23±2.11	-6.76	0.16	-1.35	7.25	<0.01(S)*
KOOS (%)	44.88±4.03	74.27±3.10	24.31	34.47	8.17	179.82	<0.01(S)*
CKRS	50.77±4.16	80.09±6.54	21.57	37.07	5.35	82.33	<0.01(S)*
OKS	35.68±4.27	47.72±3.15	6.73	17.35	3.21	52.93	<0.01(S)*

NS= Non-significant, S=Significant, W= Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

Table 4.6 demonstrate significant improvements in various physical and functional metrics from Week 0 to Week 6. Muscle Power Concentric increased from 79.00 W (±19.35) at baseline to 173.53 W (±49.91) at Week 6, with a highly significant t-value of 16.42 ($p < 0.01$). Similarly, Muscle Power Eccentric showed a notable increase from 80.79 W (±17.80) to 178.40 W (±41.96) over the same period ($t = 14.68$, $p < 0.01$). Endurance also significantly improved, with participants able to sustain exercise for longer, increasing from 10.98 seconds (±3.28) to 14.85 seconds (±3.87), showing a t-value of 9.50 ($p < 0.01$).

Isometric Strength (in kg) saw a substantial improvement from 166.70 kg (±33.15) at Week 0 to 216.34 kg (±36.60) at Week 6, with a t-value of 17.12, which is highly significant ($p < 0.01$). Interestingly, Balance scores (measured as a percentage) decreased from 6.53% (±2.74) to 3.23% (±2.11), indicating enhanced stability, with a t-value of 7.25 ($p < 0.01$), also showing significance.

Functional scores also improved markedly. The KOOS (Knee Injury and Osteoarthritis Outcome Score) increased from 44.88 (±4.03) to 74.27 (±3.10), showing a significant t-value of 179.82 ($p < 0.01$). CKRS (Cincinnati Knee Rating Scale) improved from 50.77 (±4.16) to 80.09 (±6.54), with a t-value of 82.33 ($p < 0.01$). OKS (Oxford Knee Score) also saw a substantial improvement, rising from 35.68 (±4.27) at Week 0 to 47.72 (±3.15) at Week 6, with a significant t-value of 52.93 ($p < 0.01$).

The Confidence Intervals (CI) for most variables indicated positive changes, with the lower bounds not including zero, supporting the effectiveness of the intervention. For example, Muscle Power Concentric and Eccentric demonstrated large improvements with CI values of 41.00 to 148.06 and 52.03 to 143.19, respectively. The Effect Sizes (Cohen's d) were also large, particularly for Muscle Power Concentric (2.5) and Muscle Power Eccentric (3.03), suggested substantial improvements.

Table 4. 7 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group A Male subjects.

Parameters	Week 0 Mean±S.D	Week 6 Mean±S.D	CI Lower	CI Upper	Cohen's d	t value	P value
Muscle Power Concentric (W)	80.25±18.02	172.36±50.24	38.74	145.48	2.44	13.11	<0.01(S)*
Muscle Power Eccentric (W)	79.31±17.83	176.28±41.49	51.81	142.13	3.04	22.06	<0.01(S)*
Endurance (sec)	10.64±3.45	14.61±4.00	-1.31	9.25	1.06	8.18	<0.01(S)*
Isometric strength (kg)	169.71±33.37	219.39±35.55	0.92	98.44	1.44	16.46	<0.01(S)*
Balance (%)	6.03±2.70	3.14±2.10	-6.31	0.53	-1.19	5.33	<0.01(S)*
KOOS (%)	44.12±4.04	73.63±3.10	24.42	34.6	8.2	155.92	<0.01(S)*
CKRS	49.94±4.26	78.78±6.66	20.93	36.75	5.16	70.46	<0.01(S)*
OKS	34.83±4.48	47.08±3.17	6.76	17.74	3.16	43.76	<0.01(S)*

NS= Non-significant, S=Significant, W= Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

This table shows significant improvements across various physical and functional parameters from Week 0 to Week 6 among Group A male subjects. Muscle Power Concentric increased substantially from an average of 80.25 W (±18.02) at baseline to 172.36 W (±50.24) by Week 6, with a highly significant t-value of 13.11 ($p < 0.01$). Likewise, Muscle Power Eccentric rose from 79.31 W (±17.83) to 176.28 W (±41.49), with a t-value of 22.06, indicating a strong statistical significance ($p < 0.01$).

Endurance also showed a significant increase, improving from 10.64 seconds (±3.45) to 14.61 seconds (±4.00) by Week 6, with a t-value of 8.18 ($p < 0.01$). In terms of strength, Isometric Strength increased from 169.71 kg (±33.37) to 219.39 kg (±35.55), with a highly significant t-value of 16.46 ($p < 0.01$).

Balance scores, measured as a percentage, decreased from 6.03% (±2.70) to 3.14% (±2.10), reflecting improved stability with a t-value of 5.33 ($p < 0.01$). Functional outcome scores improved as well. The KOOS (Knee Injury and Osteoarthritis Outcome Score) increased from 44.12 (±4.04) to 73.63 (±3.10), with a significant t-value of 155.92 ($p < 0.01$). The CKRS (Cincinnati Knee Rating Scale) showed a strong improvement from 49.94 (±4.26) to 78.78 (±6.66), with a t-value of 70.46 ($p < 0.01$). Lastly, the OKS (Oxford Knee Score) improved from 34.83 (±4.48) to 47.08 (±3.17), with a significant t-value of 43.76 ($p < 0.01$).

The Confidence Intervals (CI) for all variables were positive, with the lower bounds not including zero, confirming significant changes. For example, Endurance showed a positive CI range of −1.31 to 9.25, indicated an increase in performance. The Effect Size (Cohen's d) values were large, especially for Muscle Power Eccentric (3.04) and Muscle Power Concentric (2.44), showed significant improvements. Other parameters, such as Isometric Strength (1.44), KOOS (8.2), CKRS (5.16), and OKS (3.16), also demonstrated large effect sizes, suggested substantial changes.

Table 4. 8 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group A Female subjects

Parameters	Week 0 Mean±S.D	Week 6 Mean±S.D	CI Lower	CI Upper	Cohen's d	t value	p value
Muscle Power Concentric (W)	74.91±23.72	177.36±51.01	46.19	158.71	2.58	11.59	<0.01(S)*
Muscle Power Eccentric (W)	85.64±17.63	185.36±44.80	51.58	147.86	2.93	10.19	<0.01(S)*
Endurance (sec)	12.09±2.47	15.64±3.47	-0.71	7.81	1.18	4.77	<0.01(S)*
Isometric strength (kg)	156.85±31.93	206.36±39.96	-1.64	100.66	1.37	6.34	<0.01(S)*
Balance (%)	8.18±2.27	3.55±2.21	-7.8	-1.46	-2.07	6.71	<0.01(S)*
KOOS (%)	47.35±2.95	76.36±2.05	25.42	32.6	11.42	93.9	<0.01(S)*
CKRS	53.45±2.34	84.36±3.88	26.38	35.44	9.65	62.49	<0.01(S)*
OKS	38.45±1.63	49.82±2.04	8.76	13.98	6.16	46.58	<0.01(S)*

NS= Non-significant, S=Significant, W= Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

This table highlights significant improvements in physical performance and functional scores among female subjects in Group A from Week 0 to Week 6. Muscle Power Concentric increased substantially, with an initial mean of 74.91 W (±23.72) rising to 177.36 W (±51.01) by Week 6, demonstrating a highly significant t-value of 11.59 ($p < 0.01$). Likewise, Muscle Power Eccentric saw a marked improvement from 85.64 W (±17.63) to 185.36 W (±44.80), with a t-value of 10.19, indicating strong statistical significance ($p < 0.01$).

Endurance improved from an average of 12.09 seconds (±2.47) at baseline to 15.64 seconds (±3.47) at Week 6, with a t-value of 4.77 ($p < 0.01$). Isometric Strength also showed a significant increase, rising from 156.85 kg (±31.93) to 206.36 kg (±39.96), supported by a t-value of 6.34 ($p < 0.01$). Balance scores, measured as a percentage, decreased from 8.18% (±2.27) to 3.55% (±2.21), indicating enhanced stability with a t-value of 6.71 ($p < 0.01$).

In terms of functional outcomes, the KOOS (Knee Injury and Osteoarthritis Outcome Score) improved markedly, going from 47.35 (±2.95) to 76.36 (±2.05), with a highly significant t-value of 93.9 ($p < 0.01$). The CKRS (Cincinnati Knee Rating Scale) increased significantly from 53.45 (±2.34) to 84.36 (±3.88), with a t-value of 62.49 ($p < 0.01$). Lastly, the OKS (Oxford Knee Score) rose from 38.45 (±1.63) to 49.82 (±2.04), with a significant t-value of 46.58 ($p < 0.01$).

Confidence Intervals (CI) for each variable showed positive changes with the lower bounds above zero or negative, confirming meaningful improvements. For example, Muscle Power Concentric and Eccentric demonstrated large positive changes, with CIs of 46.19 to 158.71 and 51.58 to 147.86, respectively. The Cohen's d values are notably large, especially for Muscle Power Eccentric (2.93) and Muscle Power Concentric (2.58), suggested substantial improvements. Other parameters such as Endurance (1.18), Isometric Strength (1.37), KOOS (11.42), CKRS (9.65), and OKS (6.16) also exhibit large effect sizes, indicated statistically significant changes across all outcomes.

Table 4. 9 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group A based on Operated side.

Parameters	**Dominant Side**				**Non-Dominant Side**			
	Week 0 Mean±S.D	**Week 6 Mean±S.D**	**t value**	**p value**	**Week 0 Mean±S.D**	**Week 6 Mean±S.D**	**t value**	**p value**
Muscle Power Concentric	76.31±19.61	170.86±52.43	12.33	<0.01 (S)*	83.33±18.66	177.83±46.70	10.69	<0.01 (S)*

(W)								
Muscle Power Eccentric (W)	79.03±18.10	178.48±43.33	16.29	<0.01 (S)*	83.61±17.44	178.28±40.89	10.90	<0.01 (S)*
Endurance (sec)	10.21±3.00	13.86±3.74	6.53	<0.01 (S)*	12.22±3.41	16.44±3.63	7.34	<0.01 (S)*
Isometric strength (kg)	165.10±35.38	215.20±35.13	12.35	<0.01 (S)*	169.28±30.01	218.17±39.83	12.35	<0.01 (S)*
Balance (%)	6.45±2.78	3.21±2.29	5.43	<0.01 (S)*	6.67±2.74	3.28±1.84	4.71	<0.01 (S)*
KOOS (%)	45.33±4.18	74.57±3.27	136.28	<0.01 (S)*	44.14±3.77	73.80±2.82	120.79	<0.01 (S)*
CKRS	51.31±4.35	80.83±6.82	62.82	<0.01 (S)*	49.89±3.77	78.89±6.05	52.89	<0.01 (S)*
OKS	36.00±4.58	48.07±3.26	38.01	<0.01 (S)*	35.17±3.79	47.17±2.96	38.32	<0.01 (S)*

NS= Non-significant, S=Significant, W= Watts,

This table presents a comparison of physical performance and functional scores within Group A subjects based on whether the operated side was the dominant or non-dominant side over a 6-week period.

For the dominant side, Muscle Power Concentric increased significantly from 76.31 W (±19.61) at Week 0 to 170.86 W (±52.43) at Week 6, with a t-value of 12.33 ($p < 0.01$). Similarly, Muscle Power Eccentric rose from 79.03 W (±18.10) to 178.48 W (±43.33), showing high statistical significance ($t = 16.29$, $p < 0.01$). Endurance also improved from 10.21 seconds (±3.00) to 13.86 seconds (±3.74), with a t-value of 6.53 ($p < 0.01$). Isometric Strength increased from 165.10 kg (±35.38) to 215.20 kg (±35.13), showing a highly significant t-value of 12.35 ($p < 0.01$). Balance scores decreased from 6.45% (±2.78) to 3.21% (±2.29), indicating improved stability ($t = 5.43$, $p < 0.01$).

Functional scores also showed marked improvements, with KOOS rising from 45.33 (±4.18) to 74.57 (±3.27), CKRS from 51.31 (±4.35) to 80.83 (±6.82), and OKS from 36.00 (±4.58) to 48.07 (±3.26), all with $p < 0.01$.

For the non-dominant side, Muscle Power Concentric increased from 83.33 W (±18.66) to 177.83 W (±46.70), with a t-value of 10.69 ($p < 0.01$). Muscle Power Eccentric improved from 83.61 W (±17.44) to 178.28 W (±40.89), also statistically significant ($t = 10.90$, $p < 0.01$). Endurance rose from 12.22 seconds (±3.41) to 16.44 seconds (±3.63), with a t-value of 7.34 ($p < 0.01$). Isometric Strength increased from 169.28 kg (±30.01) to 218.17 kg (±39.83), with a t-value of 12.35 ($p < 0.01$). Balance scores improved, decreasing from 6.67% (±2.74) to 3.28% (±1.84), with a t-value of 4.71 ($p < 0.01$). Functional outcomes also saw improvements: KOOS increased from 44.14 (±3.77) to 73.80 (±2.82), CKRS from 49.89 (±3.77) to 78.89 (±6.05), and OKS from 35.17 (±3.79) to 47.17 (±2.96), all highly significant ($p < 0.01$).

Table 4. 10 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group B subjects.

Parameters	Week 0 Mean ± S.D	Week 6 Mean ± S.D	CI Lower	CI Upper	Cohen's d	t value	p value
Muscle Power Concentric (W)	80.61±25.78	172.51±50.32	76.97	106.83	2.3	18.11	<0.01(S)*
Muscle Power Eccentric (W)	87.04±17.87	163.10±36.11	65.42	86.7	2.67	24.17	<0.01(S)*
Endurance (sec)	11.10±2.39	11.65±2.26	-0.32	1.42	0.24	1.83	0.074(NS)
Isometric strength (kg)	161.30±41.08	211.93±42.71	34.98	66.28	1.21	22.63	<0.01(S)*
Balance (%)	7.16±2.08	4.00±2.50	-4.02	-2.3	-1.37	7.21	<0.01(S)*
KOOS (%)	44.34±3.52	73.79±2.66	28.29	30.61	9.44	179.70	<0.01(S)*
CKRS	50.18±3.63	78.98±5.92	26.97	30.63	5.87	85.96	<0.01(S)*
OKS	35.31±3.94	47.35±2.79	10.77	13.31	3.53	51.23	<0.01(S)*

NS= Non-significant, S=Significant, W=Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

This table compares the mean values of various physical and functional measures within Group B subjects from Week 0 to Week 6. Muscle Power Concentric significantly increased from 80.61 W (±25.78) at Week 0 to 172.51 W (±50.32) at Week 6, with a highly significant t-value of 18.11 ($p < 0.01$). Similarly, Muscle Power Eccentric rose from 87.04 W (±17.87) to 163.10 W (±36.11), yielding a significant t-value of 24.17 ($p < 0.01$). Although Endurance showed an increase from 11.10 seconds (±2.39) to 11.65 seconds (±2.26), this change was not statistically significant ($t = 1.83$, $p = 0.074$). Isometric Strength increased markedly from 161.30 kg (±41.08) to 211.93 kg (±42.71), with a significant t-value of 22.63 ($p < 0.01$). Balance scores improved, with values decreasing from 7.16% (±2.08) to 4.00% (±2.50), indicating better stability ($t = 7.21$, $p < 0.01$).

For functional outcomes, KOOS improved significantly from 44.34 (±3.52) to 73.79 (±2.66), CKRS from 50.18 (±3.63) to 78.98 (±5.92), and OKS from 35.31 (±3.94) to 47.35 (±2.79), all showing high significance with $p < 0.01$. In summary, Group B subjects showed significant improvements in muscle power (both concentric and eccentric), isometric strength, balance, and all functional scores over the 6-week period, while endurance showed a slight, non-significant improvement.

The Confidence Intervals (CI) consistently showed positive changes, confirming the effectiveness of the intervention. Muscle Power Concentric and Eccentric showed large improvements with CIs of (76.97) to (106.83) and (65.42) to (86.7), respectively. The Cohen's d values were large, particularly for Muscle Power Eccentric (2.67) and Muscle Power Concentric (2.3), suggested significant changes. Other parameters like Isometric Strength (1.21), KOOS (9.44), CKRS (5.87), and OKS (3.53) also have large effect sizes, confirming improvements. Endurance, however, showed a small effect size (0.24) and was not statistically significant ($p = 0.074$), suggested minimal change.

Table 4.11 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group B of Male subjects.

Parameters	Week 0 Mean ± S.D	Week 6 Mean ± S.D	CI Lower	CI Upper	Cohen's d	t value	P value
Muscle Power Concentric (W)	78.21±23.75	172.71±51.01	79.64	109.36	2.38	15.38	<0.01 (S)*
Muscle Power Eccentric (W)	84.82±17.66	159.29±38.46	63.3	85.64	2.49	18.77	<0.01 (S)*
Endurance (sec)	11.09±2.37	11.38±2.31	-0.58	1.16	0.12	0.78	0.44 (NS)
Isometric strength (kg)	161.79±45.04	211.31±44.40	32.82	66.22	1.11	18.19	<0.01 (S)*
Balance (%)	7.06±2.06	4.18±2.28	-3.69	-2.07	-1.33	6.04	<0.01 (S)*
KOOS (%)	44.92±3.60	74.22±2.51	28.14	30.46	9.44	137.40	<0.01 (S)*
CKRS	50.79±3.47	80.00±5.55	27.48	30.94	6.31	79.46	<0.01 (S)*
OKS	36.03±3.25	47.85±2.70	10.7	12.94	3.96	57.80	<0.01 (S)*

NS= Non-significant, S=Significant, W=Watts

This table 4.11 presents a comparison of various physical and functional performance metrics within male subjects in Group B from Week 0 to Week 6, Muscle Power Concentric showed a marked increase from 78.21 W

(±23.75) at Week 0 to 172.71 W (±51.01) at Week 6, with a highly significant t-value of 15.38 ($p < 0.01$). Muscle Power Eccentric also saw a substantial increase, going from 84.82 W (±17.66) to 159.29 W (±38.46), with a significant t-value of 18.77 ($p < 0.01$). Endurance exhibited a minor, non-significant change from 11.09 seconds (±2.37) to 11.38 seconds (±2.31), as indicated by a t-value of 0.78 ($p = 0.44$). Isometric Strength improved significantly from 161.79 kg (±45.04) to 211.31 kg (±44.40), showing a t-value of 18.19 ($p < 0.01$). Balance scores, which denote stability, improved significantly, decreasing from 7.06% (±2.06) to 4.18% (±2.28), with a t-value of 6.04 ($p < 0.01$).

Functional outcome scores showed significant gains as well. KOOS increased from 44.92 (±3.60) to 74.22 (±2.51), CKRS from 50.79 (±3.47) to 80.00 (±5.55), and OKS from 36.03 (±3.25) to 47.85 (±2.70), all with p-values < 0.01, indicating high statistical significance. In conclusion, male subjects in Group B displayed significant improvements in muscle power, isometric strength, balance, and functional scores over the 6-week period, while endurance remained largely unchanged.

The Confidence Intervals (CI) for each variable showed positive changes, with the lower bounds above zero, indicating reliable improvement. For example, Muscle Power Concentric and Eccentric showed significant increases, with CIs of 79.64 to 109.36 and 63.3 to 85.64, respectively. The Cohen's d values were large, particularly for Muscle Power Eccentric (2.49) and Muscle Power Concentric (2.38), reflecting substantial effect sizes. Other parameters like Isometric Strength (1.11), KOOS (9.44), CKRS (6.31), and OKS (3.96) also showed large effect sizes, confirming improvements. However, Endurance showed a small effect size (0.12) and was not statistically significant ($p = 0.44$), suggesting minimal change.

Table 4.12 Comparison of Mean values of Outcome Measures at 0 v/s 6 weeks interval within Group B of Female subjects.

Parameters	**Week 0 Mean ± S.D**	**Week 6 Mean ± S.D**	**CI Lower**	**CI Upper**	**Cohen's d**	**t value**	**p value**
Muscle Power Concentric (W)	86.06±23.75	172.06±51.01	71.15	100.85	2.16	15.38	<0.01 (S)*
Muscle Power Eccentric (W)	92.06±17.66	171.29±38.46	65.97	92.49	2.31	18.84	<0.01 (S)*
Endurance (sec)	11.13±2.37	12.268±2.31	-0.16	2.44	0.49	0.78	0.44 (NS)
Isometric strength (kg)	160.19±45.04	213.34±44.40	38.86	67.44	1.18	18.19	<0.01 (S)*
Balance (%)	7.4±2.06	3.6±2.28	-4.69	-2.91	-1.76	6.04	<0.01 (S)*
KOOS (%)	43.04±3.60	72.8±2.51	28.54	30.98	9.52	137.40	<0.01 (S)*
CKRS	48.8±3.47	76.66±5.55	26.07	29.65	5.87	79.46	<0.01 (S)*
OKS	33.66±3.25	46.2±2.70	11.24	13.84	3.77	57.80	<0.01 (S)*

NS= Non-significant, S=Significant, W=Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

Table 4.12 presents a comparison of mean values for various physical and functional performance metrics within female subjects in Group B, measured at Week 0 and Week 6. Muscle Power Concentric demonstrated a significant increase from 86.06 W (±23.75) at Week 0 to 172.06 W (±51.01) at Week 6, yielding a t-value of 15.38 ($p < 0.01$), indicating a statistically significant improvement. Similarly, Muscle Power Eccentric improved markedly from 92.06 W (±17.66) to 171.29 W (±38.46), with a t-value of 18.84 ($p < 0.01$), highlighting significant gains in eccentric muscle strength.

In terms of Endurance, the change from 11.13 seconds (±2.37) to 12.26 seconds (±2.31) was negligible, as reflected in the t-value of 0.78 ($p = 0.44$), suggesting no significant improvement over the six-week period. Isometric Strength saw a notable increase from 160.19 kg (±45.04) to 213.34 kg (±44.40), with a t-value of 18.19 ($p < 0.01$), demonstrating significant enhancement. Balance also showed improvement, with scores decreasing from 7.40% (±2.06) to 3.60% (±2.28) and a t-value of 6.04 ($p < 0.01$), indicating better stability.

Functional outcome scores reflected substantial improvements as well, with KOOS rising from 43.04 (±3.60) to 72.80 (±2.51), CKRS increasing from 48.80 (±3.47) to 76.66 (±5.55), and OKS improving from 33.66 (±3.25) to 46.20 (±2.70), all achieving p-values < 0.01, reinforcing their statistical significance.

The Confidence Intervals (CI) for each variable showed positive changes, confirming the effectiveness of the intervention. For instance, Muscle Power Concentric and Eccentric showed significant increases, with CIs of 71.15 to 100.85 and 65.97 to 92.49, respectively. The Cohen's d values were large, particularly for Muscle Power Eccentric (2.31) and Muscle Power Concentric (2.16), reflecting substantial effect sizes. Other parameters such as Isometric Strength (1.18), KOOS (9.52), CKRS (5.87), and OKS (3.77) also exhibited large effect sizes, indicating statistically significant changes. However, Endurance had a small effect size (0.49) and was not statistically significant ($p = 0.44$), suggesting minimal change.

Table 4.13 Comparison of mean values of Outcome Measures at 0 v/s 6 weeks interval within Group B based on operated side.

Para meters	Dominant Side				Non-Dominant Side			
	Week 0 Mean±S.D	Week 6 Mean±S.D	t value	p value	Week 0 Mean±S.D	Week 6 Mean±S.D	t value	P value
Muscle Power Concentric (W)	77.54±21.83	169.54±47.98	14.23	<0.01 (S)*	84.71±30.34	176.48±54.22	11.04	<0.01 (S)*
Muscle Power Eccentric (W)	84.86±16.17	157.64±28.25	22.53	<0.01 (S)*	89.95±19.94	170.38±44.22	13.59	<0.01 (S)*
Endurance (sec)	11.36±2.63	12.14±2.29	2.40	<0.01 (S)*	10.76±2.05	11.00±2.10	0.43	0.67 (NS)*
Isometric strength (kg)	156.85±27.62	208.59±36.40	19.08	<0.01 (S)*	167.24±54.37	216.39±50.52	12.86	<0.01 (S)*
Balance (%)	7.46±2.12	4.04±2.44	5.35	<0.01 (S)*	6.76±2.00	3.95±2.64	4.91	<0.01 (S)*
KOOS (%)	44.82±4.13	74.08±3.02	111.69	<0.01 (S)*	43.71±2.44	73.40±2.11	201.83	<0.01 (S)*
CKRS	50.57±4.11	79.75±6.54	62.25	<0.01 (S)*	49.67±2.89	77.95±4.93	61.69	<0.01 (S)*
OKS	35.57±4.23	47.68±3.15	38.01	<0.01 (S)*	34.95±3.60	46.90±2.21	33.66	<0.01 (S)*

NS= Non-significant, S=Significant, W=Watts, KOOS = Knee Injury and Osteoarthritis Outcome score, CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

Table 4.13 compares the mean values of various physical performance metrics and outcome scores within Group A subjects, analyzed based on the operated side (dominant v/s non-dominant) at Week 0 and Week 6.

For the dominant side, muscle power showed significant improvements, with concentric muscle power increasing from 77.54 W (±21.83) at Week 0 to 169.54 W (±47.98) at Week 6 ($t = 14.23$, $p < 0.01$) and eccentric muscle power rising from 84.86 W (±16.17) to 157.64 W (±28.25) ($t = 22.53$, $p < 0.01$). Endurance also improved, with mean scores going from 11.36 seconds (±2.63) to 12.14 seconds (±2.29) ($t = 2.40$, $p < 0.01$). Additionally, isometric strength increased significantly from 156.85 kg (±27.62) to 208.59 kg (±36.40) ($t = 19.08$, $p < 0.01$). Balance scores decreased from 7.46% (±2.12) to 4.04% (±2.44) ($t = 5.35$, $p < 0.01$), indicating improved balance. The Knee Injury and Osteoarthritis Outcome Score (KOOS) rose significantly from 44.82 (±4.13) to 74.08 (±3.02) ($t = 111.69$, $p < 0.01$), while the Cincinnati Knee Rating Score (CKRS) increased from 50.57 (±4.11) to 79.75 (±6.54) ($t = 62.25$, $p < 0.01$). Lastly, the Oxford Knee Score (OKS) improved from 35.57 (±4.23) to 47.68 (±3.15) ($t = 38.01$, $p < 0.01$).

For the non-dominant side, concentric muscle power improved from 84.71 W (±30.34) to 176.48 W (±54.22) ($t = 11.04$, $p < 0.01$), and eccentric muscle power increased from 89.95 W (±19.94) to 170.38 W (±44.22) ($t = 13.59$, $p < 0.01$). However, endurance showed no significant change, with scores moving from 10.76 seconds (±2.05) to 11.00 seconds (±2.10) ($t = 0.43$, $p = 0.67$). Isometric strength significantly increased from 167.24 kg (±54.37) to 216.39 kg (±50.52) ($t = 12.86$, $p < 0.01$), and balance improved as scores decreased from 6.76% (±2.00) to 3.95% (±2.64) ($t = 4.91$, $p < 0.01$). Similar to the dominant side, the KOOS score increased significantly from 43.71 (±2.44) to 73.40 (±2.11) ($t = 201.83$, $p < 0.01$), while the CKRS rose from 49.67 (±2.89) to 77.95 (±4.93) ($t = 61.69$, $p < 0.01$), and the OKS improved from 34.95 (±3.60) to 46.90 (±2.21) ($t = 33.66$, $p < 0.01$). Overall, these results indicate significant improvements in muscle power, strength, balance, and knee-related outcome scores in both dominant and non-dominant sides within Group A subjects after a 6-week interval.

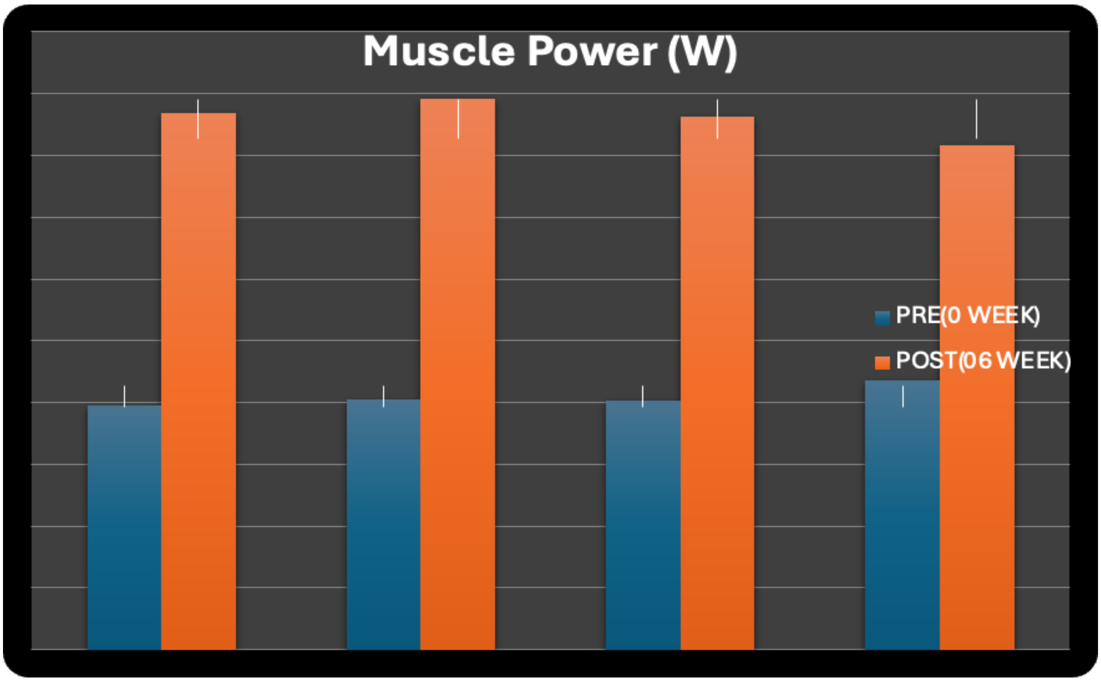


Figure 4. 5 Graphical representation of comparison of Mean values of Muscle Power at 0 v/s 6weeks interval within Group A and Group B

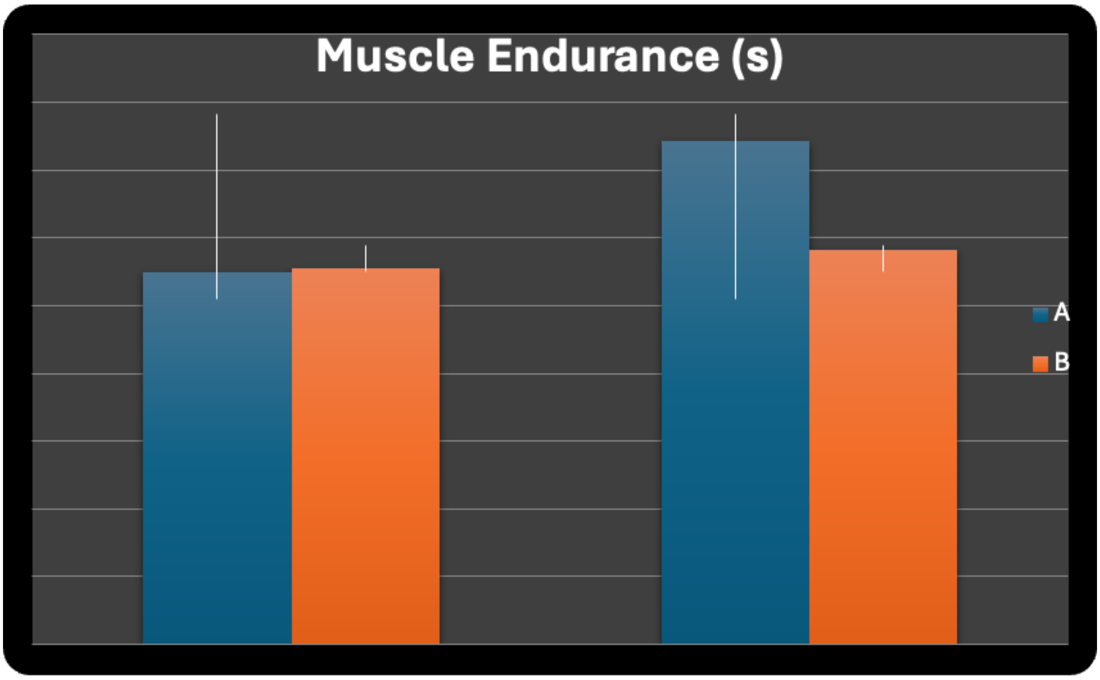


Figure 4. 6 Graphical representation of comparison of Mean value of Muscle endurance at 0 v/s 6 weeks interval within Group A and Group B

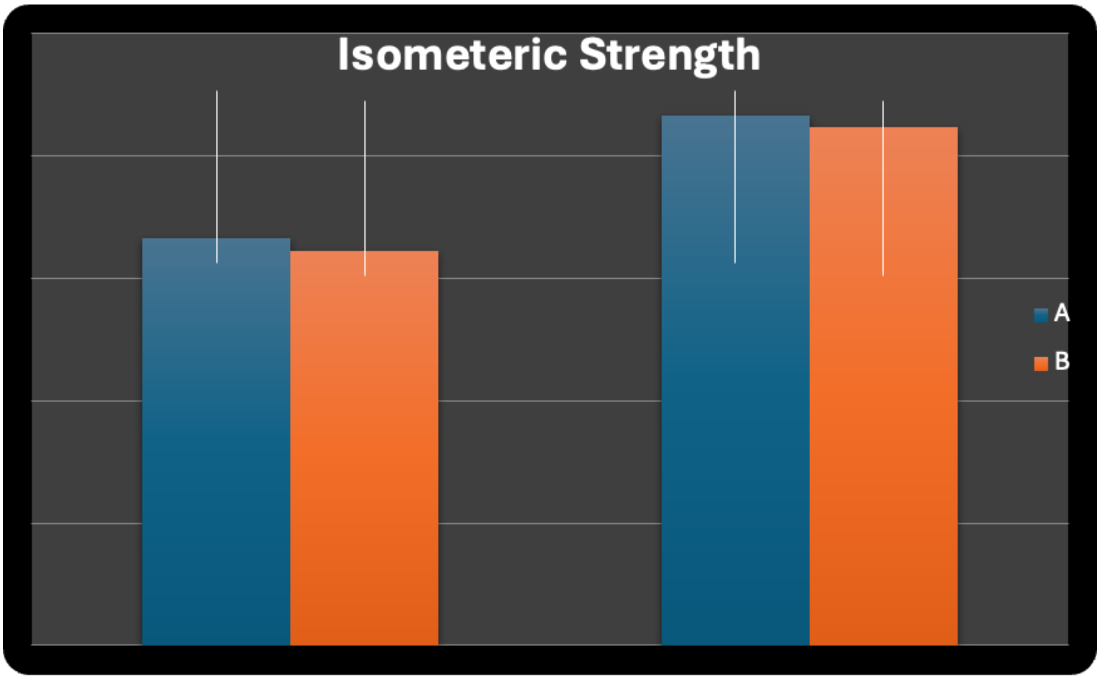


Figure 4. 7 Graphical representation of comparison of Mean value of Isometric strength at 0 v/s 6 weeks interval within Group A and Group B

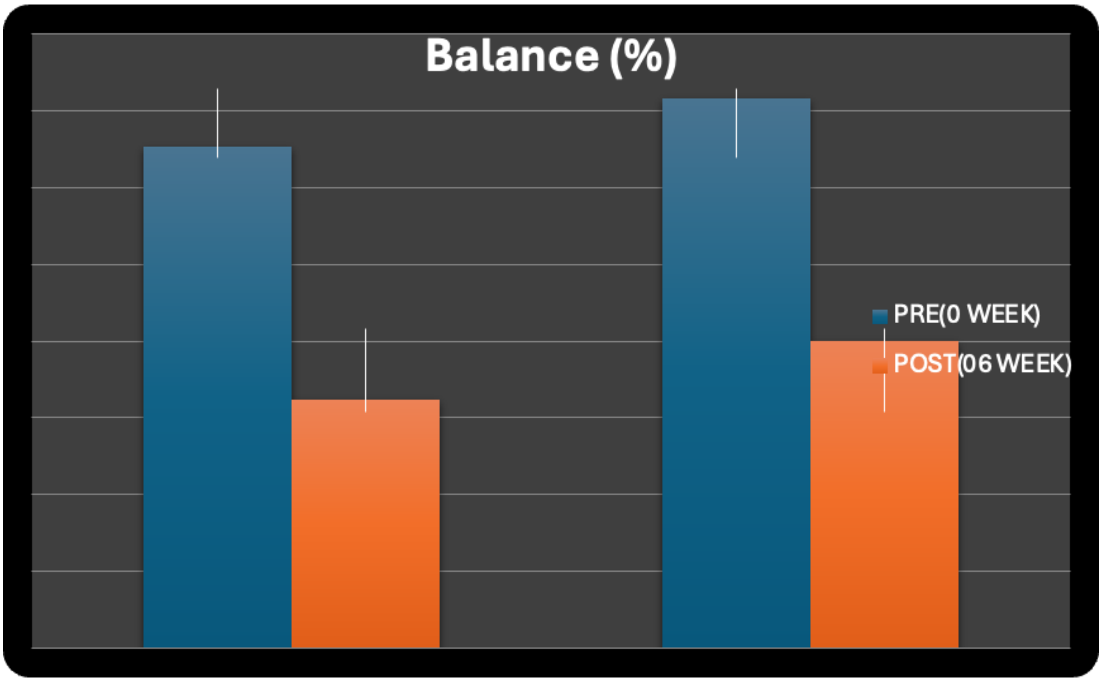


Figure 4. 8 Graphical representation of comparison of Mean value of balance at 0 v/s 6 weeks interval within Group A and Group B

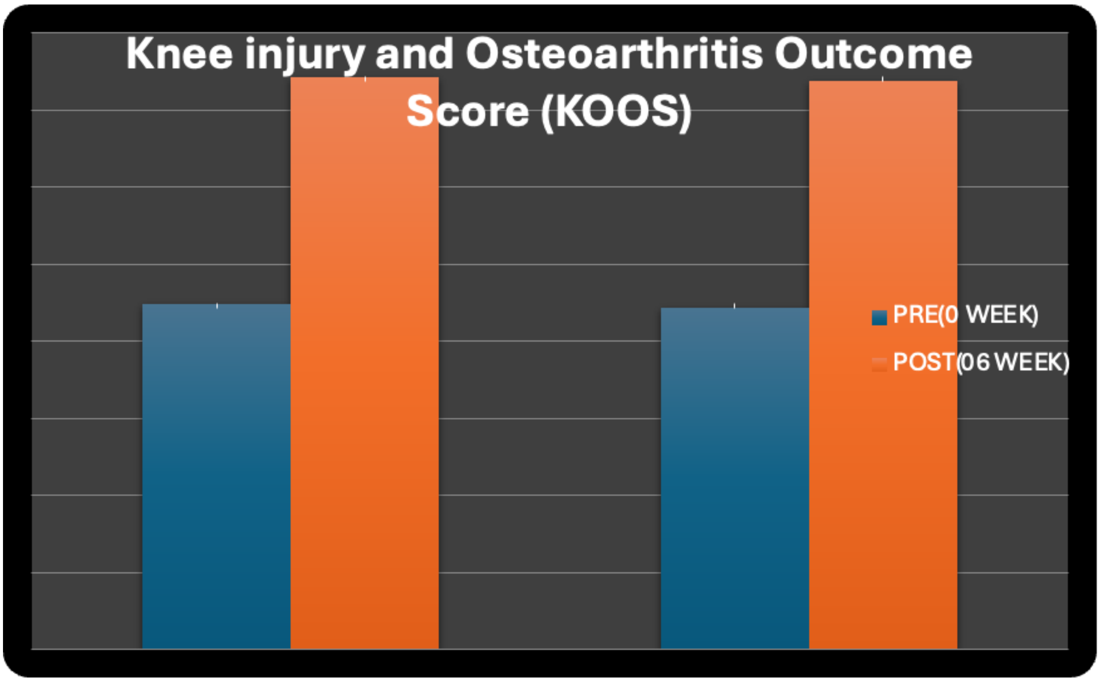


Figure 4. 9 Graphical representation of comparison of Mean value of Knee injury and Osteoarthritis Outcome Score (KOOS) at 0 v/s 6 weeks interval within Group A and Group B

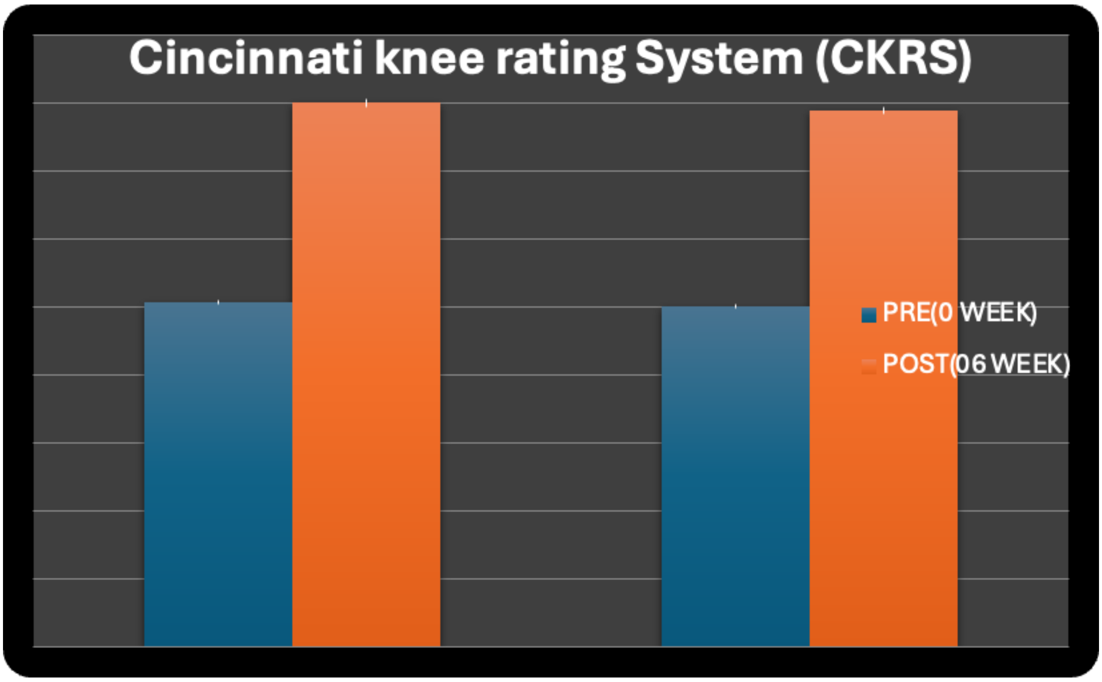


Figure 4. 10: Graphical representation of comparison of Mean value of Cincinnati knee rating System (CKRS) at 0 v/s 6 weeks interval within Group A and Group B

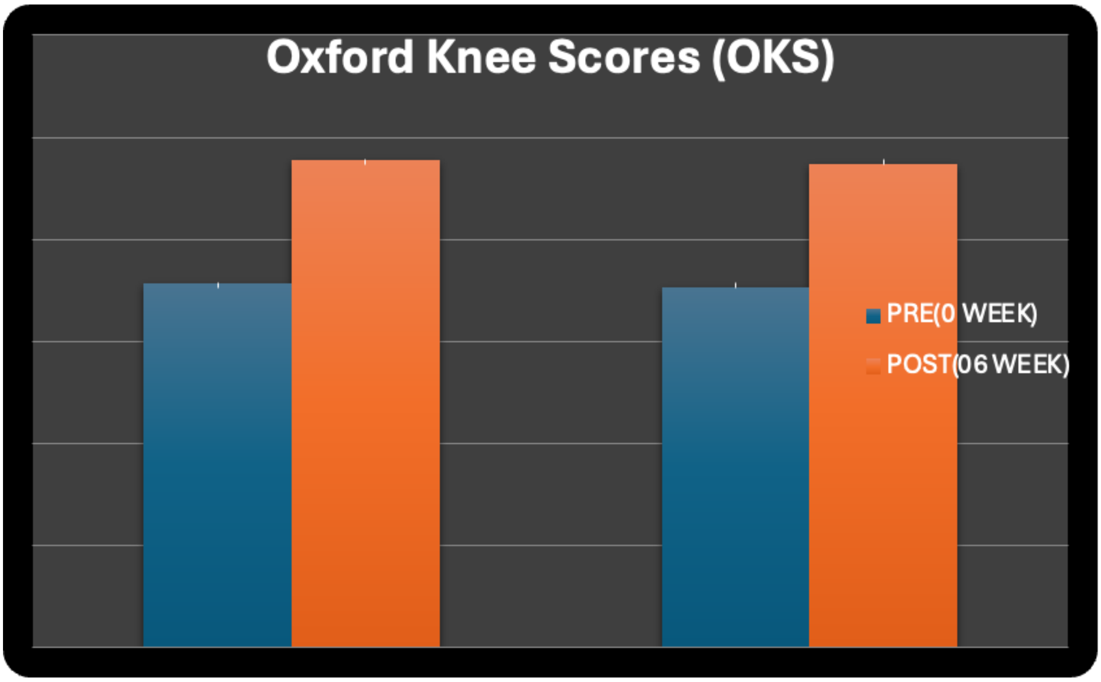


Figure 4. 11 Graphical representation of comparison of Mean value of Oxford Knee Scores (OKS) at 0 v/s 6 weeks interval within Group A and Group B

4.3 COMPARISON OF IMPROVEMENT IN THE MEAN VALUES OF OUTCOME MEASURES AT 0 V/S 6 WEEKS INTERVAL BETWEEN GROUP A AND GROUP B

Table 4.14 Improvement in Muscle Power, Isometric strength, Balance, Quality of life among Experimental and Control groups

Parameters at 0 week v/s 6 week	Group A Mean±S.D (n=47)	Group B Mean±S.D (n=49)	t value	p value
Muscle Power Concentric (W)	94.53±39.47	91.90±35.52	0.344	0.731 (NS)
Muscle Power Eccentric (W)	97.62±34.14	76.06±22.0	7.032	0.004*(S)
Isometric strength (kg)	49.63±19.88	50.62±15.66	0.271	0.786 (NS)

Balance (%)	-3.311±3.10	-3.16±3.07	0.233	0.815 (NS)
KOOS (%)	29.39±1.12	29.44±1.14	0.203	0.839 (NS)
CKRS	29.32±2.44	28.80±2.35	1.071	0.286 (NS)
OKS	9.76±4.96	10.73±4.09	1.128	0.262 (NS)

SD: Standard Deviation, NS= Non-significant; S=Significant, W=Watts, KOOS = Knee Injury and Osteoarthritis Outcome score,

CKRS= Cincinnati Knee Rating System, OKS= Oxford Knee Score

Table 4.14 Shows the comparison of improvement of mean value for Muscle Power both concentric and eccentric, Endurance, Isometric strength, Balance, Knee injury and Osteoarthritis Outcome Score and Cincinnati knee rating scores. For muscle power in the concentric phase, there was no significant difference observed, with Group A displaying a mean of 94.53 ± 39.47 W and Group B exhibiting 91.90 ± 35.52 W (t = 0.344, P = 0.731). However, in the eccentric phase, Group A, the mean muscle power was 97.62 ± 34.14 compared to Group B 76.06 ± 22.0 W, with a t value of 7.032 and a P value less than 0.05, indicating statistically significant. Isometric strength showed no significant difference between the two groups, with Group A at 49.63 ± 19.88 kg and Group B at 50.62 ± 15.66 kg (t = 0.271, P = 0.786, NS). Similarly, balance exhibited no statistically significant finding between Group A (-3.311 ± 3.10%) and Group B (-3.16 ± 3.07%), with a t value of 0.233 and a P value of 0.815. Furthermore, parameters related to knee function, as assessed by the Knee injury and Osteoarthritis Outcome Score (KOOS), Cincinnati knee rating system (CKRS) scores and, Oxford Knee scores revealed no significant differences between the two groups at 6 weeks, with P values of 0.839 (t = 0.203), 0.286 (t = 1.071), and 0.2616 (t=1.128) respectively.

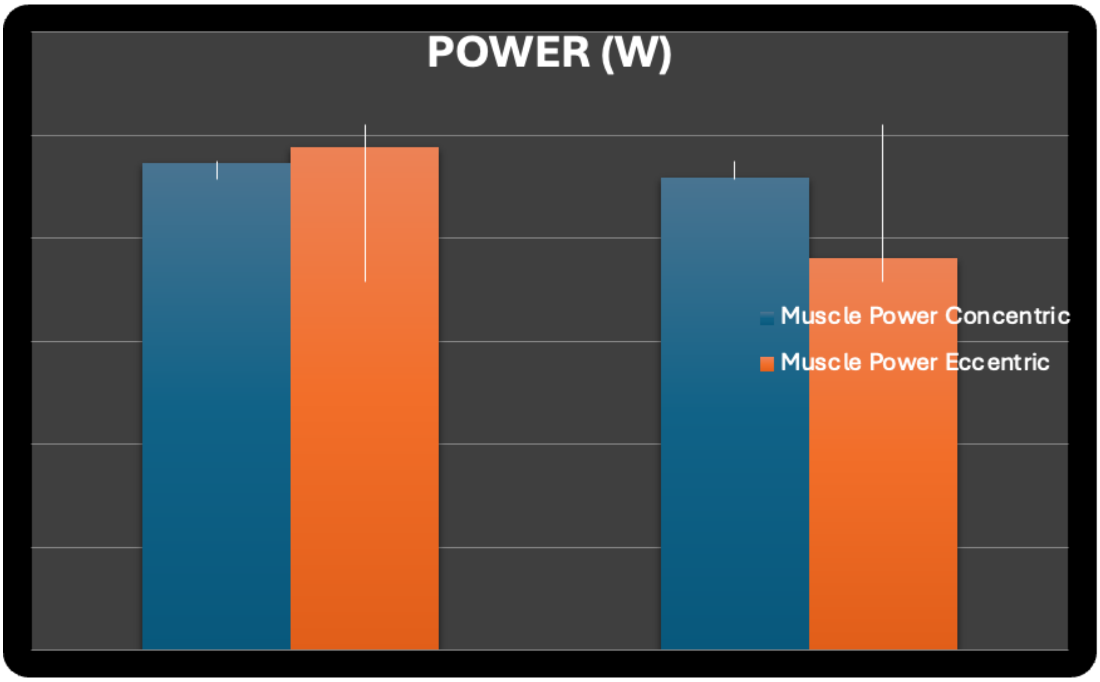


Figure 4. 12 Graphical representation of comparison of improvement in the Mean values of Muscle Power at 0 v/s 6 weeks interval between Group A and Group B

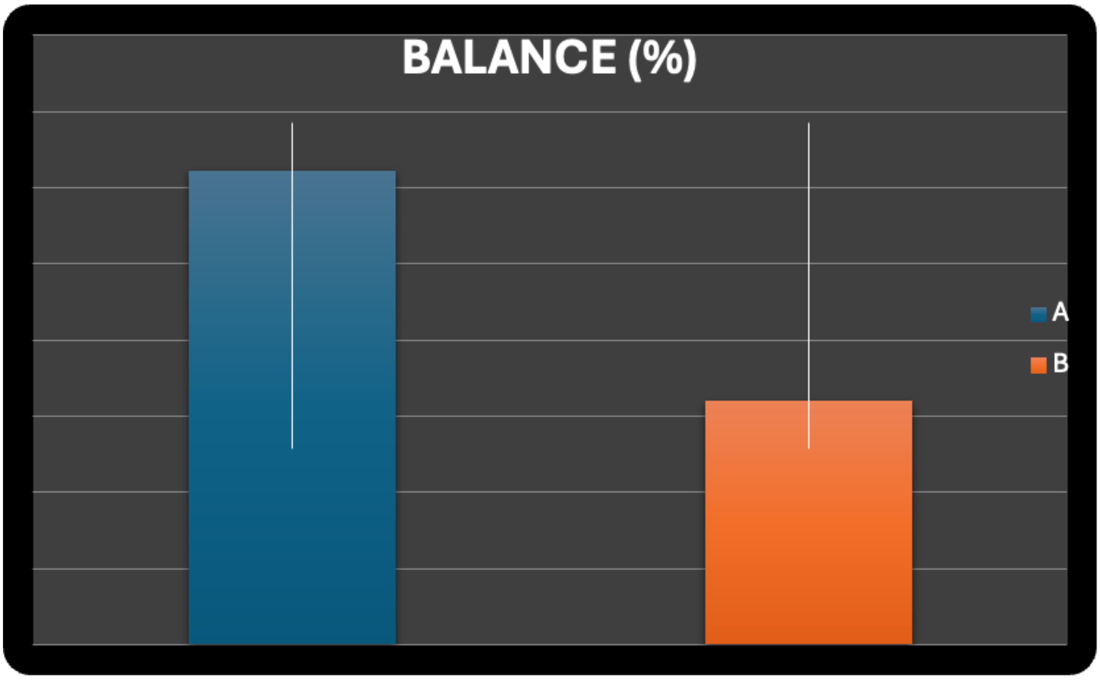


Figure 4. 13 Graphical representation of comparison of improvement in the Mean values of Balance at 0 v/s 6weeks interval between Group A and Group B

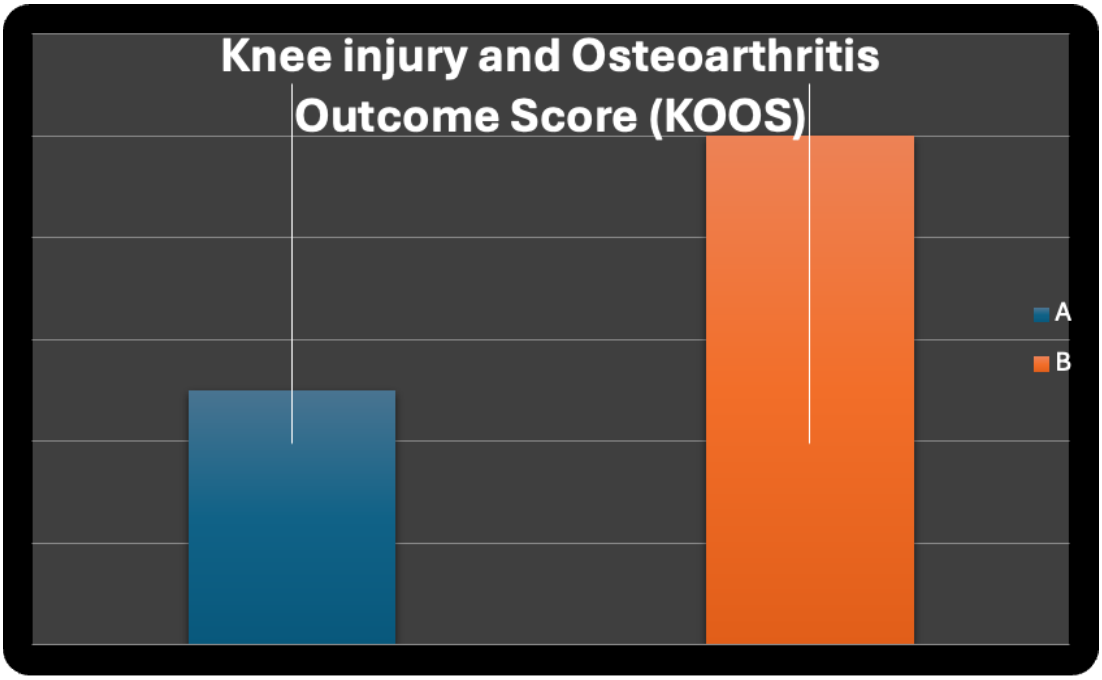


Figure 4. 14 Graphical representation of comparison of improvement in the Mean values of Knee injury and Osteoarthritis Outcome Score (KOOS) at 0 v/s 6weeks interval between Group A and Group B

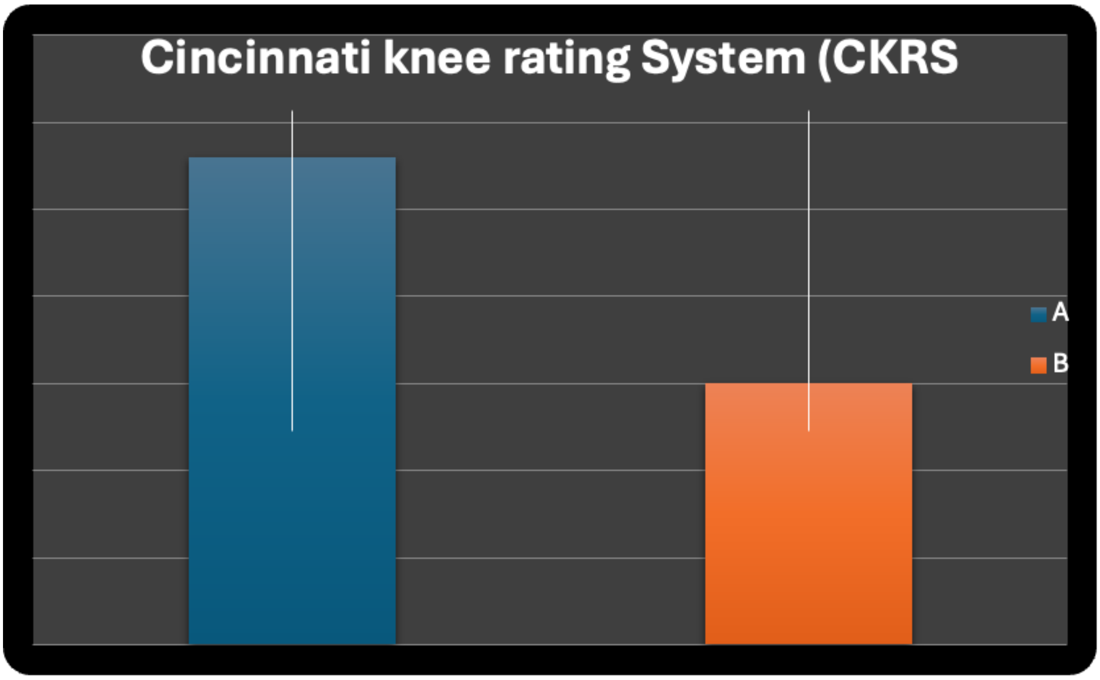


Figure 4. 15 Graphical representation of comparison of improvement in the Mean values of Cincinnati knee rating System (CKRS) at 0 v/s 6weeks interval between Group A and Group B

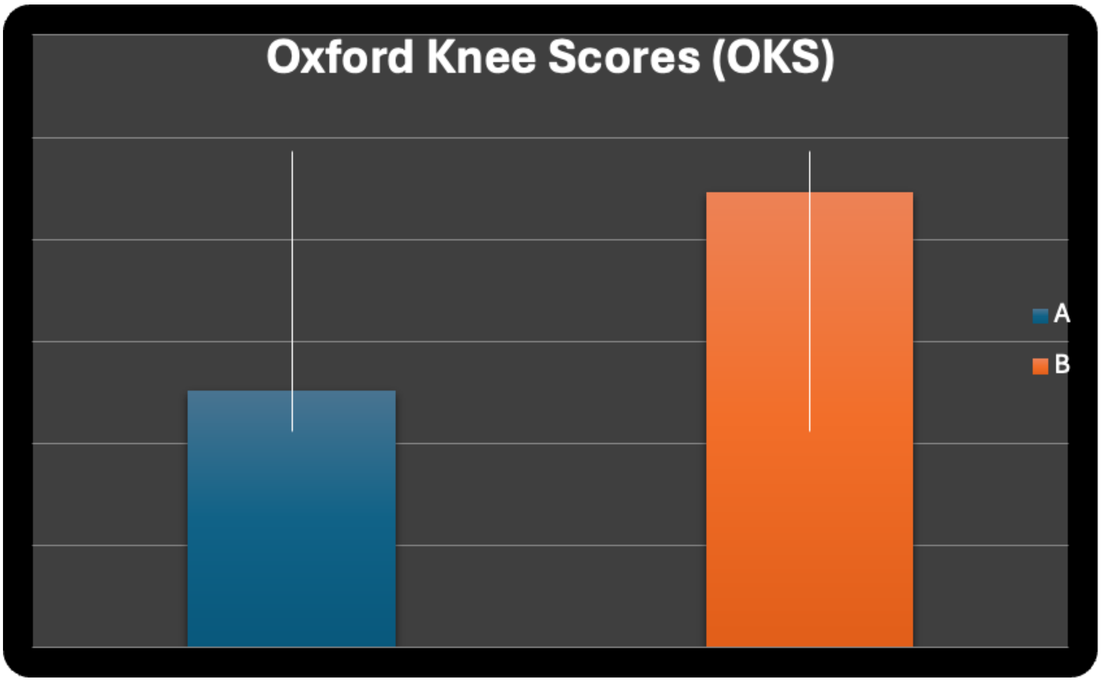


Figure 4. 16 Graphical representation of comparison of improvement in the Mean values of Oxford Knee Scores (OKS) at 0 v/s 6weeks interval between Group A and Group B

CHAPTER V

DISCUSSION

5.1 ISOINERTIAL TRAINING FOR ECCENTRIC STRENGTHENING IN ACL RECONSTRUCTION SURGERIES

In this study, a statistically significant improvement in some areas of muscle functionality; knee-related QoL and functionality; was seen due to combination of isoinertial training protocol and conventional rehabilitation protocol, compared to conventional rehabilitation performed alone in individuals who had undergone the ACLR surgery. A total of 130 subjects were initially screened to become eligible. Out of them, 96 were the subjects meeting the inclusion criteria. These participants were subsequently randomised into: the experimental group, who were subjected to the protocol of isoinertial training in addition to conventional rehabilitation and the control group who received conventional rehabilitation only. The subjects in both groups were subjected to their respective physiotherapy regimens during study period of 6weeks. The experimental group also took part in additional training in isoinertial strength, whereas the control group had a standard course of rehabilitation procedures that did not include this part of the process. The parameters studied at the baseline and at the end 6-week intervention were Muscles power, Endurance, Isometric strength, Balance, knee-related QoL, and overall knee functioning. The study addresses this problem by comparing the results between the two groups to find out the effectiveness of adding isoinertial training to the therapy regimen of patients undergoing ACL reconstructions.

The intervention had a combination of conventional rehabilitation and isoinertial eccentric resistance strengthening (D11 Plus; Desmotec, Biella, Italy) training. Since, the use of large weights does not occur in flywheel training, which results in greater quantities of eccentric stimulus, it is safer on patients recovering following ACLR. Because of its distinctive physiological training attributes, flywheel-based training could serve as an effective method for enhancing various muscle performance capabilities within a brief timeframe (Fernández-Gonzalo et al., 2014).

This study showed that both the groups in which patients received interventions isoinertial training protocol along with conventional rehabilitation protocol and conventional rehabilitation protocol only respectively improved Muscle power both in concentric and eccentric phases, Isometric strength and Balance whereas isoinertial training protocol along with conventional rehabilitation protocol improve Endurance but in contrast, the current study did not found improvement in the group B in which patients were administered conventional rehabilitation protocol only. In terms of, Knee related QoL and knee function; they were assessed using KOOS, CKRS and OKS respectively. The investigations revealed that there is significant improvement in the mean scores of KOOS, CKRS and OKS in both the groups after the completion of 6 weeks of interventions.

Muscle power, incorporating both concentric and eccentric components, stands as a cornerstone in the rehabilitation regimen for individuals who have undergone ACL reconstruction surgery. Concentric muscle contraction, marked by muscle shortening, holds paramount importance in the restoration of joint stability and functional strength. It serves as the foundation for rebuilding muscle mass and generating the necessary force to support the knee during various movements and activities. However, challenges arise in regaining concentric muscle power post-ACL reconstruction. Following surgery, patients often experience muscle weakness and atrophy due to immobilization, disuse, and surgical trauma. This weakness can significantly impair their ability to perform daily activities and engage in more strenuous exercises, hindering their overall rehabilitation progress. On the other hand, eccentric contractions, characterized by muscle lengthening, present a distinct set of challenges and opportunities in the rehabilitation journey. While eccentric exercises are essential for controlled movement during tasks such as descending stairs and decelerating during dynamic movements, they can also pose challenges for patients recovering from ACL reconstruction. One primary challenge is the risk of overloading the healing graft or surrounding structures during eccentric exercises. Since eccentric contractions involve the muscle lengthening while under tension, they can exert considerable stress on the healing tissues, potentially compromising graft integrity and increasing the likelihood of re-injury. Therefore, finding the right balance between stimulating muscle adaptation and avoiding excessive strain on the knee joint is crucial in designing effective rehabilitation programs for post-ACLR patients. Furthermore, eccentric exercises require careful supervision and guidance to ensure proper technique and progression. Patients may struggle with maintaining control and stability during eccentric movements, particularly during initial phase of rehabilitation when weakness and neuromuscular deficits are more pronounced in muscle.

In the present study, both the groups A and B showed improvement in the Muscle power both in eccentric and concentric phases. Exercises involving weight bearing between 20° and 60° flexion reduce stress on the healing ACL graft. The ACL's strain behaviour during a variety of quadriceps-dominated, weight-bearing including both concentric and eccentric components (such as lunges, step-up and step-down manoeuvres, and concentric ergometer exercises), has been extensively studied. The results indicated the highest amount of ACL strain occurs close to terminal knee extension and diminishes between 20° and 60° flexion. (Beynnon BD et al., 1997; Heijne A et al., 2007; Blackwelder WC et al., 1982; Beynnon BD et al., 2005). These studies' findings that raising resistance during weight-bearing exercise dramatically increased ACL strain during non-weight-bearing activity that is may be the most pertinent. The ACL strains resulting from loaded workouts were reduced when torques were applied at higher resistance (Fleming BC et al., 1998; Beynnon BD et al., 1997; Fleming BC et al., 2003). Our study's findings, which showed no variations in knee discomfort, effusion, or ligament laxity, provide additional credence to these earlier findings.

The therapeutic application of these results implies that after ACLR, it may be safe and tolerable to add a quadriceps intervention to strengthen it within certain parameters (weight-bearing and limited range of motion). The research results align with the findings of AlliGokeler et al. (2014) and Daniel Lorenz et al. (2014).

Further analysis of improvement in the mean power in eccentric phase showed that isoinertial training protocol along with conventional rehabilitation protocol is more effective than conventional rehabilitation protocol only. The study conducted by M de Hoyo (2014) found that flywheel exercises have a peculiarity wherein the subject must bear the weight developed during the last chain of the squat during the flexion, while vulnerable performs a fast-moving movement (usually maximal) during the extension of the knee in squat (M de Hoyo et al., 2014). Consequently, an enchained mechanical burden is associated with the primary benefit of EOL. Authors of earlier research hypothesised that a high eccentric weight would more effectively uses large motor units, which helps in carrying high loads. It ensured a beneficial increase in recruitment of large motor unit, and so power output (Beato M et al., 2021; Docherty D et al., 2007).

Muscle endurance plays a pivotal role in the comprehensive rehabilitation of post-ACL reconstruction patients. Beyond merely rebuilding strength, enhancing muscle endurance is critical for optimizing overall functional capacity. It enables individuals to sustain physical activities over prolonged periods with diminished fatigue, facilitating a smoother transition back to their pre-injury level of functionality. Moreover, muscle endurance contributes significantly to the restoration of normal gait patterns and joint stability, key components in the successful rehabilitation journey post-ACLR surgery.

Patients often face a myriad of challenges in developing and maintaining muscle endurance throughout their recovery process. The primary challenge is the initial loss of muscle endurance following ACL reconstruction surgery. Prolonged periods of immobilization, reduced physical activity, and the surgical trauma itself can lead to significant muscle deconditioning and weakness. As a result, patients may struggle to sustain prolonged periods of activity or find themselves quickly fatigued during daily tasks. However, finding the appropriate balance between challenging the muscles sufficiently to promote adaptation while avoiding overexertion and potential injury is crucial. Finally, sustaining muscle endurance gains over the long term presents an ongoing challenge for post-ACLR patients. However, competing demands and lifestyle factors may present obstacles to sustaining optimal muscle endurance levels. According to the current findings of this study, the patients showed improvement in muscle Endurance, receiving isoinertial training protocol along with conventional rehabilitation protocol from 10.98 to 14.85 whereas no improvement was observed in patients administered with conventional rehabilitation protocol only.

According to Westing SH et al. (1990), eccentric muscle activity produces a greater maximum torque than concentric muscle action. Though maximum electromyographic (EMG) activity may be lower with eccentric than concentric muscle motion, neural activation is not greater with eccentric muscle action. On the other hand, eccentric muscular movements may improve protein synthesis in muscles and contractile tissues by increasing muscle tension. The first week of continuous training will see a decrease in soreness following eccentric activity (Fridén J et al., 1983). Muscle endurance is increased because many natural movement patterns involve eccentric muscle activation, particularly when the stretch–shortening cycle is employed.

In the postoperative rehabilitation process for anterior cruciate ligament (ACL) reconstruction patients, isometric strength and balance are indispensable components. Isometric strength, characterized by static muscle contractions without joint movement, assumes a pivotal role in rebuilding strength around the knee joint. By engaging in isometric exercises, patients can target specific muscle groups without subjecting the joint to excessive stress, thus fostering muscle hypertrophy and enhancing overall stability. Moreover, isometric strength training contributes to neuromuscular control, a critical aspect of rehabilitation aimed at restoring coordination and preventing compensatory movements that may compromise joint integrity. Concurrently, balance training constitutes another essential facet of post-ACL reconstruction rehabilitation. Enhancing balance capabilities is instrumental in improving proprioception and joint awareness, both of which are vital for reducing the risk of falls and preventing re-injuries. Through targeted balance exercises, patients can refine their ability to maintain equilibrium and control joint positioning, thereby enhancing overall functional performance and minimizing the likelihood of post-surgical complications. These findings of the study suggested that both the groups in which patients received interventions isoinertial training protocol along with conventional rehabilitation protocol and conventional rehabilitation protocol only improved Isometric strength and Balance.

Further analysis of improvement in the Isometric strength and Balance showed that neither of the two interventional programs i.e. isoinertial training protocol along with conventional rehabilitation protocol and conventional rehabilitation protocol only is more effective than the other. As, very few studies have compared such interventions on Isometric strength and Balance in postoperative ACL reconstruction (ACLR) patients; therefore, conducting an exhaustive contrast with the available research is challenging. The improvement in the group A was observed as Isoinertial exercises, involving flywheel training, provide a variable resistance throughout the range of motion, challenging muscles eccentrically and concentrically. This dynamic loading not only improves Isometric strength but also targets muscles in a way that closely mimics functional movements. Consequently, this group may demonstrate greater gains in both Isometric strength and Balance due to the more comprehensive nature of their strength training. Also, as the conventional rehabilitation protocol included isometric exercises, which are effective in stabilizing the knee joint and building static strength. Patients in this group experience enhanced neuromuscular control, contributing to improved balance. This could be the possible explanation for the improvement observed in the above mentioned parameters.

In this study, Knee related QoL and knee function were assessed using KOOS, CKRS respectively. Post anterior cruciate ligament reconstruction (ACLR), patients often face a spectrum of challenges affecting their QoL. Initially, physical limitations like pain and restricted movement can hamper daily activities. As rehabilitation progresses, pain typically subside, allowing patients to regain functionality. In the aftermath of ACLR, confront a spectrum of challenges impacting their knee-related QoL. As patients progress through the rehabilitation journey, they typically experience improvements in knee function and mobility. However, despite these advancements, challenges persist that can adversely affect knee-related QoL. Persistent pain, discomfort, and stiffness may endure, particularly during physical activity or periods of increased exertion. Moreover, the psychological effect of ACLR and the associated recovery process cannot be overlooked, with patients often experience anxiety, frustration, and concerns regarding the long-term efficacy of the surgical intervention. Resuming the same amount of exercise and involvement in sports or leisure activities as before the injury, represents a significant milestone for many patients post-ACLR. However, achieving this goal may be accompanied by apprehension about re-injury and the need for ongoing vigilance to protect the reconstructed knee. Additionally, patients may require modifications to their activities to mitigate the risk of further injury, potentially impacting their ability to fully engage in their desired pursuits. Patients must navigate the complexities of maintaining a consistent exercise regimen, adhering to rehabilitation protocols, and monitoring for signs of potential complications or re-injury. Failure to adequately address these challenges can undermine the long-term success of ACLR and compromise knee-related QoL. Ultimately, the journey of knee-related QoL post-ACLR is multifaceted and dynamic, influenced by a spectrum of physical to psychosocial factors.

The investigations of the current study revealed that there is significant improvement in the mean scores of KOOS and CKRS in both the groups after the completion of 6 weeks of interventions. The patients in Group A, administered isoinertial strengthening along with conventional rehabilitation revealed improvement in patient related outcome through KOOS. The added advantage of isoinertial strength training provides the safety and Eccentric training helps address muscle imbalances commonly observed following ACL injury, such as quadriceps weakness and hamstring dominance (Vidmar MF et al., 2020). By targeting these imbalances, individuals achieve better muscle symmetry and balance, which can translate to improved functional outcomes and higher KOOS scores. Additionally, isoinertial eccentric training helps improve neuromuscular control and coordination, which are essential for proper movement patterns and joint stability (LK Lepley et al., 2017). As individuals gain better control over their muscles and movements, they may experience fewer functional limitations and a greater ability to perform daily activities without discomfort or difficulty, resulting in higher scores on KOOS subscales related to function and QoL.

Similarly, the patients in group B who only went through the conventional rehabilitation protocol improved the patient related outcome in terms of KOOS. As reported by Shaw et al. (2005) and Isberg et al. (2006), laxity was the same two years after follow-up, which means that in the first weeks after ACLR surgery, isometric exercises of the quadriceps did not harm but even enhanced the results. Further, initiating exercises in clinically important quadriceps (OKC exercises) in week four after ACLR with HS but with limited range of movement (ROM) between 45 and 90 degrees can give better results. Besides, two extensive reviews which came out in the year 2012 found out that eccentric quad exercise could be resumed after three weeks of ACLR and are a good technique of enhancing quadriceps. Neuromuscular training is also necessary to improve the outcomes after recovery (Kruse et al., 2012; Gokeler et al., 2012).

Furthermore, analysis of improvement in mean scores of KOOS, revealed no significant improvement between the group A and B 6 weeks post intervention. This finding suggests that the inclusion of isoinertial strengthening may not lead to superior outcomes in terms of knee QoL as measured by the KOOS instrument within the six-week timeframe assessed.

Post ACLR patients undergo functional recovery in their knees. Initially, they may experience limitations in mobility and strength due to surgical trauma and the healing process. As rehabilitation progresses, however, patients typically regain the muscle range and strength through targeted exercises and physical therapy. This rehabilitation phase is crucial for restoring knee stability and function. Over time, many patients are able to return to their pre-injury level of activity, though some may require modifications or adaptations.

Long-term outcomes vary, with factors such as adherence to rehabilitation, graft integrity, and individual biomechanics playing key roles. Regarding knee function, and pain and function outcome, Cincinnati knee rating System (CKRS) and Oxford Knee Score were used and revealed significant improvement in CKRS and OKS scores in both the groups receiving isoinertial strengthening in combination with conventional rehabilitation protocol, and conventional rehabilitation protocol only respectively. According to Wright et al.'s systemic review from 2008, which examined the impact of physical therapy following ACLR in four RCTs, it was plausible that an ACLR that was minimally supervised could lead to successful recovery in terms of knee function as well as quadriceps and hamstring strength. At a one-year follow-up, Dragicevic-Cvjetkovic et al. (2014) discovered that the group receiving 20 weeks of rehabilitation had improved more than the group receiving no rehabilitation at all in terms of ROM, thigh muscle circumference, and self-reported knee function (Dragicevic-Cvjetkovic et al., 2014). As for isoinertial eccentric strength training, the improvement in the scores was due to the fact that Eccentric training enhances muscle strength, particularly in the quadriceps and hamstrings, which are crucial for knee stability and function (A. Buonsenso et al., 2023). As these muscles become stronger, individuals may experience reduced pain, improved joint stability, and better overall knee function, leading to higher scores on CKRS subscales related to symptoms and activities of daily living. The flywheel ergometer provides progressive resistance throughout the range of motion, allowing for tailored and individualized rehabilitation programs (J. Xu et al., 2023).

The progressive resistance is vital for optimizing muscle strengthening exercises, which are integral to improving CKRS scores related to knee stability and function. Moreover, upon analyzing the improvement in mean scores of the Cincinnati Knee Rating System (CKRS), no enhancement observed between the groups six weeks after the intervention. This indicated that incorporating isoinertial strengthening alongside conventional rehabilitation may not result in better outcomes concerning knee function and overall QoL, during the six-week period of intervention.

The impact of limb dominance on recovery outcomes in post ACLR patients is an important area of investigation. Research indicates that limb dominance can influence Muscle power, Endurance, and overall functional recovery. In this context, the current study adds to the existing literature by comparing physical performance and functional scores of the operated dominant and non-dominant sides over a 6-week rehabilitation period.

All the patients included in the study were of right dominant sided. Patients who underwent ACLR on their dominant leg often demonstrate greater improvements in Muscle power and strength compared to those with non-dominant leg injuries. For instance, the dominant side typically exhibits more pronounced gains in muscle power, as seen in concentric and eccentric strength assessments. This trend may be attributed to the greater physical activity and neuromuscular adaptations associated with the dominant limb, which is usually more engaged in daily tasks and athletic activities.

Our findings align with those of Suh et al. (2020), who found that patients with dominant leg injuries had superior quadriceps strength compared to those with non-dominant leg injuries at the 6-month mark (Suh et al. 2020). Additionally, Zumstein et al. (2022) highlighted that injuries to the dominant suggesting that limb dominance plays a role in functional performance post-reconstruction (Zumstein et al. 2022). Similarly, Boo et al. (2020) reported that while recovery trajectories may differ, both limbs can achieve comparable outcomes given similar rehabilitation protocols (Boo et al., 2020).

These studies underscore the importance of understanding limb dominance when designing rehabilitation strategies. Although both dominant and non-dominant limbs show significant improvements in recovery, the existing disparities in muscle strength and functional performance highlight the necessity for targeted interventions. Addressing these differences during early rehabilitation may enhance recovery outcomes and promote a more balanced return to physical activity, reducing the risk of future injuries. Ultimately, this body of research emphasizes the need for individualized rehabilitation protocols that consider limb dominance to optimize recovery for all patients undergoing ACL reconstruction.

In summary, the study investigated the effects of combining isoinertial training with conventional rehabilitation versus conventional rehabilitation alone on muscle function, knee-related QoL, and function in postoperative ACL reconstruction patients over a 6-week period. Initially, 130 subjects were screened, with 96 meeting inclusion criteria and being randomly assigned to either group. Both groups underwent their respective rehabilitation protocols, with the experimental group additionally engaging in isoinertial training exercises. Various parameters, including Muscle power, Endurance, Strength, Balance, knee-related QoL, and knee function, were assessed. The study demonstrated that both groups, where patients received interventions of isoinertial training protocol alongside conventional rehabilitation protocol and conventional rehabilitation protocol alone, respectively, exhibited improvements in Muscle power in both concentric and eccentric phases, Isometric strength, and Balance. Notably, the group undergoing isoinertial training in addition to conventional rehabilitation also showed improvements in Endurance. In contrast, the study did not find significant improvement in endurance for the group receiving conventional rehabilitation alone.

The current study investigates the impact of limb dominance on recovery, revealing that those with dominant leg injuries often achieve greater improvements in muscle power and strength compared to their non-dominant counterparts. Supporting previous research, the findings emphasize the importance of tailoring rehabilitation strategies to account for limb dominance, as targeted interventions could enhance recovery outcomes and promote a balanced return to physical activity, thereby reducing the risk of future injuries. Knee-related QoL and knee function were assessed using standardized measures and revealed significant improvement in both groups post-intervention. However, there was no significant difference between the two groups in terms of knee-related QoL and knee function improvement and pain. The study suggested that while isoinertial training may offer benefits in certain aspects of rehabilitation, it may not lead to superior outcomes in knee-related QoL and function within a 6-week timeframe.

The current study addresses the research gap in the literature concerning the effectiveness of combined rehabilitation strategies for patients following ACL reconstruction. Prior studies have predominantly focused on the effectiveness of singular rehabilitation protocols, and while some have acknowledged the role of eccentric training in enhancing muscle strength and stability, few have explored the integrative effects of isoinertial training within postoperative rehabilitation frameworks. By specifically examining the combined impact of isoinertial training and conventional rehabilitation, this study provides essential insights into how such an approach can enhance recovery dynamics, particularly in terms of muscle Endurance, without causing significant muscle damage or post-training delayed onset muscle soreness (DOMS).

Moreover, the findings emphasize the need for further investigation into optimal rehabilitation protocols that incorporate various training modalities to maximize recovery outcomes for ACL reconstruction patients. As isoinertial training continues to gain traction as a viable rehabilitation method, this study serves as a foundational reference for future research endeavours aimed at exploring its long-term benefits and applications in clinical practice. By demonstrating measurable improvements in muscle function and endurance, the study advocates for the consideration of combined rehabilitation strategies that could ultimately lead to more effective recovery pathways for individuals recovering from ACL injuries.

5.2 LIMITATIONS

- Due to the nature of the intervention, it wasn't feasible to blind therapists to group allocation, which may have influence on outcome of the results.
- Additionally, the study did not directly compared the effectiveness of the isoinertial training protocol with a conventional training protocol, which could have provided more robust evidence of its efficacy.
- Small sample size that is restricted to small geographical region with lack of long term follow-up.
- The study's population comprised both non-athletic and athletic, leading to a lack of homogeneity that could limit the generalizability of the findings.
- It is a single-centre study, and the patients were from the Punjab region; which may limit the generalizability of the results to broader population or other geographical regions.

5.3 CLINICAL IMPLICATIONS

The clinical significance of this study lies in its exploration of Isoinertial Eccentric Strength Training Protocol alongside Conventional Rehabilitation Protocol with Conventional Rehabilitation Protocol alone, the study provides practical implications for clinicians in the field of rehabilitation. The investigations suggest that incorporating Isoinertial Eccentric Strength Training Protocol into conventional rehabilitation programs can lead to significant improvements in Muscle power, particularly in Eccentric muscle power and Endurance. This is crucial for individuals recovering from knee injuries or surgeries, as eccentric muscle strength plays important function in dynamic movements and daily living activities. In addition, the study underscores that considering various parameters of muscle performance, such as concentric-eccentric muscle power, in rehabilitation protocols. This indicates the potential for targeted interventions to address specific muscle weaknesses and imbalances during rehabilitation. Furthermore, the study highlights the importance of comprehensive rehabilitation programs that address multiple aspects of physical function and well-being in individuals recovering from knee injuries. By tailoring rehabilitation protocols to target specific muscle deficits and incorporating evidence-based interventions, clinicians can optimize outcomes and enhance the overall effectiveness of knee rehabilitation programs.

5.4 RECOMMENDATIONS

- The future scope of the study involves conducting long-term follow-up assessments, approximately 4-5 months post-rehabilitation, to investigate the sustained impact on activity levels and lifestyle changes.
- Additionally, future studies could focus on comparing the effectiveness of the isoinertial training protocol with conventional rehabilitation protocols and investigating the cost-effectiveness of integrating isoinertial training into conventional rehabilitation programs directly, providing more robust evidence of its efficacy.
- Finally, exploring the potential psychological impacts of different rehabilitation modalities on patient motivation, confidence, and adherence to treatment regimens could offer valuable insights into holistic approaches to injury recovery and rehabilitation.

CHAPTER-VI

CONCLUSION

Both the groups, administering Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol and Conventional Rehabilitation Protocol only respectively improved Muscle Power Eccentric and Concentric. However, on further analysis, Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol proved efficacious than Conventional Rehabilitation Protocol only in terms of Eccentric Muscle Power whereas none proved superior in terms of Concentric Muscle Power. With regards to Endurance, Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol proved to be superior than Conventional Rehabilitation Protocol only. In terms of operated dominant side, the Isoinertial Eccentric Strength Training Protocol along with Conventional Rehabilitation Protocol group showed substantial improvement in Endurance with respect to Conventional Rehabilitation Protocol only group while other parameters improved for both the groups. Both interventions were effective in improving Isometric Strength and Balance, with none proving more effective than other. In terms of knee-related QoL and Function, both interventions were effective, with no superiority observed for either group. Both the interventions proved to be efficacious in terms of pain and function outcomes of knee but neither proved to be superior to other.

REFERENCES

Atik, O. Ş., Çavuşoğlu, A. T., & Ayanoğlu, T. (2015). Is magnetic resonance imaging reliable for the evaluation of the ruptured or healed anterior cruciate ligament? Joint Diseases and Related Surgery, 26(1), 38-40.

Banks, N. F., Berry, A. C., Rogers, E. M., & Jenkins, N. D. M. (2024). Flywheel resistance training promotes unique muscle architectural and performance-related adaptations in young adults. European Journal of Sport Science, 24(12), 1765–1778. https://doi.org/10.1002/EJSC.12215

Beato, M., & Drust, B. (2021). Acceleration intensity is an important contributor to the external and internal training load demands of repeated sprint exercises in soccer players. Research in Sports Medicine, 29(1), 67-76.

Beato, M., Bigby, A. E., De Keijzer, K. L., Nakamura, F. Y., Coratella, G., & McErlain-Naylor, S. A. (2019). Post-activation potentiation effect of eccentric overload and traditional weightlifting exercise on jumping and sprinting performance in male athletes. PloS One, 14(9), e0222466.

Beato, M., de Keijzer, K. L., Fleming, A., Coates, A., La Spina, O., Coratella, G., & McErlain-Naylor, S. A. (2020). Post flywheel squat vs. flywheel deadlift potentiation of lower limb isokinetic peak torques in male athletes. Sports Biomechanics, 1-4.

Beato, M., De Keijzer, K. L., Leskauskas, Z., Allen, W. J., Iacono, A. D., & McErlain-Naylor, S. A. (2021). Effect of postactivation potentiation after medium vs. high inertia eccentric overload exercise on standing long jump, countermovement jump, and change of direction performance. The Journal of Strength & Conditioning Research, 35(9), 2616-2621.

Beato, M., De Keijzer, K. L., Leskauskas, Z., Allen, W. J., Iacono, A. D., & McErlain-Naylor, S. A. (2021). Effect of postactivation potentiation after medium vs. high inertia eccentric overload exercise on standing long jump, countermovement jump, and change of direction performance. The Journal of Strength & Conditioning Research, 35(9), 2616-2621.

Beato, M., De Keijzer, K. L., Muñoz-Lopez, A., Raya-González, J., Pozzo, M., Alkner, B. A., & Norrbrand, L. (2024). Current guidelines for the implementation of flywheel resistance training technology in sports: a consensus statement. Sports Medicine, 54(3), 541-556.

Beato, M., Madruga-Parera, M., Piqueras-Sanchiz, F., Moreno-Pérez, V., & Romero-Rodriguez, D. (2021). Acute effect of eccentric overload exercises on change of direction performance and lower-limb muscle contractile function. Journal of Strength and Conditioning Research, 35(12), 3327-3333.

Beato, M., Maroto-Izquierdo, S., Turner, A. N., & Bishop, C. (2021). Implementing strength training strategies for injury prevention in soccer: Scientific rationale and methodological recommendations. International Journal of Sports Physiology and Performance, 16(3), 456-461.

Beato, M., McErlain-Naylor, S. A., Halperin, I., & Iacono, A. D. (2020). Current evidence and practical applications of flywheel eccentric overload exercises as postactivation potentiation protocols: A brief review. International Journal of Sports Physiology and Performance, 15(2), 154-161.

Beato, M., Stiff, A., & Coratella, G. (2021). Effects of postactivation potentiation after an eccentric overload bout on countermovement jump and lower-limb muscle strength. The Journal of Strength & Conditioning Research, 35(7), 1825-1832.

Braden C. Fleming, Heidi Oksendahl, B. D. B. (2004). Open- or Closed-Kinetic Chain Exercises After Anterior Cruciate Ligament Reconstruction? Exercise and Sport Sciences Reviews.

Beynnon, B. D., Johnson, R. J., Fleming, B. C., Stankewich, C. J., Renstrom, P. A., & Nichols, C. E. (1997). The strain behavior of the anterior cruciate ligament during squatting and active flexion-extension: A comparison of an open and a closed kinetic chain exercise. American Journal of Sports Medicine, 25, 823-829.

Beynnon, B. D., Uh, B. S., & Johnson, R. J., et al. (2005). Rehabilitation after anterior cruciate ligament reconstruction: A prospective, randomized, double-blind comparison of programs administered over 2 different time intervals. American Journal of Sports Medicine, 33, 347-359.

Bianchi, M., Anderson, L., Brownlee, T., Bossi, L., & Beato, M. (2022). The effect of two sessions of combined jump and sprint training per week on fitness parameters in soccer players: A randomized controlled trial. Biology of Sport, 40(3), 699-706.

Bolia, I. K., Haratian, A., Bell, J. A., Hasan, L. K., Saboori, N., Palmer, R., Petrigliano, F. A., & Weber, A. E. (2021). Managing perioperative pain after anterior cruciate ligament (ACL) reconstruction: Perspectives from a sports medicine surgeon. Open Access Journal of Sports Medicine, 12, 129-138.

Boo, H. C., Howe, T. S., & Koh, J. S. (2020). Effect of leg dominance on early functional outcomes and return to sports after anterior cruciate ligament reconstruction. Journal of Orthopaedic Surgery, 28(1), 2309499019896232.

Brasileiro, J. S., Pinto, O. M., Ávila, M. A., & Salvini, T. F. (2011). Functional and morphological changes in the quadriceps muscle induced by eccentric training after ACL reconstruction. Brazilian Journal of Physical Therapy, 15, 284-290.

Bulow, A., Anderson, J. E., Leiter, J. R., MacDonald, P. B., & Peeler, J. D. (2021). Safety and effectiveness of a perturbation-based neuromuscular training program on dynamic balance in adolescent females: A randomized controlled trial. International Journal of Sports Physical Therapy, 16(4), 1001.

Buonsenso, A., Centorbi, M., Iuliano, E., Di Martino, G., Della Valle, C., Fiorilli, G., Calcagno, G., & di Cagno, A. (2023). A systematic review of flywheel training effectiveness and application on sport-specific performances. Sports, 11(4), 76.

Chamorro-Moriana, G., Perez-Cabezas, V., Espuny-Ruiz, F., Torres-Enamorado, D., & Ridao-Fernández, C. (2022). Assessing knee functionality: Systematic review of validated outcome measures. Annals of Physical and Rehabilitation Medicine, 65(6), 101608.

Clement, N. D., Afzal, I., Liu, P., Phoon, K. M., Asopa, V., Sochart, D. H., & Kader, D. F. (2022). The Oxford Knee Score is a reliable predictor of patients in a health state worse than death and awaiting total knee arthroplasty. Arthroplasty, 4(1), 33.

Cooper, H. M. (1989). Integrating research: A guide for literature reviews. Sage Publications, Inc.

Coratella, G., Beato, M., Bertinato, L., Milanese, C., Venturelli, M., & Schena, F. (2022). Including the eccentric phase in resistance training to counteract the effects of detraining in women: A randomized controlled trial. Journal of Strength and Conditioning Research, 36(11), 3023-3031.

Coratella, G., Beato, M., Cè, E., Scurati, R., Milanese, C., Schena, F., & Esposito, F. (2019). Effects of in-season enhanced negative work-based vs traditional weight training on change of direction and hamstrings-to-quadriceps ratio in soccer players. Biology of Sport, 36(3), 241-248.

Coury, H. J., Brasileiro, J. S., Salvini, T. F., Poletto, P. R., Carnaz, L., & Hansson, G. A. (2006). Change in knee kinematics during gait after eccentric isokinetic training for quadriceps in subjects submitted to anterior cruciate ligament reconstruction. Gait & Posture, 24(3), 370-374.

Cunniffe, E., Beato, M., Grainger, A., McConnell, W., & Blake, C. (2022). The characteristics of within match play acceleration and deceleration activity in international hockey. The Journal of Sport and Exercise Science.

Dash, S. K., Mishra, D., Sahu, H., Moharana, A. K., Angrish, S., & Deepak, T. S. (2023). Functional outcomes following arthroscopic anterior cruciate ligament (ACL) reconstruction using the Sironix titanium button and the polyetheretherketone (PEEK) button: A retrospective observational study. Cureus, 15(9).

Davey, A., Endres, N. K., Johnson, R. J., & Shealy, J. E. (2019). Alpine skiing injuries. Sports Health, 11(1), 18-26.

De Hoyo, M., de la Torre, A., Pradas, F., Sañudo, B., Carrasco, L., & Mateo-Cortes, J. (2014). Effects of eccentric overload bout on change of direction and performance in soccer players. International Journal of Sports Medicine, 36, 308–314.

De Keijzer, K. L., Gonzalez, J. R., & Beato, M. (2022). The effect of flywheel training on strength and physical capacities in sporting and healthy populations: An umbrella review. PLOS ONE, 17(2), e0264375.

De Keijzer, K. L., McErlain-Naylor, S. A., & Beato, M. (2022). The effect of flywheel inertia on peak power and its inter-session reliability during two unilateral hamstring exercises: Leg curl and hip extension. Frontiers in Sports and Active Living, 4, 898649.Bernárdez-Vázquez R, Raya-González J, Castillo D, Beato M. Resistance training variables for optimization of muscle hypertrophy: an umbrella review. Frontiers in Sports and Active Living. 2022:270.

De Keijzer, K. L., McErlain-Naylor, S. A., Iacono, A. D., & Beato, M. (2020). Effect of volume on eccentric overload-induced postactivation potentiation of jumps. International Journal of Sports Physiology and Performance, 15(7), 976-981.

De Keijzer, K. L., Raya-González, J., LópezSamanés, Á., Moreno Perez, V., & Beato, M. (2023). Perception and use of flywheel resistance training amongst therapists in sport. Frontiers in Sports and Active Living, 5, 1141431.

De Keijzer, K., McErlain-Naylor, S. A., Brownlee, T. E., Raya-González, J., & Beato, M. (2022). Perception and application of flywheel training by professional soccer practitioners. Biology of Sport, 39(4), 809-817.

de Padua, V. B. C., Saithna, A., Chagas, E. F. B., Zutin, T. L. M., Piazzalunga, L. F., Patriarcha, L. F., Gelas, P. J. L., & Helito, C. P. (2021). Rate of tibial tunnel malposition is not changed by drilling entirely within the stump of preserved remnants during ACL reconstruction: A prospective comparative 3D-CT study. Orthopaedic Journal of Sports Medicine, 9(10), 23259671211037324.

Desio, S. M., Burks, R. T., & Bachus, K. N. (1998). Soft tissue restraints to lateral patellar translation in the human knee. The American Journal of Sports Medicine, 26(1), 59–65.

Diermeier, T., Rothrauff, B. B., Engebretsen, L., Lynch, A. D., Ayeni, O. R., Paterno, M. V., Xerogeanes, J. W., Fu, F. H., Karlsson, J., Musahl, V., Svantesson, E., HamrinSenorski, E., Rauer, T., & Meredith, S. J. (2020). Treatment after anterior cruciate ligament injury: Panther Symposium ACL Treatment Consensus Group. Knee Surgery, Sports Traumatology, Arthroscopy, 28(8), 2390-2402.

Dimitrios, S., Pantelis, M., & Kalliopi, S. (2012). Comparing the effects of eccentric training with eccentric training and static stretching exercises in the treatment of patellar tendinopathy: A controlled clinical trial. Clinical Rehabilitation, 26(5), 423-430.

Docherty, D., & Hodgson, M. J. (2007). The application of postactivation potentiation to elite sport. International Journal of Sports Physiology and Performance, 2, 439–444.

Dragicevic-Cvjetkovic, D., Jandric, S., Bijeljac, S., Palija, S., Manojlovic, S., & Talic, G. (2014). The effects of rehabilitation protocol on functional recovery after anterior cruciate ligament reconstruction. Medical Archives, 68(5), 350.

Eberl, R. (2019). Anterior cruciate ligament rupture in children with open growth plate: Diagnostics and treatment. Der Unfallchirurg, 122, 17-21.Kim SJ, Kim HK. Reliability of the anterior drawer test, the pivot shift test, and the Lachman test. Clinical Orthopaedics and Related Research. 1995 Aug 1;317:237-42.

Fernández-Gonzalo, R., Lundberg, T. R., Alvarez-Alvarez, L., & de Paz, J. A. (2014). Muscle damage responses and adaptations to eccentric-overload resistance exercise in men and women. European Journal of Applied Physiology, 114, 1075-1084.

Fineberg, M. S., Zarins, B., & Sherman, O. H. (2000). Current concepts: Practical considerations in anterior cruciate ligament replacement surgery. Arthroscopy: The Journal of Arthroscopic & Related Surgery, 16(7), 715–724.

Fleming, B. C., Beynnon, B. D., Renstrom, P. A., Peura, G. D., Nichols, C. E., & Johnson, R. J. (1998). The strain behavior of the anterior cruciate ligament during bicycling: An in vivo study. American Journal of Sports Medicine, 26, 109-118.

Fleming, B. C., Ohlen, G., Renstrom, P. A., Peura, G. D., Beynnon, B. D., & Badger, G. J. (2003). The effects of compressive load and knee joint torque on peak anterior cruciate ligament strains. American Journal of Sports Medicine, 31, 701-707.

Forogh, B., Aslanpour, H., Fallah, E., Babaei-Ghazani, A., & Ebadi, S. (2019). Adding high-frequency transcutaneous electrical nerve stimulation to the first phase of post anterior cruciate ligament reconstruction rehabilitation does not improve pain and function in young male athletes more than exercise alone: a randomized single-b. Disability and Rehabilitation, 41(5), 514–522. https://doi.org/10.1080/09638288.2017.1399294

Fridén, J., Seger, J., Sjöström, M., & Ekblom, B. (1983). Adaptive response in human skeletal muscle subjected to prolonged eccentric training. International Journal of Sports Medicine, 4(03), 177-183.

Fukuda, T. Y., Fingerhut, D., Moreira, V. C., Camarini, P. M., Scodeller, N. F., Duarte Jr, A., Martinelli, M., & Bryk, F. F. (2013). Open kinetic chain exercises in a restricted range of motion after anterior cruciate ligament reconstruction: A randomized controlled clinical trial. The American Journal of Sports Medicine, 41(4), 788-794.

Gans, I., Retzky, J. S., Jones, L. C., & Tanaka, M. J. (2018). Epidemiology of recurrent anterior cruciate ligament injuries in National Collegiate Athletic Association sports: The Injury Surveillance Program, 2004-2014. Orthopaedic Journal of Sports Medicine, 6(6), 2325967118777823.

Gans, I., Retzky, J. S., Jones, L. C., & Tanaka, M. J. (2018). Epidemiology of recurrent anterior cruciate ligament injuries in National Collegiate Athletic Association sports: The Injury Surveillance Program, 2004-2014. Orthopaedic Journal of Sports Medicine, 6(6), 2325967118777823.

Gerami, M. H., Haghi, F., Pelarak, F., & Mousavibaygei, S. R. (2022). Anterior cruciate ligament (ACL) injuries: A review on the newest reconstruction techniques. Journal of Family Medicine and Primary Care, 11(3), 852-856.

Gerber, J. P., Marcus, R. L., Dibble, L. E., Greis, P. E., & LaStayo, P. C. (2006). Early application of negative work via eccentric ergometry following anterior cruciate ligament reconstruction: A case report. Journal of Orthopaedic & Sports Physical Therapy, 36(5), 298-307.

Gerber, J. P., Marcus, R. L., Dibble, L. E., Greis, P. E., Burks, R. T., & LaStayo, P. C. (2007). Safety, feasibility, and efficacy of negative work exercise via eccentric muscle activity following anterior cruciate ligament reconstruction. Journal of Orthopaedic & Sports Physical Therapy, 37(1), 10-18.

Gerber, J. P., Marcus, R. L., Dibble, L. E., & LaStayo, P. C. (2009). The Use of Eccentrically Biased Resistance Exercise to Mitigate Muscle Impairments Following Anterior Cruciate Ligament Reconstruction: A Short Review. Sports Health, 1(1), 31–38. https://doi.org/10.1177/1941738108327531

Giummarra, M., Vocale, L., & King, M. (2022). Efficacy of non-surgical management and functional outcomes of partial ACL tears: A systematic review of randomized trials. BMC Musculoskeletal Disorders, 23(1), 332.

Goh, J. C., Lee, P. Y., & Bose, K. (1995). A cadaver study of the function of the oblique part of vastus medialis. Journal of Bone and Joint Surgery - British Volume, 77(2), 225–231.

Gokeler, A., Bisschop, M., & Benjaminse, A., et al. (2014). Quadriceps function following ACL reconstruction and rehabilitation: Implications for optimization of current practices. Knee Surgery, Sports Traumatology, Arthroscopy, 22(5), 1163-1174.

Gokeler, A., Bisschop, M., & Benjaminse, A., et al. (2014). Quadriceps function following ACL reconstruction and rehabilitation: Implications for optimization of current practices. Knee Surgery, Sports Traumatology, Arthroscopy, 22, 1163–1174.

Grelsamer, R. P., & Klein, J. R. (1998). The biomechanics of the patellofemoral joint. Journal of Orthopaedic & Sports Physical Therapy, 28(5), 286–298.

Grevnerts, H. T., Krevers, B., & Kvist, J. (2022). Treatment decision-making process after an anterior cruciate ligament injury: Patients', orthopaedic surgeons' and physiotherapists' perspectives. BMC Musculoskeletal Disorders, 23(1), 782.

Griffin, J. W., Tooms, R. E., van der Zwaag, R. O., Bertorini, T. E., & O'Toole, M. L. (1993). Eccentric muscle performance of elbow and knee muscle groups in untrained men and women. Medicine and Science in Sports and Exercise, 25(8), 936-944.

Heard, W. M., Chahal, J., & Bach, B. R. (2013). Recognizing and managing complications in ACL reconstruction. Sports Medicine & Arthroscopy Review, 21(2), 106-112.

Heijne, A., Fleming, B. C., Renstrom, P. A., Peura, G. D., Beynnon, B. D., & Werner, S. (2004). Strain on the anterior cruciate ligament during closed kinetic chain exercises. Medicine & Science in Sports & Exercise, 36, 935-941.

Henderson, F. J., Konishi, Y., Shima, N., & Shimokochi, Y. (2022). Effects of 8-Week Exhausting Deep Knee Flexion Flywheel Training on Persistent

Quadriceps Weakness in Well-Trained Athletes Following Anterior Cruciate Ligament Reconstruction. International Journal of Environmental Research and Public Health, 19(20), 13209. https://doi.org/10.3390/IJERPH192013209

Herzog, W. (2018). Why are muscles strong, and why do they require little energy in eccentric action? Journal of Sport and Health Science, 7(3), 255-264.Barker L, Loosbrock A, Spry E, Ciccone A, Grindstaff T. Velocity-Specific Relationships Among Eccentric and Concentric Force Velocity Profiles and Jumping Performance. International journal of strength and conditioning. 2024 Jan 19;4(1).

Isberg, J., Faxén, E., & Brandsson, S., et al. (2006). Early active extension after anterior cruciate ligament reconstruction does not result in increased laxity of the knee. Knee Surgery, Sports Traumatology, Arthroscopy, 14, 1108–1115.

Jensen, K., & Di Fabio, R. P. (1989). Evaluation of eccentric exercise in treatment of patellar tendinitis. Physical Therapy, 69(3), 211-216.

John, R., Dhillon, M. S., Syam, K., Prabhakar, S., Behera, P., & Singh, H. (2016). Epidemiological profile of sports-related knee injuries in northern India: An observational study at a tertiary care centre. Journal of Clinical Orthopaedics and Trauma, 7(3), 207-211.

John, R., Dhillon, M. S., Syam, K., Prabhakar, S., Behera, P., & Singh, H. (2016). Epidemiological profile of sports-related knee injuries in northern India: An observational study at a tertiary care centre. Journal of Clinical Orthopaedics and Trauma, 7(3), 207-211.

Jonhagen, S., Nemeth, G., & Eriksson, E. (1994). Hamstring injuries in sprinters: The role of concentric and eccentric hamstring muscle strength and flexibility. The American Journal of Sports Medicine, 22(2), 262-266.

Joshi, A., Singh, N., Basukala, B., Bista, R., Maharjan, B., & Pradhan, I. (2022). Epidemiological profile of anterior cruciate ligament injuries in a tertiary referral trauma center of Nepal. BMC Musculoskeletal Disorders, 23(1), 595.

Joshi, A., Singh, N., Basukala, B., Bista, R., Maharjan, B., & Pradhan, I. (2022). Epidemiological profile of anterior cruciate ligament injuries in a tertiary referral trauma center of Nepal. BMC Musculoskeletal Disorders, 23(1), 595.

Kowalchuk, K., & Butcher, S. (2019). Eccentric overload flywheel training in older adults. Journal of Functional Morphology and Kinesiology, 4(3), 61.

Kruse, L. M., Gray, B., & Wright, R. W. (2012). Rehabilitation after anterior cruciate ligament reconstruction: A systematic review. Journal of Bone and Joint Surgery American, 94, 1737–1748.

Kushare, I., Ghanta, R. B., Ditzler, M., & Jadhav, S. P. (2021). Arcuate sign-fibular head avulsion fracture and associated injuries in the pediatric and adolescent population. Emergency Radiology, 28(4), 723-727.

Lack, S., Barton, C., Vicenzino, B., & Morrissey, D. (2014). Outcome predictors for conservative patellofemoral pain management: A systematic review and meta-analysis. Sports Medicine, 44(12), 1703–1716.

LaStayo, P. C., Woolf, J. M., Lewek, M. D., Snyder-Mackler, L., Reich, T., & Lindstedt, S. L. (2003). Eccentric muscle contractions: Their contribution to injury, prevention, rehabilitation, and sport. Journal of Orthopaedic & Sports Physical Therapy, 33(10), 557-571.

Lelli, A., Di Turi, R. P., Spenciner, D. B., & Dòmini, M. (2016). The “Lever Sign”: A new clinical test for the diagnosis of anterior cruciate ligament rupture. Knee Surgery, Sports Traumatology, Arthroscopy, 24, 2794-2797.

Lepley, L. K., & Palmieri-Smith, R. M. (2013). Effect of eccentric strengthening after anterior cruciate ligament reconstruction on quadriceps strength. Journal of Sport Rehabilitation, 22(2), 150-156.

Lepley, L. K., Lepley, A. S., Onate, J. A., & Grooms, D. R. (2017). Eccentric exercise to enhance neuromuscular control. Sports Health, 9(4), 333-340.

Liu, W., Wu, Y., Wang, X., Kuang, S., Su, C., Xiong, Y., Tang, H., Xiao, Y., & Gao, S. (2023). ACL stump and ACL femoral landmarks are equally reliable in

ACL reconstruction for assisting ACL femoral tunnel positioning. Knee Surgery, Sports Traumatology, Arthroscopy, 31(1), 219-228.Sim K, Rahardja R, Zhu M, Young SW. Optimal Graft Choice in Athletic Patients with Anterior Cruciate Ligament Injuries: Review and Clinical Insights. Open Access J Sports Med. 2022; 13:55-67.

Lorenz, D., & Reiman, M. (2011). The role and implementation of eccentric training in athletic rehabilitation: Tendinopathy, hamstring strains, and ACL reconstruction. International Journal of Sports Physical Therapy, 6(1), 27.

Lorenz, D., & Reiman, M. (2011). The role and implementation of eccentric training in athletic rehabilitation: Tendinopathy, hamstring strains, and ACL reconstruction. International Journal of Sports Physical Therapy, 6(1), 27-44.

Maroto-Izquierdo, S., García-López, D., Beato, M., Bautista, I. J., Hernández-Davó, J. L., Raya-González, J., & Martín-Rivera, F. (2024). Force production and electromyographic activity during different flywheel deadlift exercises. Sports, 12(4), 95.

Martelli, S., & Pinskerova, V. (2002). The shapes of the tibial and femoral articular surfaces in relation to tibiofemoral movement. Journal of Bone and Joint Surgery - British Volume, 84(5), 607–613.

Martín-Rivera, F., Beato, M., Alepuz-Moner, V., & Maroto-Izquierdo, S. (2022). Use of concentric linear velocity to monitor flywheel exercise load. Frontiers in Physiology.

McErlain-Naylor, S. A., & Beato, M. (2021). Concentric and eccentric inertia–velocity and inertia–power relationships in the flywheel squat. Journal of Sports Sciences, 39(10), 1136-1143.

McErlain-Naylor, S. A., & Beato, M. (2021). Post flywheel squat potentiation of vertical and horizontal ground reaction force parameters during jumps and changes of direction. Sports, 9(1), 5.

McErlain-Naylor, S. A., & Beato, M. (2022). Factors influencing the jump momentum–sprint momentum correlation: A data simulation. European Journal of Sport Science, 22(12), 1847-1855.

Meister, B. R., Michael, S. P., & Moyer, R. A., et al. (2000). Anatomy and kinematics of the lateral collateral ligament of the knee. The American Journal of Sports Medicine, 28(6), 869–878.

Muñoz-López, A., Nakamura, F. Y., & Beato, M. (2023). Eccentric overload differences between loads and training variables on flywheel training. Biology of Sport, 40(4), 1151-1158.

Musahl, V., Engler, I. D., Nazzal, E. M., Dalton, J. F., Lucidi, G. A., Hughes, J. D., Zaffagnini, S., Della Villa, F., Irrgang, J. J., Fu, F. H., & Karlsson, J. (2022). Current trends in the anterior cruciate ligament part II: Evaluation, surgical technique, prevention, and rehabilitation. Knee Surgery, Sports Traumatology, Arthroscopy, 30(1), 34-51.

Noailles, T., Chalopin, A., Boissard, M., Lopes, R., Bouguennec, N., & Hardy, A. (2019). Incidence and risk factors for cyclops syndrome after anterior cruciate ligament reconstruction: A systematic literature review. Orthopaedics& Traumatology: Surgery & Research, 105(7), 1401-1405.

Nonnato, A., Hulton, A. T., Brownlee, T. E., & Beato, M. (2022). The effect of a single session of plyometric training per week on fitness parameters in professional female soccer players: A randomized controlled trial. Journal of Strength and Conditioning Research, 36(4), 1046-1052.

Ogrodzka-Ciechanowicz, K., Głąb, G., Ślusarski, J., & Gądek, A. (2021). Quadriceps muscle strength recovery with the use of high tone power therapy after anterior cruciate ligament reconstruction: a randomized controlled trial. BMC Musculoskeletal Disorders, 22(1), 1–10. https://doi.org/10.1186/S12891-021-04862-W/TABLES/4

Pandis, N., Chung, B., Scherer, R. W., Elbourne, D., & Altman, D. G. (2017). CONSORT 2010 statement: Extension checklist for reporting within-person randomized trials. BMJ, 357, j2490.

Pang, L., Li, P., Li, T., Li, Y., Zhu, J., & Tang, X. (2022). Arthroscopic anterior cruciate ligament repair versus autograft anterior cruciate ligament reconstruction: A meta-analysis of comparative studies. Frontiers in Surgery, 9, 887522.

Paterno, M. V. (2015). Incidence and predictors of second anterior cruciate ligament injury after primary reconstruction and return to sport. Journal of Athletic Training, 50(10), 1097-1099.

Paterno, M. V. (2015). Incidence and predictors of second anterior cruciate ligament injury after primary reconstruction and return to sport. Journal of Athletic Training, 50(10), 1097-1099.

Pelegrinelli, A. R., Guenka, L. C., Dias, J. M., Bela, L. F., Silva, M. F., Moura, F. A., Brown, L. E., & Cardoso, J. R. (2018). Isokinetic muscle performance after anterior cruciate ligament reconstruction: A case-control study. International Journal of Sports Physical Therapy, 13(5), 882.

Phatama, K. Y., Aziz, A., Bimadi, M. H., Oktafandi, I. G. N. A. A., Cendikiawan, F., & Mustamsir, E. (2021). Knee injury and osteoarthritis outcome score: Validity and reliability of an Indonesian version. Ochsner Journal, 21(1), 63-67.

Piqueras-Sanchiz, F., Sabido, R., Raya-González, J., Madruga-Parera, M., Romero-Rodríguez, D., Beato, M., de Hoyo, M., Nakamura, F. Y., & Hernández-Davó, J. L. (2020). Effects of different inertial load settings on power output using a flywheel leg curl exercise and its inter-session reliability. Journal of Human Kinetics, 74(1), 215-226.

Powers, C. M., Landel, R., & Perry, J. (1996). Timing and intensity of vastus muscle activity during functional activities in subjects with and without patellofemoral pain. Physical Therapy, 76(9), 946–955; discussion 956–967.

Raya-González, J., Castillo, D., & Beato, M. (2021). The flywheel paradigm in team sports: A soccer approach. Strength & Conditioning Journal, 43(1), 12-22.

Raya-González, J., Castillo, D., de Keijzer, K. L., & Beato, M. (2022). Considerations to optimize strength and muscle mass gains through flywheel resistance devices: A narrative review. Strength & Conditioning Journal.

Raya-González, J., de Keijzer, K. L., Bishop, C., & Beato, M. (2022). Effects of flywheel training on strength-related variables in female populations: A systematic review. Research in Sports Medicine, 30(4), 353-370.

Raya-González, J., Pulido, J. J., Beato, M., Ponce-Bordón, J. C., López del Campo, R., Resta, R., &García-Calvo, T. (2022). Analysis of the effect of injuries on match performance variables in professional soccer players: A retrospective, experimental longitudinal design. Sports Medicine-Open, 8(1), 31.

Reider, B., Marshall, J. L., Koslin, B., Ring, B., & Girgis, F. G. (1981). The anterior aspect of the knee joint. Journal of Bone and Joint Surgery - American Volume, 63(3), 351–356.

Sepúlveda, F., Sánchez, L., Amy, E., & Micheo, W. (2017). Anterior cruciate ligament injury: Return to play, function, and long-term considerations. Current Sports Medicine Reports, 16(3), 172-178.

Shaikh, H., Herbst, E., Rahnemai-Azar, A. A., Bottene Villa Albers, M., Naendrup, J. H., Musahl, V., Irrgang, J. J., & Fu, F. H. (2017). The Segond fracture is an avulsion of the anterolateral complex. American Journal of Sports Medicine, 45(10), 2247-2252.

Shaw, T., Williams, M. T., & Chipchase, L. S. (2005). Do early quadriceps exercises affect the outcome of ACL reconstruction? A randomized controlled trial. Australian Journal of Physiotherapy, 51, 9–17.

Shirakura, K., Kato, K., & Udagawa, E. (1992). Characteristics of the isokinetic performance of patients with injured cruciate ligaments. The American Journal of Sports Medicine, 20(6), 754-760.

Silva, H., Nakamura, F. Y., Beato, M., & Marcelino, R. (2022). Acceleration and deceleration demands during training sessions in football: A systematic review. Science and Medicine in Football.

Simon, S. R., Alaranta, H., & An, K. N., et al. (2000). Kinesiology. In J. A. Buckwalter, T. A. Einhorn, & S. R. Simon (Eds.), Orthopaedic basic science: Biology and biomechanics of the musculoskeletal system (2nd ed., pp. 730–827). American Academy of Orthopaedic Surgeons.

Spudić, D., Smajla, D., & Šarabon, N. (2024). Force–velocity–power profiling in flywheel squats: Differences between sports and association with countermovement jump and change of direction performance. Journal of sports sciences, 42(15), 1464-1476.

Stanish, W. D., Rubinovich, R. M., & Curwin, S. (1986). Eccentric exercise in chronic tendinitis. Clinical Orthopaedics and Related Research, 208, 65-68.

Stojanović, M. D., Mikić, M., Drid, P., Calleja-González, J., Maksimović, N., Belegišanin, B., & Sekulović, V. (2021). Greater power but not strength gains using flywheel versus equivolumed traditional strength training in junior basketball players. International Journal of Environmental Research and Public Health, 18(3), 1181.

Suarez-Arrones, L., Núñez, F. J., Lara-Lopez, P., Di Salvo, V., & Méndez-Villanueva, A. (2020). Inertial flywheel knee- and hip-dominant hamstring strength exercises in professional soccer players: Muscle use and velocity-based (mechanical) eccentric overload. PLoS ONE, 15(10), e0239977. https://doi.org/10.1371/JOURNAL.PONE.0239977

Suh, D. K., Lee, J. H., Rhim, H. C., Cho, I. Y., Han, S. B., & Jang, K. M. (2021). Comparison of muscle strength and neuromuscular control up to 1 year after anterior cruciate ligament reconstruction between patients with dominant leg and non-dominant leg injuries. The Knee, 29, 15-25.

Tatiya, D., Chitapure, T., Shaikh, A., & Jaju, A. (2021). The role of eccentric training and pain neuroscience education (PNE) to improve quadriceps muscle strength, and function in post ACL repair: A case report. International Journal of Kinesiology and Sports Science, 9(3), 40–43.

Vaudreuil, N. J., Rothrauff, B. B., de SA, D., & Musahl, V. (2019). The pivot shift: Current experimental methodology and clinical utility for anterior cruciate ligament rupture and associated injury. Current Reviews in Musculoskeletal Medicine, 12, 41-49.

Vidmar, M. F., Baroni, B. M., Michelin, A. F., Mezzomo, M., Lugokenski, R., Pimentel, G. L., & Silva, M. F. (2020). Isokinetic eccentric training is more effective than constant load eccentric training for quadriceps rehabilitation following anterior cruciate ligament reconstruction: A randomized controlled trial. Brazilian Journal of Physical Therapy, 24(5), 424-432.

Wang, H., Fleischli, J. E., & Zheng, N. N. (2012). Effect of lower limb dominance on knee joint kinematics after anterior cruciate ligament reconstruction. Clinical Biomechanics, 27(2), 170-175.

Wang, L. J., Zeng, N., Yan, Z. P., Li, J. T., & Ni, G. X. (2020). Post-traumatic osteoarthritis following ACL injury. Arthritis Research & Therapy, 22(1), 57.

Westing, S. H., & Seger, J. Y. (1989). Eccentric and concentric torque-velocity characteristics, torque output comparisons, and gravity effect torque corrections for the quadriceps and hamstring muscles in females. International Journal of Sports Medicine, 10(3), 175-180.

Westing, S. H., Seger, J. Y., & Thorstensson, A. (1990). Effects of electrical stimulation on eccentric and concentric torque-velocity relationships during knee extension in man. ActaPhysiologicaScandinavica, 140(1), 17-22.

Wright, R. W., Preston, E., Fleming, B. C., Amendola, A., Andrish, J. T., Bergfeld, J. A., Dunn, W. R., Kaeding, C., Kuhn, J. E., Marx, R. G., & McCarty, E. C. (2008). A systematic review of anterior cruciate ligament reconstruction rehabilitation–part I: Continuous passive motion, early weight bearing, postoperative bracing, and home-based rehabilitation. The Journal of Knee Surgery, 21(03), 217-224.

Wu, F., Colak, C., & Subhas, N. (2022). Preoperative and postoperative magnetic resonance imaging of the cruciate ligaments. Magnetic Resonance Imaging Clinics of North America, 30(2), 261-275.

Xu, B., Zhang, H., Li, B., & Wang, W. (2018). Comparison of magnetic resonance imaging for patients with acute and chronic anterior cruciate ligament tears. Medicine (Baltimore), 97(10), e0001.

Xu, J., Thompson, B. J., Spencer, S. B., Studenka, B. E., & Bressel, E. (2023). Effects of flywheel resistance training on muscle function and sport-specific performance in collegiate club water polo players. Research Quarterly for Exercise and Sport, 94(1), 98-109.

Zumstein, F., Centner, C., & Ritzmann, R. (2022). How limb dominance influences limb symmetry in ACL patients: effects on functional performance. BMC Sports Science, Medicine and Rehabilitation, 14(1), 206.

APPENDIX-I

PATIENT ASSESSMENT FORM
GENERAL

Patient Name:

Patient History

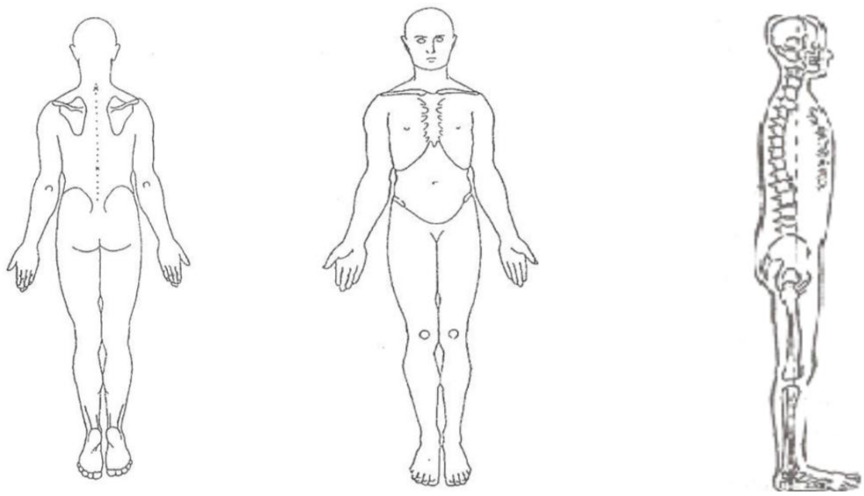
ADDRESS (Province-District) :			**PHONE No:**		
PATIENT AGE:		**F**	**M**	**Diagnosis:**	
1.	**Civil Status**	Single	Married	Number of children:	
2.	**Job & Occupation**	Armed forces	Farmers, fisherman	Non qualified worker	Technician
		Office workers	Retired	Unemployed & not active	Student
3.	**Education level**	Can write	Can read	Class:	
4.	**History of the trauma/illness**	Date:	Circumstances/ Etiology:		
	Associated diseases:				
5.	**Medical History/Treatment**	Hospital:		Care:	
	Evolution since the beginning	Improved	Worse	Remarks:	
	Medication:			X-ray/Other ex:	
6.	**Psychological Status**				
	Motivation/Emotional Status	Good	Bad	Comments:	
	Attitude/Compliance	Good	Bad	Comments:	
	Cognitive Status and others *(Mainly for Neurological Conditions)*				
	Concentration/Memory	Good	Bad	Comments:	
	Communication (understanding, speaking)	Good	Bad	Comments:	
	Bowel/Bladder control	Yes	No	Comments:	
	Swallowing	Good	Bad	Comments:	
	Breathing (ability to cough)	Good	Bad	Comments:	
	Vision	Good	Bad	Comments:	
	Hearing	Good	Bad	Comments:	
7.	**Living Condition**				
	House	Good	Bad	Comments:	
	Environment	Rural	Urban	Mountain	Flooded fields
	Family	Present	Absent	Comments:	
	Friends	Present	Absent	Comments:	
	Cultural Environment	Supportive	Limitative	Comments:	
8.	**Medical and Social Support**				
	Accessibility to Medical Services	Yes	No	Comments:	
	Accessibility to Social Services	Yes	No	Comments:	
	Security Situation	Good	Bad	Comments:	
9.	**Main patient's concerns:**				
10.	**Main patient's expectations:**				

Current Treatment:	1st	2nd	3rd/>

Remarks:

Physical Examination:

Mark on the body-chart deformities or joint anomalies, back deformities or anomalies, edema, shoulder subluxation etc.



Remarks:

Skin & soft tissues problem		
DISORDERS	**Minor**	**Important**
Swelling		
Callus		
Scar		
Wound		
Temperature		
Infection		
Pain		
Abnormal Sensation		

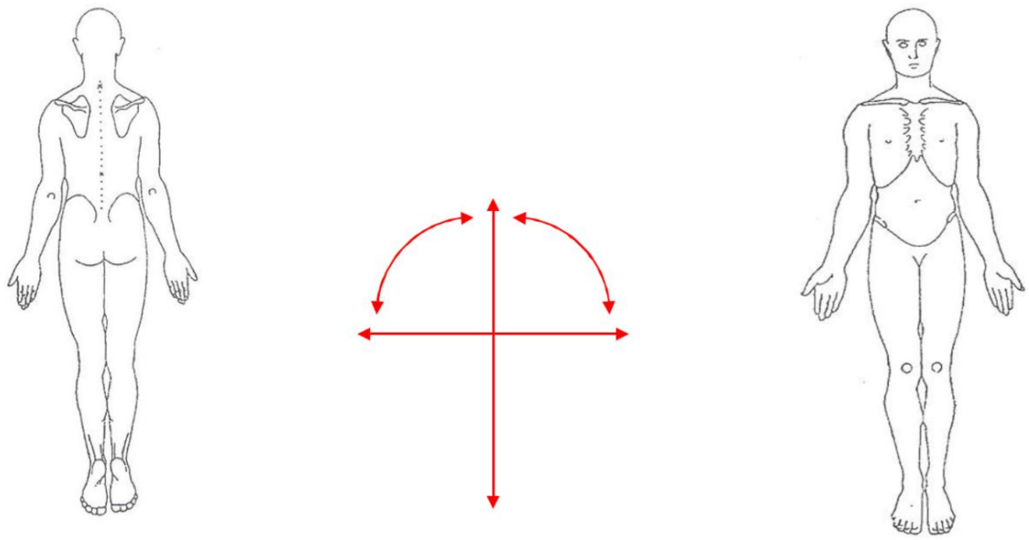
Sensation			
Sensitivity	**L**	**R**	(Specification)
Superficial			
Deep			
Numbness			
Paraesthesia			
Other			

Reflexes:

	R			L			Comments
BTR	**+**	**-**	normal	**+**	**-**	normal	
TTR	**+**	**-**	normal	**+**	**-**	normal	
KTR	**+**	**-**	normal	**+**	**-**	normal	
ATR	**+**	**-**	normal	**+**	**-**	normal	
Babinsky							

\+ Hyper reflex; **-** Hypo reflex

Body chard of pain/symptoms distribution:



Pain:

Date of first complains:

Evolution since the beginning of the pain:

Evolution in 24h & scale 0 -10:

Pain ↑(increase) with:

Pain ↓(decrease) with:

Patient's category	SIN	ROM	MOMP	EOR

SIN: severe, irritable, nature **ROM**: range of motion **EOR**: end of range **MOMP**: momentary pain

Neurodynamics

Tests	R	L	Sensitive component
SLR			
Slump			
PKB			
ULNT1			
ULNT2			
ULNT2			
ULNT3			

Range of Motion:

- Passive ROM should be recorded during first assessment and before discharging the patients

LOWER LIMB			Date Assessment ………………		Date Follow up ………………	
			L	R	L	R
HIP						
	Flexion	120				
	Extension	30				
	Abduction	45				
	Adduction	30				
	Medial Rotation	30				
	Lateral Rotation	60				
KNEE						
	Flexion	135				
	Extension	0				
ANKLE-FOOT						
	Dorsi Flexion	30				
	Plantar Flexion	45				
	Inversion	35				
	Eversion	15				
NECK						
	Flexion	cm				
	Extension	cm				
	Latero-Flexion R	cm				
	Latero-Flexion L	cm				
	Rotation R	cm				
	Rotation L	cm				
TRUNK						
	Global Flexion	cm				
	Thoracic Flexion					
	(OttTest)	cm				
	Lumbar Flexion					
	(Schober test)	cm				
	Global Extension	cm				
	Latero-Flexion R	cm				
	Latero-Flexion L	cm				
	Rotation R (write OK or imp.)					
	Rotation L (write OK or imp.)					

UPPER LIMB			Date Assessment ………………		Date Follow up ………………	
			L	R	L	R
SHOULDER						
	Flexion	180				
	Extension	60				
	Abduction	180				
	Adduction	30				
	Medial Rotation	95				
	Lateral Rotation	80				
ELBOW						
	Flexion	150				
	Extension	0				
FOREARM						
	Pronation	80				
	Supination	80				
FOREARM						
	Pronation	80				
	Supination	80				
WRIST						
	Flexion	80				
	Extension	80				
	Abduction	20				
FINGERS						
	Thumb opposition					
	MP Flexion	90				
	MP Extension	40				
	IP Flexion	120				

Remarks:

Muscle Test:

- Muscle test should be recorded during first assessment and before discharging the patient

LOWER LIMB		Date Assessment		Date Follow up	
		L	R	L	R
HIP	**Comments**				
Flexors					
Extensors					
Abductors					
Adductors					
Lateral Rot.					
Medial Rot.					
KNEE					
Flexors					
Extensors					
ANKLE					
Dorsi Flex.					
Plantar Flex.					
Inversors					
Eversors					
FOOT					
Flexors					
Extensors					
TRUNK					
Flexors					
Extensor					
R. Bending					
L. Bending					
R. Rotation					
L. Rotation					

UPPER LIMB		Date Assessment		Date Follow up	
		L	R	L	R
SHOULDER	**Comments**				
Flexors					
Extensors					
Abductors					
Adductors					
Lateral Rot.					
Medial Rot.					
Elevators					
Depressors					
Antepulsors					
Retropulsors					
ELBOW					
Flexors					
Extensors					
FOREARM					
Supinators					
Pronators					
WRIST					
Flexors					
Extensors					
FINGERS					
Flexors					
Extensors					
Abductors					
Opposition					

QUOTATION FOR MUSCLE TESTING according to Manual Muscle Testing Oxford Scale	
0	*No contraction present*
1	*Contraction visible without movement*
2	*Movement possible without gravity or incomplete against gravity*
3	*Movement possible against gravity into the fullest available range*
4	*Movement resistance possible against gravity and an added moderate*
5	*Muscle functions normally*

Muscle Tone:

- Muscle test should be recorded during first assessment and before discharging the patient

LOWER LIMB		Date Assessment		Date Follow up	
		L	R	L	R
HIP	**Comments**				
Flexors					
Extensors					
Abductors					
Adductors					
Lateral Rot.					
Medial Rot.					
KNEE					
Flexors					
Extensors					
ANKLE					
Dorsi Flex.					
Plantar Flex.					
Inversors					
Eversors					
FOOT					
Flexors					
Extensors					
TRUNK					
Flexors					
Extensor					
R. Bending					
L. Bending					
R. Rotation					
L. Rotation					

UPPER LIMB		Date Assessment		Date Follow up	
		L	R	L	R
SHOULDER	**Comments**				
Flexors					
Extensors					
Abductors					
Adductors					
Lateral Rot.					
Medial Rot.					
Elevators					
Depressors					
Antepulsors					
Retropulsors					
ELBOW					
Flexors					
Extensors					
FOREARM					
Supinators					
Pronators					
WRIST					
Flexors					
Extensors					
FINGERS					
Flexors					
Extensors					
Abductors					
Opposition					

QUOTATION FOR MUSCLE TONE according to Modified Ashworth Scale	
0	*No increase in tone*
1	*Slight increase in tone giving a catch when limb is moved*
2	*More marked increase in tone*
3	*Considerable increase in tone – passive movement difficult*
4	*Limb rigid*
Write ⇩ in case of hypotone (flaccidity)	

Functional Evaluation:

Balance disorders

Sitting	Normal	
	Good	
	Poor	
	Not possible	
Standing	Normal	
	Good	
	Poor	
	Not possible	

Coordination

UPPER LIMBS	Good		Poor		Not Possible	
	L	R	L	R	L	R
LOWER LIMBS	L	R	L	R	L	R
Comments:						

Gait Analysis				
FRONTAL PLANE **Observations :**				
SAGITTAL PLANE **Observations :**				
Functional Quality of the gait	**Normal**	**Good**	**Poor**	**Comments:**
1. CADENCE				
2. CADENCE				
3. SPEED				
4. FATIGUE				

Other Remarks:

APPENDIX-II

PATIENT INFORMATION SHEET

1. **Project Title**

   Isoinertial training for eccentric strengthening in Anterior Cruciate Ligament reconstruction surgeries: An experimental trial

2. **Principal Investigator and Co-Investigator, if any, with the contact number and organization:**

   PI: Som Gupta (Ph.D. Scholar)

   Head, Department of Physiotherapy

   Fortis Hospital, Ludhiana

   Mobile No.- 9815370607

   Email Id- drsomgupta@yahoo.co.in

   Co PI: Dr. Ramesh Chandra Patra

   Assistant Professor

   Department of Physiotherapy

   Lovely Professional University

   Phagwara, Punjab

   Mobile No.- 9653174563

   Email Id- Ramesh.19500@lpu.co.in

3. **What is the purpose of this research?**

   You are invited to take part in research study titled Isoinertial training for eccentric strengthening in Anterior Cruciate Ligament reconstruction surgeries: An experimental trial. The aim of the study is to evaluate the effectiveness of isoinertial eccentric overload strengthening in combination with traditional rehabilitation method in patients with Anterior Cruciate Ligament (ACL) reconstruction surgeries on muscle power, endurance and isometric strength. Additionally, to evaluate the effectiveness of isoinertial eccentric overload strengthening in combination with traditional rehabilitation method in patients with Anterior Cruciate Ligament (ACL) reconstruction surgeries on balance, Knee injury and Osteoarthritis Outcome Score (KOOS) and on Knee Related quality of life (CKRS).

4. Who can participate in the research?

Any individual who meets the following criteria can take part in this study:

- Post ACL reconstruction patients, aged between 18- 45 years done by same surgeon using STG (Semitendinosus gracilis graft).
- 3weeks post ACL reconstruction surgery patients.

However, you will not be suitable to participate in this study if you have the following:

- Previous ACLR (ACL reconstruction surgery).
- Previous knee surgery.
- Unable to fulfil follow-up requirements.

5. What is the expected duration of my participation?

Expected duration of study will be 3 years and your participation is expected for 6weeks. You will be called for treatment twice a week for 6 weeks.

6. What will be done if I take part in this research?

You will be included in the study three weeks post ACL reconstruction surgery. You will be assessed by researcher for below mentioned outcomes measures;

Muscle power, endurance, isometric strength, balance and knee related quality of life score. Follow up assessment/reading will be taken after every 3 weeks.

7. How will my privacy and the confidentiality of my research records be protected?

Principal investigator has your identifiable information (e.g. names, contact information, etc) and this will not be released to any other person and out most care will be taken to keep it confidential. Identifiable information will never be used in a publication or presentation. All your identifiable health information and research data will be coded (i.e. only identified with a code number) at the earliest possible stage of the research.

8. What are the possible discomforts and risks for the participants?

Possible risk may include but are not limited to;

- Muscle fatigue due to some exercises during exercise program
- Muscle or joint pain due to over doing of learned exercises
- Mild swelling in the joint
- Inconvenience e.g. giving up time to participate in the research project

9. Will there be reimbursement for participation?

No

10. **What are the possible benefits to me and others?**

We cannot guarantee that you will benefits from being in the study. However, the program will help to better understand whether eccentric overload training using flywheel (Desmotec) is effective in post operative rehabilitation.

11. **Can I refuse to participate in this research?**

Yes, you can. Your decision to participate in this research is voluntary and completely up to you. You can also withdraw from the research at any time without giving any reason, by informing the principal investigator and all your data collected will be discarded. Refusal to participate or withdraw from participation will not affect your rehabilitation program in this centre or cause loss of benefits to which you are otherwise entitled.

12. **Whom should I call if I have any questions or problems?**

Please contact the Principal Investigator Som Gupta at (M- +919815370607)

APPENDIX-III

INFORMED CONSENT FORM TO PARTICIPATE IN THE CLINICAL STUDY

Study Title: Isoinertial training for eccentric strengthening in Anterior Cruciate Ligament reconstruction surgery: An experimental trial

Principal Investigator with the contact number and organization:

Mr. Som Gupta (Ph.D. Scholar),
Head, Department of Physiotherapy
Fortis Hospital, Ludhiana
Mobile No.- 9815370607
Email Id- drsomgupta@yahoo.co.in

Subject's Name: ____

Subject's Initials: ____________________

Date of Birth/Age: __________________, Sex: ______________

Address of the Subject:

____

____

____

Contact number(s) of the Subject:

____

Occupation: Student/Self Employed/Service/Housewife/others (please specify)

____

(Please tick as appropriate)
Qualification: _________________________

Please sign this consent form only after you have had a chance to ask questions and have received acceptable answers to all of your questions. By signing this page, you will be confirming the following statements:

S.No.	Statement	Initial Box (Subject)
(i)	I confirm that I have read and understood the information for the above study and have had time to think about it and the opportunity to ask questions.	[ ]
(ii)	I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.	[ ]

(iii)	I understand that the investigator, the Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the study I agree to this access. However, I understand that my identity will not be revealed in any information released to third parties or published.	[ ]
(iv)	I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).	[ ]
(v)	I agree to take part in the above study.	[ ]
(vi)	I agree to the photo-taking/audio-recording/video-recording of my participation in the research.	[ ]
(vii)	I have been informed in person and in a comprehensible manner about the study, possible discomforts/risks and about nature, significance and scope of the clinical study and my responsibilities in this context. My questions have been answered satisfactorily. I have had sufficient time to make my decision. I will follow the doctor's instructions required for the conduct of this clinical study.	[ ]

Signature of the Subject with Date:

Name of Subject: ____

Signature (or thumb impression)
of Subject with Date: _____________________________________

Investigator or the person who conducted the Informed Consent Discussion:

I confirm that I have personally explained the nature, purpose, duration, and foreseeable effects of the study to the subject named above.

I have carefully explained the nature of the above research study to the subject. I hereby certify that to the best of my knowledge, the person signing this consent form understands the nature, demands, benefits, and risks of participating and that his/her signature is valid. A medical problem or language or educational barrier has not precluded his/ her understanding.

Study Investigator's Name: ____

Signature of the Investigator with Date: ________________________________

APPENDIX-IV

<u>रोगी सूचना पत्र</u>

1. **<u>प्रोजेक्ट का शीर्षक</u>**

   पूर्वकाल क्रूसिएट लिगामेंट पुनर्निर्माण सर्जरी में सनकी मजबूत बनाने के लिए आइसोसिंथियल प्रशिक्षण: एक परीक्षण

2. **<u>प्रधान अन्वेषक और सह-अन्वेषक, यदि कोई हो, संपर्क नंबर और संगठन के साथ:</u>**

   PI: सोम गुप्ता (पीएचडी स्कॉलर)
   प्रमुख, फिजियोथेरेपी विभाग
   फोर्टिस अस्पताल, लुधियाना
   मोबाइल नंबर- 9815370607
   ईमेल आईडी- drsomgupta@yahoo.co.in

   Co PI: डॉ। रमेश चंद्र पात्रा
   सहेयक प्रोफेसर
   फिजियोथेरेपी विभाग
   लवली प्रोफेशनल यूनिवर्सिटी
   फगवाड़ा, पंजाब
   मोबाइल नंबर- 9653174563
   ईमेल आईडी- Ramesh.19500@lpu.co.in

3. **<u>इस शोध का उद्देश्य क्या है?</u>**

   आपको पूर्वकाल क्रूसिएट लिगामेंट पुनर्निर्माण सर्जरी में सनकी मजबूती के लिए Isoinertial प्रशिक्षण शीर्षक अनुसंधान अध्ययन में भाग लेने के लिए आमंत्रित किया गया है : एक प्रयोगात्मक परीक्षण । अध्ययन का उद्देश्य मांसपेशियों की शक्ति, धीरज और सममितीय शक्ति पर पूर्वकाल क्रूसिएट लिगामेंट (एसीएल) पुनर्निर्माण सर्जरी के साथ रोगियों में पारंपरिक पुनर्वास विधि के साथ संयोजन में isoinertial सनकी अधिभार को मजबूत बनाने की प्रभावशीलता का मूल्यांकन करना है। इसके अतिरिक्त पूर्वकाल क्रूसिएट लिगामेंट (ACL) पुनर्निर्माण सर्जरी, घुटने की चोट और ऑस्टियोआर्थराइटिस आउटकम वेलकम स्कोर (KOOS) और घुटने से संबंधित जीवन की गुणवत्ता (CKRS) के साथ रोगियों में पारंपरिक पुनर्वास विधि के साथ संयोजन में isoinertial सनकी अधिभार की प्रभावशीलता का मूल्यांकन ।

4. **<u>शोध में कौन भाग ले सकता है?</u>**

   निम्न मानदंडों को पूरा करने वाला कोई भी व्यक्ति इस अध्ययन में भाग ले सकता है:

   - एसीएल पुनर्निर्माण रोगियों को पोस्ट करें, एसटीजी (सेमिटेंडिनोस ग्रैसिलिस ग्राफ्ट) का उपयोग करके एक ही सर्जन द्वारा 18-45 वर्ष के बीच की आयु ।
   - 3 सप्ताह के बाद एसीएल पुनर्निर्माण सर्जरी के रोगी।

     हालाँकि, यदि आपके पास निम्नलिखित हैं, तो आप इस अध्ययन में भाग लेने के लिए उपयुक्त नहीं होंगे:
   - पिछला ACLR (ACL पुनर्निर्माण सर्जरी) ।
   - पिछली घुटने की सर्जरी ।

- अनुवर्ती आवश्यकताओं को पूरा करने में असमर्थ ।

5. **<u>मेरी भागीदारी की अपेक्षित अवधि क्या है?</u>**

अध्ययन की अपेक्षित अवधि 3 वर्ष होगी और आपकी भागीदारी 6 सप्ताह के लिए अपेक्षित है। आपको 6 सप्ताह के लिए सप्ताह में दो बार उपचार के लिए बुलाया जाएगा।

6. **<u>अगर मैं इस शोध में भाग लूंगा तो क्या होगा?</u>**

आप अध्ययन में तीन सप्ताह के बाद एसीएल पुनर्निर्माण सर्जरी में शामिल होंगे। आप नीचे उल्लिखित परिणामों के लिए शोधकर्ता द्वारा मूल्यांकन किया जाएगा ;

मांसपेशियों की शक्ति, धीरज, सममितीय शक्ति, संतुलन और घुटने से संबंधित जीवन स्तर की गुणवत्ता। अनुवर्ती मूल्यांकन / पढ़ना हर 3 सप्ताह के बाद लिया जाएगा।

7. **<u>मेरी गोपनीयता और मेरे शोध रिकॉर्ड की गोपनीयता कैसे सुरक्षित रहेगी?</u>**

Principal जांचकर्ता के पास आपकी पहचान योग्य information (जैसे नाम, संपर्क जानकारी, आदि) है और इसे किसी अन्य व्यक्ति को जारी नहीं किया जाएगा और इसे गोपनीय रखने के लिए सबसे अधिक देखभाल की जाएगी। पहचान योग्य जानकारी का उपयोग कभी भी प्रकाशन या प्रेसेंटेशन में नहीं किया जाएगा । आपके सभी पहचाने जाने योग्य स्वास्थ्य जानकारी और अनुसंधान डेटा को कोडित किया जाएगा (यानी केवल एक कोड संख्या के साथ पहचाना गया) अनुसंधान के शुरुआती संभावित चरण में।

8 . **<u>प्रतिभागियों के लिए संभावित असुविधाएँ और जोखिम क्या हैं?</u>**

संभावित जोखिम में शामिल हो सकते हैं लेकिन सीमित नहीं हैं;

- व्यायाम कार्यक्रम के दौरान कुछ व्यायाम के कारण मांसपेशियों की थकान
- अधिक व्यायाम करने के कारण मांसपेशियों या जोड़ों में दर्द
- जोड़ में हल्का सूजन
- असुविधा जैसे अनुसंधान परियोजना में भाग लेने के लिए समय देना

9 . **<u>क्या भागीदारी के लिए प्रतिपूर्ति होगी?</u>**

नहीं

10. **<u>मेरे और अन्य लोगों के लिए संभावित लाभ क्या हैं?</u>**

हम इस बात की गारंटी नहीं दे सकते हैं कि अध्ययन में आपको लाभ होगा । हालांकि, यह कार्यक्रम बेहतर ढंग से समझने में मदद करेगा कि क्या फ्लाइ हील (डेस्मोटेक) का उपयोग करते हुए सनकी अधिभार प्रशिक्षण पोस्ट ऑपरेटिव पुनर्वास में प्रभावी है ।

11. **<u>क्या मैं इस शोध में भाग लेने से इनकार कर सकता हूं?</u>**

हाँ आप कर सकते हैं। इस शोध में भाग लेने का आपका निर्णय स्वैच्छिक है और पूरी तरह से आपके ऊपर है। आप बिना किसी कारण के किसी भी समय अनुसंधान से वापस ले सकते हैं , मुख्य अन्वेषक को सूचित करके और आपके द्वारा एकत्रित सभी डेटा को छोड़ दिया जाएगा । भाग लेने या बराबर से वापस लेने के इनकार ticipation अपने को प्रभावित नहीं करेगा लाभ के इस केंद्र या कारण नुकसान में पुनर्वास कार्यक्रम फिट जो करने के लिए आप अन्यथा रहे हैं हकदार।

12. **<u>अगर मुझे कोई प्रश्न या समस्या है तो मुझे क्या कॉल करना चाहिए?</u>**

कृपया प्रधान अन्वेषक सोम गुप्ता से संपर्क करें (M- +919815370607)

APPENDIX-V

<u>नैदानिक अध्ययन में भाग लेने के लिए सूचित सहमति फार्म</u>

अध्ययन का शीर्षक: पूर्वकाल क्रूसिएट लिगामेंट पुनर्निर्माण सर्जरी में सनकी मजबूती के लिए इओसिन्ट्रियल प्रशिक्षण: एक प्रायोगिक परीक्षण

संपर्क नंबर और संगठन के साथ प्रधान अन्वेषक:

श्री सोम गुप्ता (पीएचडी स्कॉलर),

प्रमुख, फिजियोथेरेपी विभाग

फोर्टिस अस्पताल, लुधियाना

मोबाइल नंबर- 9815370607

ईमेल आईडी- drsomgupta@yahoo.co.in

विषय का नाम: ____

विषय की शुरुआत : ________________________

जन्म तिथि / आयु: ______________________, लिंग: __________________

विषय का

पता: ____

____

संपर्क नंबर विषय की: ________________________________

व्यवसाय: छात्र / स्वयं कार्यरत / सेवा / गृहिणी / अन्य (कृपया निर्दिष्ट करें) _______________

(कृपया उपयुक्त के रूप में टिक करें)

योग्यता: ______________________________

कृपया इस सहमति फॉर्म पर हस्ताक्षर करने के बाद ही प्रश्न पूछें और अपने सभी प्रश्नों के स्वीकार्य उत्तर प्राप्त करें। इस पृष्ठ पर हस्ताक्षर करके, आप निम्नलिखित कथनों की पुष्टि करेंगे :

एस न.	**कोई विवरण**	**प्रारंभिक बॉक्स (विषय)**
(i)	मैं पुष्टि करता हूँ कि मैंने उपरोक्त अध्ययन के लिए दी गई जानकारी को पढ़ और समझ लिया है तथा मुझे इस पर विचार करने का समय मिला है तथा प्रश्न पूछने का अवसर भी मिला है।	[ ]
(ii)	मैं समझता हूं कि अध्ययन में मेरी भागीदारी स्वैच्छिक है और मैं किसी भी समय, बिना कोई कारण बताए, अपनी चिकित्सा देखभाल या कानूनी अधिकारों को प्रभावित किए बिना, इसमें शामिल होने से पीछे हटने के लिए स्वतंत्र हूं।	[ ]

(iii)	मैं समझता हूँ कि जांचकर्ता, आचार समिति और विनियामक प्राधिकरणों को वर्तमान अध्ययन और इसके संबंध में किए जाने वाले किसी भी अन्य शोध के संबंध में मेरे स्वास्थ्य रिकॉर्ड को देखने के लिए मेरी अनुमति की आवश्यकता नहीं होगी, भले ही मैं अध्ययन से हट जाऊँ, मैं इस पहुँच के लिए सहमत हूँ। हालाँकि, मैं समझता हूँ कि तीसरे पक्ष को जारी की गई या प्रकाशित किसी भी जानकारी में मेरी पहचान का खुलासा नहीं किया जाएगा।	[ ]
(iv)	मैं इस अध्ययन से प्राप्त किसी भी डेटा या परिणाम के उपयोग को प्रतिबंधित नहीं करने के लिए सहमत हूं, बशर्ते ऐसा उपयोग केवल वैज्ञानिक उद्देश्यों के लिए हो।	[ ]
(v)	मैं उपरोक्त अध्ययन में भाग लेने के लिए सहमत हूं।	[ ]
(vi)	**मैं अनुसंधान में अपनी भागीदारी की फोटो लेने/ऑडियो रिकॉर्डिंग/वीडियो रिकॉर्डिंग के लिए सहमत हूं।**	[ ]
(vii)	मुझे व्यक्तिगत रूप से और समझने योग्य तरीके से अध्ययन, संभावित असुविधाओं/जोखिमों और नैदानिक अध्ययन की प्रकृति, महत्व और दायरे और इस संदर्भ में मेरी जिम्मेदारियों के बारे में जानकारी दी गई है। मेरे सवालों का संतोषजनक उत्तर दिया गया है। मुझे अपना निर्णय लेने के लिए पर्याप्त समय मिला है। मैं इस नैदानिक अध्ययन के संचालन के लिए आवश्यक डॉक्टर के निर्देशों का पालन करूंगा।	[ ]

दिनांक के साथ विषय का हस्ताक्षर:

विषय का नाम : ____

हस्ताक्षर (या अंगूठे का निशान) दिनांक के साथ ____

अन्वेषक या वह व्यक्ति जिसने सूचित सहमति चर्चा आयोजित की :

मैं पुष्टि करता हूं कि मैंने व्यक्तिगत रूप से प्रकृति, उद्देश्य, अवधि, ऊपर वर्णित विषय के लिए अध्ययन के एक घनीय प्रभाव की व्याख्या की है ।

मैंने उपरोक्त शोध अध्ययन की प्रकृति को विषय के बारे में ध्यान से समझाया है। मैं इस बात को प्रमाणित करता हूं कि मेरे सर्वोत्तम ज्ञान के लिए, इस सहमति पत्र पर हस्ताक्षर करने वाला व्यक्ति भाग लेने की प्रकृति, मांगों, लाभों और जोखिमों को समझता है और यह कि उसका हस्ताक्षर मान्य है। एक चिकित्सा समस्या या भाषा या शैक्षिक बाधा ने उसकी समझ को समाप्त नहीं किया है।

अध्ययन अन्वेषक का नाम: ____

दिनांक के साथ अन्वेषक का हस्ताक्षर: ____________________________________

APPENDIX-VI

ਮਰੀਜ਼ ਜਾਣਕਾਰੀ ਸ਼ੀਟ

1. **ਪ੍ਰੋਜੈਕਟ ਦਾ ਸਿਰਲੇਖ**

ਐਂਟੀਰੀਅਰ ਕਰੂਸੀਅਟ ਲਿਗਮੈਂਟ ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਵਿੱਚ ਵਿਸਮਾਸੀ ਮਜ਼ਬੂਤੀ ਲਈ ਵੱਖਰੀ ਸਿਖਲਾਈ: ਇੱਕ ਪ੍ਰਯੋਗਾਤਮਕ ਟਰਾਇਲ

2. **ਪ੍ਰਮੁੱਖ ਜਾਂਚਕਰਤਾ ਅਤੇ ਸਹਿ-ਜਾਂਚਕਰਤਾ, ਜੇ ਕੋਈ ਹੈ ਤਾਂ ਸੰਪਰਕ ਨੰਬਰ ਅਤੇ ਸੰਗਠਨ ਦੇ ਨਾਲ:**

ਪੀਆਈ: ਸੋਮ ਗੁਪਤਾ (ਪੀਐਚਡੀ ਸਕਾਲਰ)
ਮੁਖੀ, ਫਿਜ਼ੀਓਥੈਰੇਪੀ ਵਿਭਾਗ
ਫੋਰਟਿਸ ਹਸਪਤਾਲ, ਲੁਧਿਆਣਾ
ਮੋਬਾਈਲ ਨੰਬਰ- 9815370607
ID- ਈਮੇਲ drsomgupta@yahoo.co.in

ਸਹਿ ਪੀਆਈ: ਡਾ ਰਮੇਸ਼ ਚੰਦਰ ਪਾਤਰ
ਸਹਾਇਕ ਪ੍ਰੋਫੈਸਰ
ਫਿਜ਼ੀਓਥੈਰੇਪੀ ਵਿਭਾਗ
ਲਵਲੀ ਪ੍ਰੋਫੈਸ਼ਨਲ ਯੂਨੀਵਰਸਿਟੀ
ਫਗਵਾੜਾ, ਪੰਜਾਬ
ਮੋਬਾਈਲ ਨੰਬਰ- 9653174563
ਈਮੇਲ ਆਈਡੀ- ਰਮੇਸ਼ .95900@lpu.co.in

3. **ਇਸ ਖੋਜ ਦਾ ਉਦੇਸ਼ ਕੀ ਹੈ?**

ਤੁਹਾਨੂੰ ਖੋਜ ਅਧਿਐਨ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਸੱਦਾ ਰਹੇ ਹਨ ਸਿਰਲੇਖ ਇੱਕ ਤਜਰਬੇ ਦੀ ਸੁਣਵਾਈ: anterior Cruciate ਯੋਜਕ ਉਸਾਰੀ ਸਰਜਰੀ ਵਿਚ ਖਿੱਚਿਆ ਮਜ਼ਬੂਤ Isoinertial ਸਿਖਲਾਈ **.** ਅਧਿਐਨ ਦਾ ਉਦੇਸ਼ ਮਾਸਪੇਸ਼ੀਆਂ ਦੀ ਸ਼ਕਤੀ, ਸਹਿਣਸ਼ੀਲਤਾ ਅਤੇ ਆਈਸੋਮੈਟ੍ਰਿਕ ਤਾਕਤ 'ਤੇ ਐਂਟੀਰੀਅਰ ਕਰੂਸੀਏਟ ਲਿਗਮੈਂਟ (ਏਸੀਐਲ) ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਵਾਲੇ ਰਵਾਇਤਾਂ ਵਿਚ ਰਵਾਇਤੀ ਮੁੜ ਵਸੇਬੇ ਦੇ ਢੰਗ ਦੇ ਨਾਲ ਜੋੜ ਕੇ ਆਈਸਨੋਰਟੀਅਲ ਈਸਟਰਿਕ ਓਵਰਲੋਡ ਨੂੰ ਮਜ਼ਬੂਤ ਕਰਨ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨਾ ਹੈ. ਇਸ ਤੋਂ ਇਲਾਵਾ ਸੰਤੁਲਨ, ਗੋਡੇ ਦੀ ਸੱਟ ਅਤੇ ਗਠੀਏ ਦੇ ਨਤੀਜਿਆਂ ਦੇ ਅੰਕੜੇ (ਕੇ.ਓ.ਓ.ਐੱਸ.) ਅਤੇ ਗੋਡੇ ਨਾਲ ਸਬੰਧਤ ਜੀਵਨ ਦੀ ਗੁਣਵਤਾ (ਸੀ.ਕੇ.ਆਰ.ਐੱਸ.) ਦੇ ਰੋਗੀਆਂ ਵਿਚ ਐਂਟੀਰੀਅਰ ਕਰੂਸੀਏਟ ਲਿਗਮੈਂਟ (ਏ.ਸੀ.ਐੱਲ.) ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਵਾਲੇ ਰਵਾਇਤਾਂ ਵਿਚ ਰਵਾਇਤੀ ਮੁੜ ਵਸੇਬੇ ਦੇ ਢੰਗ ਦੇ ਨਾਲ ਜੋੜ ਕੇ ਈਸੋਏਂਸੀਅਲ ਐਕਸਟਰਿਕ ਓਵਰਲੋਡ ਨੂੰ ਮਜ਼ਬੂਤ ਕਰਨ ਦੇ ਪ੍ਰਭਾਵ ਦਾ ਮੁਲਾਂਕਣ ਕਰੋ .

4. **ਖੋਜ ਵਿਚ ਕੌਣ ਹਿੱਸਾ ਲੈ ਸਕਦਾ ਹੈ?**

ਕੋਈ ਵੀ ਵਿਅਕਤੀ ਜੋ ਹੇਠਾਂ ਦਿੱਤੇ ਮਾਪਦੰਡਾਂ ਨੂੰ ਪੂਰਾ ਕਰਦਾ ਹੈ ਉਹ ਇਸ ਅਧਿਐਨ ਵਿਚ ਹਿੱਸਾ ਲੈ ਸਕਦਾ ਹੈ:

- ਪੋਸਟ ਏਸੀਐਲ ਦੇ ਪੁਨਰ ਨਿਰਮਾਣ ਵਾਲੇ ਮਰੀਜ਼, ਐਸਟੀਜੀ (ਸੇਮੀਟੈਂਡੀਨੋਸਸ ਗ੍ਰੈਸੀਲਿਸ ਗ੍ਰਾਫਟ) ਦੀ ਵਰਤੋਂ ਕਰਦਿਆਂ ਇਕੋ ਸਰਜਨ ਦੁਆਰਾ ਕੀਤੇ ਗਏ 18- 45 ਸਾਲ ਦੇ ਵਿਚਕਾਰ .
- 3 ਹਫ਼ਤੇ ਬਾਅਦ ACL ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਦੇ ਮਰੀਜ਼.

ਹਾਲਾਂਕਿ, ਜੇ ਤੁਸੀਂ ਹੇਠ ਲਿਖਿਆਂ ਨੂੰ ਪੜ੍ਹਦੇ ਹੋ ਤਾਂ ਤੁਸੀਂ ਇਸ ਅਧਿਐਨ ਵਿੱਚ ਹਿੱਸਾ ਲੈਣ ਦੇ ਯੋਗ ਨਹੀਂ ਹੋਵੋਗੇ:

- ਪਿਛਲਾ ACLR (ACL ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ) .
- ਪਿਛਲੀ ਗੋਡੇ ਦੀ ਸਰਜਰੀ .
- ਫਾਲੋ-ਅਪ ਸ਼ਰਤਾਂ ਨੂੰ ਪੂਰਾ ਕਰਨ ਵਿੱਚ ਅਸਮਰੱਥ .

5. **ਮੇਰੀ ਭਾਗੀਦਾਰੀ ਦੀ ਅਨੁਮਾਨਤ ਮਿਆਦ ਕਿੰਨੀ ਹੈ?**

ਅਧਿਐਨ ਦੀ ਅਨੁਮਾਨਤ ਮਿਆਦ 3 ਸਾਲ ਹੋਵੇਗੀ ਅਤੇ ਤੁਹਾਡੀ ਭਾਗੀਦਾਰੀ 6 ਹਫਤੇ ਲਈ ਉਮੀਦ ਕੀਤੀ ਜਾ ਸਕਦੀ ਹੈ. ਤੁਹਾਨੂੰ ਇਲਾਜ ਲਈ ਹਫ਼ਤੇ ਵਿਚ ਦੋ ਵਾਰ 6 ਹਫ਼ਤਿਆਂ ਲਈ ਬੁਲਾਇਆ ਜਾਵੇਗਾ.

6. **ਜੇ ਮੈਂ ਇਸ ਖੋਜ ਵਿੱਚ ਹਿੱਸਾ ਲੈਂਦਾ ਹਾਂ ਤਾਂ ਕੀ ਕੀਤਾ ਜਾਵੇਗਾ?**

ACL ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਤੋਂ ਬਾਅਦ ਤਿੰਨ ਹਫਤਿਆਂ ਬਾਅਦ ਤੁਸੀਂ ਅਧਿਐਨ ਵਿੱਚ ਸ਼ਾਮਲ ਹੋਵੋਗੇ. ਤੁਹਾਡੇ ਦੁਆਰਾ ਹੇਠਾਂ ਦੱਸੇ ਨਤੀਜਿਆਂ ਦੇ ਉਪਾਵਾਂ ਲਈ ਖੋਜਕਰਤਾ ਦੁਆਰਾ ਮੁਲਾਂਕਣ ਕੀਤਾ ਜਾਵੇਗਾ ;

ਮਾਸਪੇਸ਼ੀ ਦੀ ਸ਼ਕਤੀ, ਸਹਿਣਸ਼ੀਲਤਾ, ਆਈਸੋਮੈਟ੍ਰਿਕ ਤਾਕਤ, ਸੰਤੁਲਨ ਅਤੇ ਗੋਡਿਆਂ ਨਾਲ ਸਬੰਧਤ ਜੀਵਨ ਸਕੋਰ. ਫਾਲੋ ਅਪ ਅਸੈਸਮੈਂਟ / ਰੀਡਿੰਗ ਹਰ 3 ਹਫਤਿਆਂ ਬਾਅਦ ਲਈ ਜਾਵੇਗੀ.

7. **ਮੇਰੀ ਗੁਪਤਤਾ ਅਤੇ ਮੇਰੇ ਖੋਜ ਰਿਕਾਰਡਾਂ ਦੀ ਗੁਪਤਤਾ ਕਿਵੇਂ ਸੁਰੱਖਿਅਤ ਕੀਤੀ ਜਾਏਗੀ?**

ਪੀ ਦੇ ਸਿਧਾਂਤਕ ਜਾਂਚਕਰਤਾ ਦੀ ਤੁਹਾਡੀ ਪਛਾਣ ਯੋਗ ਆਈ ਨੈਰਮਿਕੇਸ਼ਨ (ਜਿਵੇਂ ਕਿ ਨਾਮ, ਸੰਪਰਕ ਜਾਣਕਾਰੀ, ਆਦਿ) ਹੈ ਅਤੇ ਇਹ ਕਿਸੇ ਹੋਰ ਵਿਅਕਤੀ ਨੂੰ ਜਾਰੀ ਨਹੀਂ ਕੀਤਾ ਜਾਏਗਾ ਅਤੇ ਇਸ ਨੂੰ ਗੁਪਤ ਰੱਖਣ ਲਈ ਵਧੇਰੇ ਦੇਖਭਾਲ ਕੀਤੀ ਜਾਵੇਗੀ. ਪਛਾਣਯੋਗ ਜਾਣਕਾਰੀ ਨੂੰ ਕਦੇ ਵੀ ਕਿਸੇ ਪ੍ਰਕਾਸ਼ਨ ਜਾਂ ਪ੍ਰੈਸ ਐਂਟੇਸ਼ਨ ਵਿੱਚ ਨਹੀਂ ਵਰਤਿਆ ਜਾਏਗਾ. ਤੁਹਾਡੀ ਸਾਰੀ ਪਛਾਣ ਯੋਗ ਸਿਹਤ ਜਾਣਕਾਰੀ ਅਤੇ ਖੋਜ ਡੇਟਾ ਖੋਜ ਦੇ ਮੁ theਲੇ ਸੰਭਵ ਪੜਾਅ 'ਤੇ ਕੋਡ ਕੀਤੇ ਜਾਣਗੇ (ਅਰਥਾਤ ਸਿਰਫ ਇਕ ਕੋਡ ਨੰਬਰ ਨਾਲ ਪਛਾਣਿਆ ਗਿਆ ਹੈ).

8. **ਭਾਗੀਦਾਰਾਂ ਲਈ ਸੰਭਾਵਿਤ ਅਸੁਵਿਧਾਵਾਂ ਅਤੇ ਜੋਖਮ ਕੀ ਹਨ?**

ਸੰਭਾਵਤ ਜੋਖਮ ਸ਼ਾਮਲ ਹੋ ਸਕਦੇ ਹਨ ਪਰ ਸੀਮਿਤ ਨਹੀਂ;

- ਕਸਰਤ ਪ੍ਰੋਗਰਾਮ ਦੌਰਾਨ ਕੁਝ ਅਭਿਆਸਾਂ ਕਾਰਨ ਮਾਸਪੇਸ਼ੀਆਂ ਦੀ ਥਕਾਵਟ
- ਮਾਸਪੇਸ਼ੀ ਜਾਂ ਜੋੜਾਂ ਦਾ ਦਰਦ, ਸਿਖਲਾਈਆਂ ਗਈਆਂ ਕਸਰਤ ਕਰਨ ਦੇ ਕਾਰਨ
- ਸੰਯੁਕਤ ਵਿਚ ਹਲਕੇ ਸੋਜ
- ਅਸੁਵਿਧਾ ਜਿਵੇਂ ਕਿ ਖੋਜ ਪ੍ਰੋਜੈਕਟ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਸਮਾਂ ਦੇਣਾ

9. **ਕੀ ਭਾਗੀਦਾਰੀ ਲਈ ਅਦਾਇਗੀ ਹੋਵੇਗੀ?**

ਨਹੀਂ

10. **ਮੇਰੇ ਅਤੇ ਹੋਰਾਂ ਲਈ ਸੰਭਾਵਤ ਲਾਭ ਕੀ ਹਨ?**

ਅਸੀਂ ਇਸ ਗੱਲ ਦੀ ਗਰੰਟੀ ਨਹੀਂ ਦੇ ਸਕਦੇ ਕਿ ਤੁਸੀਂ ਅਧਿਐਨ ਵਿਚ ਬੀ ਇੰਗ ਤੋਂ ਲਾਭ ਪ੍ਰਾਪਤ ਕਰੋਗੇ. ਹਾਲਾਂਕਿ, ਪ੍ਰੋਗਰਾਮ ਬਿਹਤਰ ਤਰੀਕੇ ਨਾਲ ਇਹ ਸਮਝਣ ਵਿਚ ਸਹਾਇਤਾ ਕਰੇਗਾ ਕਿ ਕੀ ਫਲਾਈਵ ਹੀਲ (ਡੇਸਮੋਟੇਕ) ਦੀ ਵਰਤੋਂ ਕਰਦਿਆਂ ਸੈਂਟਰਿਕ ਓਵਰਲੋਡ ਸਿਖਲਾਈ ਪੋਸਟ ਆਪਰੇਟਿਵ ਪੁਨਰਵਾਸ ਵਿਚ ਅਸਰਦਾਰ ਹੈ .

11. **ਕੀ ਮੈਂ ਇਸ ਖੋਜ ਵਿੱਚ ਹਿੱਸਾ ਲੈਣ ਤੋਂ ਇਨਕਾਰ ਕਰ ਸਕਦਾ ਹਾਂ?**

ਤੂੰ ਕਰ ਸਕਦਾ. ਇਸ ਰੀਸਾ ਆਰਚ ਵਿੱਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਤੁਹਾਡਾ ਫੈਸਲਾ ਸਵੈਇੱਛਤ ਹੈ ਅਤੇ ਪੂਰੀ ਤਰ੍ਹਾਂ ਤੁਹਾਡੇ ਤੇ ਨਿਰਭਰ ਕਰਦਾ ਹੈ. ਤੁਸੀਂ ਬਿਨਾਂ ਕਿਸੇ ਕਾਰਨ ਦੇ ਕਿਸੇ ਵੀ ਸਮੇਂ ਖੋਜ ਤੋਂ ਪਿੱਛੇ ਹਟ ਸਕਦੇ ਹੋ , ਪ੍ਰਮੁੱਖ ਜਾਂਚਕਰਤਾ ਨੂੰ ਦੱਸ ਕੇ ਅਤੇ ਇਕੱਤਰ ਕੀਤੇ ਤੁਹਾਡੇ ਸਾਰੇ ਡੇਟਾ ਨੂੰ ਰੱਦ ਕਰ ਦਿੱਤਾ ਜਾਵੇਗਾ . ਭਾਗੀਦਾਰੀ ਤੋਂ ਇਨਕਾਰ ਕਰਨ ਜਾਂ ਪਾਰਟ ਟੀਸੀ ਤੋਂ ਵਾਪਸੀ ਲੈਣ ਨਾਲ ਇਸ ਕੇਂਦਰ ਵਿਚ ਤੁਹਾਡੇ ਪੁਨਰਵਾਸ ਪ੍ਰੋਗਰਾਮ 'ਤੇ ਕੋਈ ਅਸਰ ਨਹੀਂ ਪਏਗਾ ਜਾਂ ਤੁਹਾਡੇ ਨੁਕਸਾਨ ਦੇ ਨੁਕਸਾਨ ਦਾ ਕਾਰਨ ਨਹੀਂ ਹੋਵੇਗਾ ਜਿਸ ਦੇ ਤੁਸੀਂ ਹੱਕਦਾਰ ਹੋ.

12. **ਜੇ ਮੈਨੂੰ ਕੋਈ ਪ੍ਰਸ਼ਨ ਜਾਂ ਸਮੱਸਿਆਵਾਂ ਹਨ ਤਾਂ ਮੈਨੂੰ ਕਿਸ ਨੂੰ ਕਾਲ ਕਰਨੀ ਚਾਹੀਦੀ ਹੈ?**

ਕਿਰਪਾ ਕਰਕੇ ਪ੍ਰਮੁੱਖ ਜਾਂਚਕਰਤਾ ਸੋਮ ਗੁਪਤਾ ਨਾਲ ਸੰਪਰਕ ਕਰੋ (ਐਮ- +919815370607)

APPENDIX-VII

ਕਲੀਨਿਕਲ ਸਟੱਡੀ ਵਿਚ ਭਾਗ ਲੈਣ ਲਈ ਸੂਚਿਤ ਫਾਰਮੈਟ

ਅਧਿਐਨ ਦਾ ਸਿਰਲੇਖ: ਐਂਟੀਰੀਅਰ ਕਰੂਸੀਅਟ ਲਿਗਮੈਂਟ ਪੁਨਰ ਨਿਰਮਾਣ ਸਰਜਰੀ ਵਿਚ ਵਿਸਮਾਸੀ ਮਜ਼ਬੂਤੀ ਲਈ ਅਲੱਗ ਸਿਖਲਾਈ

ਸੰਪਰਕ ਨੰਬਰ ਅਤੇ ਸੰਗਠਨ ਦੇ ਨਾਲ ਪ੍ਰਮੁੱਖ ਜਾਂਚਕਰਤਾ:

ਸ੍ਰੀ ਸੋਮ ਗੁਪਤਾ (ਪੀਐਚਡੀ ਸਕਾਲਰ),
ਮੁਖੀ, ਫਿਜ਼ੀਓਥੈਰੇਪੀ ਵਿਭਾਗ
ਫੋਰਟਿਸ ਹਸਪਤਾਲ, ਲੁਧਿਆਣਾ
ਮੋਬਾਈਲ ਨੰਬਰ- 9815370607
ID- ਈਮੇਲ drsomgupta@yahoo.co.in

ਵਿਸ਼ੇ ਦਾ ਨਾਮ: ____

ਵਿਸ਼ੇ ਦੇ ਅਰੰਭਕ : _________________________

ਜਨਮ ਮਿਤੀ / ਉਮਰ: _______________________, ਲਿੰਗ: __________________

ਵਿਸ਼ੇ ਦਾ
ਪਤਾ: ____

____

____

ਸੰਪਰਕ ਨੰਬਰ (ਹਵਾਈਅੱਡੇ) ਵਿਸ਼ੇ ਦੀ: ____

ਕਿੱਤਾ: ਵਿਦਿਆਰਥੀ / ਸਵੈ ਰੁਜ਼ਗਾਰ / ਸੇਵਾ / ਘਰੇਲੂ ਔਰਤ / ਹੋਰ (ਕਿਰਪਾ ਕਰਕੇ
ਦੱਸੋ) _________________________

(ਕਿਰਪਾ ਕਰਕੇ ਉਚਿਤ ਤੌਰ ਤੇ ਨਿਸ਼ਾਨ ਲਗਾਓ)

ਯੋਗਤਾ: ______________________________

ਕਿਰਪਾ ਕਰਕੇ ਇਸ ਸਹਿਮਤੀ ਫਾਰਮ 'ਤੇ ਦਸਤਖਤ ਕਰੋ ਤਾਂ ਹੀ ਜਦੋਂ ਤੁਹਾਨੂੰ ਪ੍ਰਸ਼ਨ ਪੁੱਛਣ ਦਾ ਮੌਕਾ ਮਿਲਿਆ ਅਤੇ ਤੁਹਾਡੇ ਸਾਰੇ ਪ੍ਰਸ਼ਨਾਂ ਦੇ ਸਵੀਕਾਰ ਯੋਗ ਜਵਾਬ ਪ੍ਰਾਪਤ ਹੋਏ. ਇਸ ਪੇਜ ਤੇ ਦਸਤਖਤ ਕਰਕੇ, ਤੁਸੀਂ ਹੇਠਾਂ ਦਿੱਤੇ ਕਥਨ ਦੀ ਪੁਸ਼ਟੀ ਕਰ ਰਹੇ ਹੋ:

ਲੜੀ ਨੰਬਰ	**ਕੋਈ ਬਿਆਨ ਨਹੀਂ**	**ਸ਼ੁਰੂਆਤੀ ਬਾਕਸ (ਵਿਸ਼ਾ)**
(i)	ਮੈਂ ਪੁਸ਼ਟੀ ਕਰਦਾ/ਕਰਦੀ ਹਾਂ ਕਿ ਮੈਂ ਉਪਰੋਕਤ ਅਧਿਐਨ ਲਈ ਜਾਣਕਾਰੀ ਨੂੰ ਪੜ੍ਹ ਅਤੇ ਸਮਝ ਲਿਆ ਹੈ ਅਤੇ ਇਸ ਬਾਰੇ ਸੋਚਣ ਦਾ ਸਮਾਂ ਅਤੇ ਸਵਾਲ ਪੁੱਛਣ ਦਾ ਮੌਕਾ ਮਿਲਿਆ ਹੈ।	[ ]
(ii)	ਮੈਂ ਸਮਝਦਾ/ਸਮਝਦੀ ਹਾਂ ਕਿ ਅਧਿਐਨ ਵਿੱਚ ਮੇਰੀ ਭਾਗੀਦਾਰੀ ਸਵੈਇੱਛਤ ਹੈ ਅਤੇ ਇਹ ਕਿ ਮੈਂ ਕਿਸੇ ਵੀ ਸਮੇਂ, ਬਿਨਾਂ ਕੋਈ ਕਾਰਨ ਦੱਸੇ, ਮੇਰੀ ਡਾਕਟਰੀ ਦੇਖਭਾਲ ਜਾਂ ਕਾਨੂੰਨੀ ਅਧਿਕਾਰਾਂ ਨੂੰ ਪ੍ਰਭਾਵਿਤ ਕੀਤੇ ਬਿਨਾਂ ਵਾਪਸ ਲੈਣ ਲਈ ਸੁਤੰਤਰ ਹਾਂ।	[ ]
(iii)	ਮੈਂ ਸਮਝਦਾ/ਸਮਝਦੀ ਹਾਂ ਕਿ ਤਫ਼ਤੀਸ਼ਕਾਰ, ਨੈਤਿਕਤਾ ਕਮੇਟੀ ਅਤੇ ਰੈਗੂਲੇਟਰੀ ਅਥਾਰਟੀਆਂ ਨੂੰ ਮੌਜੂਦਾ ਅਧਿਐਨ ਦੇ ਸਬੰਧ ਵਿੱਚ ਮੇਰੇ ਸਿਹਤ ਰਿਕਾਰਡਾਂ ਨੂੰ ਦੇਖਣ ਲਈ	[ ]

	ਮੇਰੀ ਇਜਾਜ਼ਤ ਦੀ ਲੋੜ ਨਹੀਂ ਹੋਵੇਗੀ ਅਤੇ ਇਸ ਦੇ ਸਬੰਧ ਵਿੱਚ ਕੀਤੀ ਜਾਣ ਵਾਲੀ ਕਿਸੇ ਵੀ ਹੋਰ ਖੋਜ, ਭਾਵੇਂ ਮੈਂ ਇਸ ਤੋਂ ਹਟ ਜਾਂਦਾ ਹਾਂ। ਅਧਿਐਨ ਮੈਂ ਇਸ ਪਹੁੰਚ ਲਈ ਸਹਿਮਤ ਹਾਂ। ਹਾਲਾਂਕਿ, ਮੈਂ ਸਮਝਦਾ/ਸਮਝਦੀ ਹਾਂ ਕਿ ਤੀਜੀ ਧਿਰ ਨੂੰ ਜਾਰੀ ਜਾਂ ਪ੍ਰਕਾਸ਼ਿਤ ਕੀਤੀ ਗਈ ਕਿਸੇ ਵੀ ਜਾਣਕਾਰੀ ਵਿੱਚ ਮੇਰੀ ਪਛਾਣ ਪ੍ਰਗਟ ਨਹੀਂ ਕੀਤੀ ਜਾਵੇਗੀ।	
(iv)	ਮੈਂ ਇਸ ਅਧਿਐਨ ਤੋਂ ਪੈਦਾ ਹੋਣ ਵਾਲੇ ਕਿਸੇ ਵੀ ਡੇਟਾ ਜਾਂ ਨਤੀਜਿਆਂ ਦੀ ਵਰਤੋਂ ਨੂੰ ਸੀਮਤ ਨਾ ਕਰਨ ਲਈ ਸਹਿਮਤ ਹਾਂ ਬਸ਼ਰਤੇ ਅਜਿਹੀ ਵਰਤੋਂ ਕੇਵਲ ਵਿਗਿਆਨਕ ਉਦੇਸ਼ਾਂ(ਆਂ) ਲਈ ਹੋਵੇ।	[ ]
(v)	ਮੈਂ ਉਪਰੋਕਤ ਅਧਿਐਨ ਵਿੱਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਸਹਿਮਤ ਹਾਂ।	[ ]
(vi)	ਮੈਂ ਖੋਜ ਵਿੱਚ ਆਪਣੀ ਭਾਗੀਦਾਰੀ ਦੀ ਫੋਟੋ-ਲੈਕਿੰਗ/ਆਡੀਓ-ਰਿਕਾਰਡਿੰਗ/ਵੀਡੀਓ-ਰਿਕਾਰਡਿੰਗ ਲਈ ਸਹਿਮਤ ਹਾਂ।	[ ]
(vii)	ਮੈਨੂੰ ਅਧਿਐਨ, ਸੰਭਾਵੀ ਅਸੁਵਿਧਾਵਾਂ/ਜੋਖਮਾਂ ਅਤੇ ਕਲੀਨਿਕਲ ਅਧਿਐਨ ਦੀ ਪ੍ਰਕਿਰਤੀ, ਮਹੱਤਤਾ ਅਤੇ ਦਾਇਰੇ ਬਾਰੇ ਅਤੇ ਇਸ ਸੰਦਰਭ ਵਿੱਚ ਮੇਰੀਆਂ ਜ਼ਿੰਮੇਵਾਰੀਆਂ ਬਾਰੇ ਵਿਅਕਤੀਗਤ ਤੌਰ 'ਤੇ ਅਤੇ ਸਮਝਣ ਯੋਗ ਤਰੀਕੇ ਨਾਲ ਸੂਚਿਤ ਕੀਤਾ ਗਿਆ ਹੈ। ਮੇਰੇ ਸਵਾਲਾਂ ਦਾ ਤਸੱਲੀਬਖਸ਼ ਜਵਾਬ ਦਿੱਤਾ ਗਿਆ ਹੈ। ਮੇਰੇ ਕੋਲ ਆਪਣਾ ਫੈਸਲਾ ਲੈਣ ਲਈ ਕਾਫ਼ੀ ਸਮਾਂ ਹੈ। ਮੈਂ ਇਸ ਕਲੀਨਿਕਲ ਅਧਿਐਨ ਦੇ ਸੰਚਾਲਨ ਲਈ ਡਾਕਟਰ ਦੀਆਂ ਹਦਾਇਤਾਂ ਦੀ ਪਾਲਣਾ ਕਰਾਂਗਾ।	[ ]

ਤਾਰੀਖ ਦੇ ਨਾਲ ਵਿਸ਼ਾ ਦੇ ਦਸਤਖਤ:

ਵਿਸ਼ੇ ਦਾ ਨਾਮ : ____

ਦਸਤਖਤ (ਜਾਂ ਅੰਗੂਠੇ ਦੀ ਛਾਪ) ਤਾਰੀਖ ਦੇ ਨਾਲ ਵਿਸ਼ਾ: ____

ਜਾਂਚਕਰਤਾ ਜਾਂ ਉਹ ਵਿਅਕਤੀ ਜਿਸ ਨੇ ਸੂਚਿਤ ਸਹਿਮਤੀ ਬਾਰੇ ਵਿਚਾਰ ਵਟਾਂਦਰੇ ਕੀਤੇ :

ਮੈਂ ਇਸ ਗੱਲ ਦੀ ਪੁਸ਼ਟੀ ਕਰਦਾ ਹਾਂ ਕਿ ਮੈਂ ਉਪਰੋਕਤ ਨਾਮ ਵਾਲੇ ਵਿਸ਼ੇ ਨਾਲ ਅਧਿਐਨ ਦੇ ਸੁਭਾਅ, ਉਦੇਸ਼, ਅੰਤਰਾਲ, ਅਧਿਐਨ ਦੇ ਅਨੁਮਾਨਤ ਪ੍ਰਭਾਵਾਂ ਦੀ ਨਿੱਜੀ ਤੌਰ ਤੇ ਵਿਆਖਿਆ ਕੀਤੀ ਹੈ .

ਮੈਂ ਵਿਸ਼ੇ ਨਾਲ ਉਪਰੋਕਤ ਖੋਜ ਅਧਿਐਨ ਦੀ ਪ੍ਰਕਿਰਤੀ ਨੂੰ ਧਿਆਨ ਨਾਲ ਦੱਸਿਆ ਹੈ. ਮੈਂ ਇਥੇ ਪ੍ਰਮਾਣਿਤ ਕਰਦਾ ਹਾਂ ਕਿ ਮੇਰੇ ਸਭ ਤੋਂ ਉੱਤਮ ਗਿਆਨ ਲਈ, ਇਸ ਸਹਿਮਤੀ ਫਾਰਮ ਤੇ ਹਸਤਾਖਰ ਕਰਨ ਵਾਲਾ ਵਿਅਕਤੀ ਭਾਗ ਲੈਣ ਦੇ ਸੁਭਾਅ, ਮੰਗਾਂ, ਲਾਭਾਂ ਅਤੇ ਜੋਖਮਾਂ ਨੂੰ ਸਮਝਦਾ ਹੈ ਅਤੇ ਉਸਦੀ ਦਸਤਖਤ ਯੋਗ ਹਨ. ਇੱਕ ਮੈਡੀਕਲ ਸਮੱਸਿਆ ਜਾਂ ਭਾਸ਼ਾ ਜਾਂ ਵਿਦਿਅਕ ਰੁਕਾਵਟ ਨੇ ਉਸਦੀ ਸਮਝ ਨੂੰ ਬੰਦ ਨਹੀਂ ਕੀਤਾ.

ਅਧਿਐਨ ਜਾਂਚਕਰਤਾ ਦਾ ਨਾਮ: ____

ਮਿਤੀ ਦੇ ਨਾਲ ਜਾਂਚਕਰਤਾ ਦੇ ਦਸਤਖਤ: ___________________________________

APPENDIX-VIII

DATA COLLECTION FORM

Group______________ Date of Enrolment______________________ Serial No. ___________

Name____ Age__________ Gender_____________

		Pre Intervention	Post Intervention
Power (W)	Concentric (W)		
	Eccentric (W)		
Isometric (Kg)			
Endurance (Sec)			
Balance (%)			
KOOS			
CKRS			
OKS			

KNEE INJURY AND OSTEOARTHRITIS OUTCOME SCORE (KOOS)

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is a questionnaire designed to assess short and long-term patient-relevant outcomes following knee injury. The KOOS is self-administered and assesses five outcomes: pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. The KOOS meets basic criteria of outcome measures and can be used to evaluate the course of knee injury and treatment outcome. KOOS is patient-administered, the format is user-friendly and it takes about 10 minutes to fill out.

Scoring instructions

The KOOS's five patient-relevant dimensions are scored separately: Pain (nine items); Symptoms (seven items); ADL Function (17 items); Sport and Recreation Function (five items); Quality of Life (four items). A Likert scale is used and all items have five possible answer options scored from 0 (No problems) to 4 (Extreme problems) and each of the five scores is calculated as the sum of the items included.

Interpretation of scores

Scores are transformed to a 0–100 scale, with zero representing extreme knee problems and 100 representing no knee problems as common in orthopaedic scales and generic measures. Scores between 0 and 100 represent the percentage of total possible score achieved.

Patient's Name: .... **Date: ....**

Pain

P1 How often is your knee painful?	Never	Monthly	Weekly	Daily	Always

What degree of pain have you experienced the last week when…?

P2 Twisting/pivoting on your knee	None	Mild	Moderate	Severe	Extreme
P3 Straightening knee fully	None	Mild	Moderate	Severe	Extreme
P4 Bending knee fully	None	Mild	Moderate	Severe	Extreme
P5 Walking on flat surface	None	Mild	Moderate	Severe	Extreme
P6 Going up or down stairs	None	Mild	Moderate	Severe	Extreme
P7 At night while in bed	None	Mild	Moderate	Severe	Extreme
P8 Sitting or lying	None	Mild	Moderate	Severe	Extreme
P9 Standing upright	None	Mild	Moderate	Severe	Extreme

Symptoms

Sy1 How severe is your knee stiffness after first wakening in the morning?	None	Mild	Moderate	Severe	Extreme
Sy2 How severe is your knee stiffness after sitting, lying, or resting later in the day?	None	Mild	Moderate	Severe	Extreme
Sy3 Do you have swelling in your knee?	Never	Rarely	Sometimes	Often	Always
Sy4 Do you feel grinding, hear clicking or any other type of noise when your knee moves?	Never	Rarely	Sometimes	Often	Always
Sy5 Does your knee catch or hang up when moving?	Never	Rarely	Sometimes	Often	Always
Sy6 Can you straighten your knee fully?	Always	Often	Sometimes	Rarely	Never
Sy7 Can you bend your knee fully?	Always	Often	Sometimes	Rarely	Never

Activities of daily living

What difficulty have you experienced the last week…?

A1 Descending	None	Mild	Moderate	Severe	Extreme
A2 Ascending stairs	None	Mild	Moderate	Severe	Extreme
A3 Rising from sitting	None	Mild	Moderate	Severe	Extreme
A4 Standing	None	Mild	Moderate	Severe	Extreme

A5 Bending to floor/picking up an object	None	Mild	Moderate	Severe	Extreme
A6 Walking on flat surface	None	Mild	Moderate	Severe	Extreme
A7 Getting in/out of car	None	Mild	Moderate	Severe	Extreme
A8 Going shopping	None	Mild	Moderate	Severe	Extreme
A9 Putting on socks/stockings	None	Mild	Moderate	Severe	Extreme
A10 Rising from bed	None	Mild	Moderate	Severe	Extreme
A11 Taking off socks/stockings	None	Mild	Moderate	Severe	Extreme
A12 Lying in bed (turning over, maintaining knee position)	None	Mild	Moderate	Severe	Extreme
A13 Getting in/out of bath	None	Mild	Moderate	Severe	Extreme
A14 Sitting	None	Mild	Moderate	Severe	Extreme
A15 Getting on/off toilet	None	Mild	Moderate	Severe	Extreme
A16 Heavy domestic duties (shovelling, scrubbing floors, etc)	None	Mild	Moderate	Severe	Extreme
A17 Light domestic duties (cooking, dusting, etc)	None	Mild	Moderate	Severe	Extreme

Sport and recreation function

What difficulty have you experienced the last week…?

Sp1 Squatting	None	Mild	Moderate	Severe	Extreme
Sp2 Running	None	Mild	Moderate	Severe	Extreme
Sp3 Jumping	None	Mild	Moderate	Severe	Extreme
Sp4 Turning/twisting on your injured knee	None	Mild	Moderate	Severe	Extreme
Sp5 Kneeling	None	Mild	Moderate	Severe	Extreme

Knee-related quality of life

Q1 How often are you aware of your knee problems?	Never	Monthly	Weekly	Daily	Always
Q2 Have you modified your lifestyle to avoid potentially damaging activities to your knee?	Not at all	Mildly	Moderately	Severely	Totally
Q3 How troubled are you with lack of confidence in your knee?	Not at all	Mildly	Moderately	Severely	Totally
Q4 In general, how much difficulty do you have with your knee?	None	Mild	Moderate	Severe	Extreme

KOOS Score : ....

MODIFIED CINCINNATI KNEE RATING SYSTEM (CKRS)

Patient's Name: .... **Date: ....**

Pain	
20	No pain, normal knee, performs 100%.
16	Occasional pain with strenuous sports or heavy work, knee not entirely normal, some limitations but minor and tolerable.
12	Occasional pain with light recreational sports or moderate work activities, running or, heavy labour, strenuous sports.
8	Pain, usually brought on by sports, light recreational activities or moderate work. Occasionally occurs with walking, standing or light work.
4	Pain is a significant problem with simple activity such as walking, relieved by rest, unable to do sports.
0	Pain present all the time. Not relieved by rest.
Swelling	
10	No swelling
8	Occasional swelling with strenuous sports or heavy work. Some limitations but minor and tolerable.
6	Occasional swelling with light recreational sports or moderate work activities. Frequently brought on by vigorous activities, running, heavy labour, and strenuous sport.
4	Swelling limits sports and moderate work. Occurs infrequently with simple walking activities or light work (approx 3 times a year)
2	Swelling brought on by simple walking activities and light work. Relieved by rest.
0	Severe problem all the time, with simple walking activities.
Giving Way	
20	No giving way.
16	Occasional giving way with strenuous sports or heavy work. Can participate in all sports but some guarding or limitations present.
12	Occasional giving way with light sports or moderate work. Able to compensate but limits vigorous activities, sports, or heavy work not able to cut or twist suddenly.
8	Giving way limits sports and moderate work, occurs infrequently with walking or light work (approx 3 times year)
4	Giving way with simple walking activities and light work. Occurs once per month, requires guarding
0	Severe problem with simple walking activities, cannot turn or twist while walking without giving way

Overall activity level	
20	No limitation, normal knee, able to do everything including strenuous sports or heavy labour
16	Perform sports including vigorous activities but at a lower performance level: involves guarding or some limits to heavy labour
12	Light recreational activities possible with rare symptoms, more strenuous activities cause problems. Active but in different sports; limited to moderate work
8	No sports or recreational activities possible. Walking with rare symptoms; limited to light work.
4	Walking, ADL cause moderate symptoms, frequent limitations.
0	Walking, ADL cause severe problems, persistent symptoms.
Walking	
10	Walking unlimited.
8	Slight/mild problem
6	Moderate problem: smooth surface possible up to approx 800m
0	Severe problem, only 2-3 blocks possible
1	2 Severe problem; requires stick or crutches
Stairs	
10	Normal, unlimited
8	Slight/mild problem
6	Moderate problems only 10-15 steps possible
4	Severe problem; requires banister support
2	Severe problem on 1-5 steps possible
Running Activity	
5	Normal, unlimited; fully competitive, strenuous
4	Slight mild problem; run half speed
3	Moderate problem 2-4 km
2	Severe problem only 1-2 blocks possible
1	Severe problem only a few steps
Jumping or Twisting Activity	
5	Normal, unlimited, fully competitive, strenuous
4	Slight to mild problem; some guarding but sport possible
3	Moderate problem; gave up strenuous sports, recreational sports possible
2	Severe problem; affects all sports; must constantly guard
1	Severe problem; only light activity possible (golf, swimming)

CKRS Score : ....

This is a rating scale which again asks you about your knee. Please circle the statement which best applies to you

Functional Rating Score	
0	No Pain
1	Slight pain after vigorous activity, sport/work/activities of daily living NOT affected
2	Mild pain after limited activity, sport/work activities of daily living ARE affected
3	Moderate pain after limited activity, sport/work/activities of daily living ARE affected
4	Severe pain with activity or rest pain

GRADING

<30 Poor 30-54 Fair 55-79 Good >80 Excellent

OXFORD KNEE SCORE

Patient's name ....……...…. **Date ....**

Please answer the following 12 multiple choice questions.
During the past 4 weeks …….

1.	How would you describe the pain you usually have in your knee ? ☐ None ☐ Very mild ☐ Mild ☐ Severe	7.	Could you kneel down and get up again afterwards? ☐ Yes, easily ☐ With little difficulty ☐ With extreme difficulty ☐ No, Impossible
2.	Have you had any trouble washing and drying yourself (all over) because of your knee ? ☐ No trouble at all ☐ Very little trouble ☐ Moderate trouble ☐ Extreme difficulty ☐ Impossible to do	8.	Are you troubled by pain in your knee at night in bed? ☐ Not at all ☐ Only one or two nights ☐ Some nights ☐ Most nights ☐ Every night
3.	Have you had any trouble getting in and out of the car or using public transport because of your knee ? (With or without a stick) ☐ No trouble at all ☐ Very little trouble ☐ Moderate trouble ☐ Extreme difficulty ☐ Impossible to do	9.	How much has pain from your knee interfered with your usual work? (including housework) ☐ Not at all ☐ A little bit ☐ Moderately ☐ Greatly ☐ Totally
4.	For how long are you able to walk before the pain in your knee becomes eve re ? (with or without a stick) ☐ No pain ? 60 min ☐ 16 – 60 minutes ☐ 5 – 15 minutes ☐ Around the house only ☐ Not at all – severe on walking	10.	Have you felt that your knee might suddenly give away or let you down ? ☐ Rarely / Never ☐ Sometimes or just at first ☐ Often, not at first ☐ Most of the time ☐ All the time
5.	After a meal (sat at a table), how painful has it been for you to stand up from a chair because of your knee ? ☐ Not at all painful ☐ Slightly painful ☐ Moderately pain ☐ Very painful ☐ Unbearable	11.	Could you do household shopping on your own ? ☐ Yes, easily ☐ With little difficulty ☐ With moderate difficulty ☐ With extreme difficulty ☐ No, impossible
6.	Have you been limping when walking, because of your knee ? ☐ Rarely / never ☐ Sometimes or just at first ☐ Often, not just at first ☐ Most of the time ☐ All of the time	12.	Could you walk down a flight of stairs ? ☐ Yes, easily ☐ With little difficulty ☐ With moderate difficulty ☐ With extreme difficulty ☐ No, impossible

Oxford Knee Score : ....

Grading for the Oxford Knee Score

Score 0 to 19	May indicate severe knee arthritis : It is highly likely that you may well require some form of surgical intervention, contact your family physician for a consult with an Orthopaedic Surgeon.
Score 20 to 29	May indicate moderate to severe knee arthritis. See your family physician for an assessment and x-ray. Consider a consult with an Orthopaedic Surgeon.
Score 30 to 39	May indicate mild to moderate knee arthritis. Consider seeing your family physician for an assessment and possible x-ray. You may benefit from non-surgical treatment, such as exercise, weight loss, and for anti-inflammatory medication.
Score 40 to 48	May indicate satisfactory joint function. May not require any formal treatment

APPENDIX – IX

INSTITUTIONAL EHICS COMMITTEE

Lovely Professional University, Punjab

Ph.: +91-1824-444039, Email : ao_pharma.lit@lpu.co.in

<table>
<tr>
<td>Chairperson :
Dr. H.S. Gill

Deputy Chairman :
Dr. Monica Gulati

Members :
Dr. Shivani Tandon
Dr. Naresh Kundra
Dr. N. K. Gupta
Dr. Meenu Chopra
Mr. Dharminder Singh Dhillon
Dr. Sasmita Kaur
Sardar angina Singh

Member Secretary :
Dr. Navneet Khurana</td>
<td>LPU/IEC/2021/01/21
Date : 17.03. 21

To

Som Gupta
School of Physiotherapy,
Lovely Professional University (Punjab)

Dear Sir / Madam,

The Ethics committee has studies the research proposal submitted by Som Gupta on research topic “Isoinertial training for eccentric strengthening in anterior cruciate ligament reconstruction surgeries : an experimental trial”.

It has been decided to accord approval to this study protocol.

Thanking you,

Your sincerely

(Member Secretary)</td>
</tr>
</table>

Trials

RESEARCH Open Access

Effects of isoinertial training on muscle power, endurance, isometric strength, and balance: randomized clinical trial in patients with post-ACL reconstruction

Ramesh Chandra Patra[1*†], Som Gupta[1†], A. Yashudas[1] and Sanjeev Mahajan[2]

Abstract

Background ACL reconstruction surgery leads to temporary limitations in knee movement due to weakness in the quadriceps, swelling, and stiffness. Effective therapy is necessary to regain strength and functionality. While flywheel resistance training enhances strength and eccentric loading, there is limited knowledge about its effectiveness in conjunction with conventional rehabilitation methods. This study evaluates the impact of both conventional rehabilitation and isoinertial therapy on muscle power, endurance, isometric strength, and balance in patients following ACL repair.

Methods A total of 96 out of 136 patients aged 18 to 45 who had been randomly assigned to groups were included 3 weeks post-procedure. Over 6 weeks, 47 patients in group A (n = 47) participated in both isoinertial training and conventional therapy protocals while in group B ($n=49$) followed a conventional rehabilitation protocol for just 30 min daily. To assess the patients' muscle power, endurance, isometric strength, and balance, a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy) was utilized both before and after the 6-week treatment period.

Results Group A had statistically significant increases in eccentric muscular power ($p=0.0001$), whereas there was no noticeable difference between the two groups in isometric strength, balance, or concentric power ($p=0.731$, $p=0.786$, and $p=0.815$, respectively).

Conclusion The finding indicates that isometric strength, balance, and both concentric and eccentric muscular power were successfully improved by both 6-week interventions: traditional rehabilitation alone and in conjunction with isoinertial training. But when compared to traditional therapy alone, the isoinertial training group showed better gains in muscular endurance. There were no discernible variations in the groups' isometric strength or balance results. The study also emphasizes how isoinertial training can effectively increase eccentric power.

Trial registration.

The ethics approval number is LPU/IEC/2018/01/09. Registered in the Clinical Trials Registry of India under CTRI/2019/06/019858 dated 23/09/2021.

Keywords ACL reconstruction, Isoinertial training, Conventional rehabilitation, Muscle power

†Ramesh Chandra Patra and Som Gupta are co-first authors.

*Correspondence:
Ramesh Chandra Patra
rameshpatra2208@gmail.com
Full list of author information is available at the end of the article

Background

The knee is one of the most injured joints in the human body. Participating in sport greatly increases the risk of injury to the knee. In recent studies, 40% of all ligamentous injuries to the knee are caused by anterior cruciate ligament (ACL) injuries, with 70% of ACL injuries occurring during athletic activity.[1] ACL injuries are widespread in many sports, including football, basketball, skiing, netball, volleyball, and rugby, because these sports involve jumping, cutting, and decelerating, which are the top causes of ACL injuries.[2] An ACL damage raises the risk of further injuries by causing recurring periods of instability at the knee joint. However, ACL rupture is no longer seen as a career-threatening injury due to advancements in surgery and rehabilitation. Study shows 89% of professional football players resume their prior level of play following a knee injury.[3, 4]

The assessment of ACL surgery, outcomes, and rehabilitation has been explored extensively in various studies over the years.[5] Research indicates that the main focal points are injury prevention and perturbation training. After undergoing ACL surgery, rehabilitation commonly incorporates perturbation training, which may consist of dynamic proprioceptive exercises and activities tailored to specific sports, aiming to lower the chance of recurrence and possibly tackle the fundamental reason for the injury.[6, 7]

Rehabilitation following ACL replacement is continuing to advance rapidly. A review of recent research indicates that functional knee bracing and perturbation training programs are advantageous in rehabilitation programs that occur prior to, during, and after surgery. The necessity for a criteria-based approach to progress through the final stages of ACL reconstruction rehabilitation, as well as the return to sports, is also highlighted.[8] Eccentric overload exercise has been shown in numerous studies to be highly beneficial for rehabilitation after ACL repair surgery.[9]

Isoinertial training is a "newly developed technique that is becoming very popular worldwide for patient rehabilitation." The isoinertial modality provides an additional eccentric load. Originally, flywheel-based isoinertial training was designed to maintain the health of astronauts' muscles while in space.[10] Instead of relying on gravity-dependent weights, it utilizes isoinertial technology, which facilitates maximal concentric and eccentric muscle activities through brief periods of eccentric overload.[11] Research has shown that flywheel resistance training increases eccentric muscle loads and boosts strength. [12] In healthy individuals, isoinertial exercise leads to greater peripheral neuronal adaptations and muscle growth compared to weight-loaded resistance training, likely due to the added eccentric overload.[13]

Numerous rehabilitation techniques have been shown to effectively support patients recovering from anterior cruciate ligament reconstruction surgery, as indicated by previous research studies. Isoinertial concentric-eccentric maximum exercise has been identified as a viable therapeutic approach within various post-surgical rehabilitation protocols since it does not lead to significant muscle damage or clinically relevant delayed onset muscular soreness (DOMS). However, for optimal outcomes, this treatment approach should not be used in isolation. There is a scarcity of case studies exploring the combined effects of isoinertial training for eccentric strengthening in the context of ACL repair procedures. Therefore, the objective of this study is to investigate how postoperative patients who have undergone ACL reconstruction surgery perform concerning muscle power, endurance, isometric strength, and balance when they participate in an isoinertial training regimen in combination with a traditional rehabilitation program or solely follow the conventional rehabilitation protocol.

Methodology

The study used an interventional experimental design in accordance with CONSORT (Consolidated Standards of Reporting Trials) guidelines as part of a randomized controlled trial to evaluate the effectiveness of isoinertial eccentric overload strengthening in addition to conventional rehabilitation techniques in patients having ACL reconstruction surgery. From July 2020 to September 2023, Fortis Hospital in Ludhiana, Punjab, India, served as the site of the study. Clinicaltrials.gov registered the study (CTRI/2021/09/036933) and the Institutional Human Ethical Committee granted ethical approval. Written and verbal agreement was obtained from each patient, and the Indian Medical Research Council's Good Clinical Practice and the World Medical Association's 2013 Declaration of Helsinki's ethical guidelines were closely adhered to.

The sample size of 95 patients was determined by predicting a minimum of 82 participants using a two-tailed test, $\alpha = 0.05$, power $(1 - \beta) = 0.80$, and effect size = 0.25, using G*Power 3.1 software. We also expanded the sample size to 96 to accommodate for a 15% dropout rate. Patients were randomly divided into two groups, group A and group B. A lottery approach was used for randomization, where an impartial administrator who was not participating in the trial drew sealed opaque envelopes. All the time, allocation concealment was kept intact. The Consolidated Standards of Reporting Trials (CONSORT) is shown in Fig. 1.

Group A received both isoinertial strengthening and the conventional rehabilitation treatment, whereas Group B received only the conventional rehabilitation

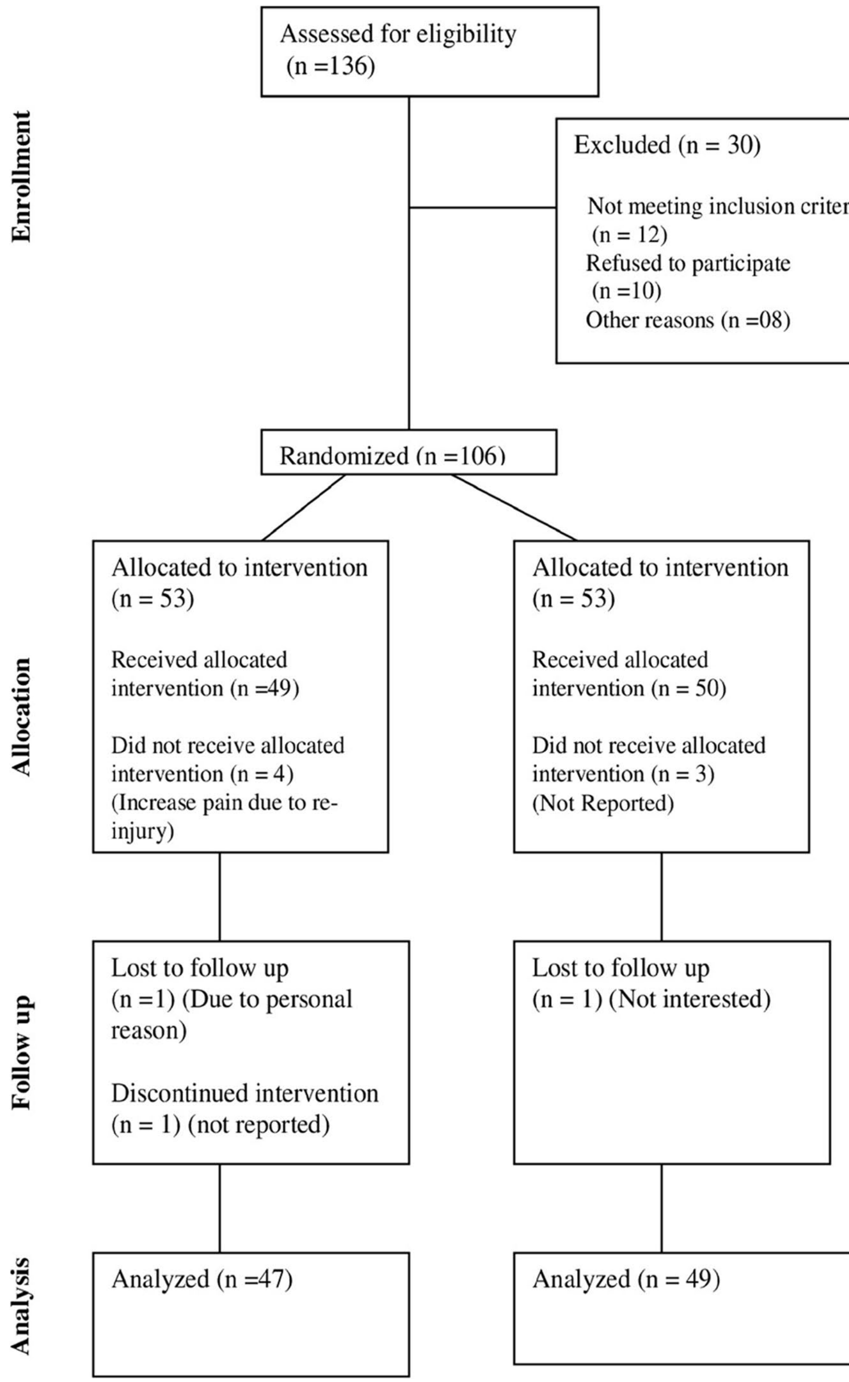


Fig. 1 CONSORT diagram showing the flow of participants through each stage of a randomized trial

protocol. Patients between the ages of 18 and 45 who had undergone ACL reconstruction surgery 3 weeks prior and who had been treated by the same surgeon with a semi-tendinosis gracilis graft were eligible. Patients who had previously undergone ACL reconstruction surgery, had previously undergone knee surgery, refused to sign the consent form, had physical limitations that affected their gait or lower limb activity, were unable to perform isoinertial training, or did not understand English, Hindi, or Punjabi were excluded.

One hundred thirty-six patients at Fortis Hospital who had ACL reconstruction surgery were screened for the study; 96 of them satisfied the selection requirements. Group assignment was concealed from outcome assessors. Because of the nature of the intervention, therapists who provided treatment were not included in outcome assessments but could not be blinded. Using a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy), the muscle power, endurance, isometric strength, and balance of each patient were evaluated. Assessments were performed at baseline and following the intervention period, which lasted 6 weeks for 60 min in group A and 30 min in group B, respectively.

Flywheel ergometer (D11 Plus; Desmotec, Biella, Italy): Peak force was measured using an isoinertial device (D11 full, Desmotec, Biella, Italy) to conduct the lower extremity isometric strength test (ISOMET). A strap that had one end fastened to the gadget and the other to the participant's vest served as the link between the two. To prevent the respondent from moving up, the strap was tightened. Two contact panels of the Desmotec device are linked to a computer running the software (D. Soft, Desmotec, Biella, Italy). The participant places his hands on his hips while standing in a semi-squat stance with his flexion at a 100-degree angle. The subject applies pressure to the plates for 10 s at the sign, which is the maximum voluntary isometric contraction. The participant's force is measured by the contact panels and recorded on the computer. Thus, isometric strength and endurance were evaluated along with eccentric and concentric muscular power. For 10 s, the patient stands on the platform with loaded plates in a semi-squat position with his hands on his hips and flexion at a 100-degree angle. Any deviation from the zero on either the left or right side is noted, and the percentage of deviation is thus tracked.[14]

Interventions

Group A

The experimental group consisted of 47 subjects who received an additional 30-min isoinertial strengthening protocol twice a week for 6 weeks. This was done in addition to the conventional rehabilitation protocol (Table 1), which was given every day for 6 weeks until phase 2 and a half. The treatment was given for 30 min every day, 6 days a week.[15]

This protocol used a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy) to assess maximal power peak, muscle endurance, balance shift, total work done, and maximal isometric force. Using a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy), a half-squat exercise was used to accomplish eccentric overload training. The regimen of lunges and squats on the flywheel ergometer's pressure plate platform in three sets of ten repetitions each, done twice a week, with a 1-min passive recovery period in between (see Fig. 2). An investigator qualitatively assessed each repetition, providing the individuals with kinematic feedback and strongly motivating them to execute to the best of their abilities within the intended power zone. The patients were told to control the eccentric phase until the knee reached about 90° of flexion and then execute the concentric phase as quickly as possible. During EOL exercise, each patient will be given the cumulative load listed below: Two disks were identified: one large (diameter 0.285 m; mass 1.9 kg; inertia 0.02 kg·m^2) and one medium (diameter 0.240 m; mass 1.1 kg; inertia 0.008 kg·m^2). The ergometer's (D11 Plus) calculated inertia is 0.0011 kg·m^2 (refer Table 1).[16]

Group B

Forty-nine patients in group **B** received conventional rehabilitation protocol for a total of 6 weeks, 30 min a day, 6 days a week, until week 6 of phase 2 and a half.[15] Table 1 provides information on the interventional program, shown in Fig. 3.

Statistical analysis

The SPSS software was used to analyze the data. The independent *t*-test was used to compare the baseline characteristics of the groups. The effects of the interventions within the groups were evaluated using Student's *t*-test for all outcome measures. The 95% CI was computed with alpha set at 0.05. The independent *t*-test was used to determine whether a significant difference was found.

Results

The mean age (years) of the patients in groups A and B of this study was 29.94 ± 6.78 and 30.20 ± 7.45, respectively ($p = 0.832$), suggesting that there is no discernible age difference between the groups (see Table 2). The baseline values of muscle power, endurance, isometric strength, and balance, together with the patients' demographic characteristics (age, height, and weight), were compared and found to be statistically non-significantly different.

cm centimeter, *kg* kilogram, *M* male, *F* female, X^2 chi-square.

Table 3 explains how postoperative patients who had ACL repair surgery compared their mean values for muscle power, endurance, isometric strength, and balance before and after the intervention within the two groups. The findings of the analysis indicated that both groups A and B had statistically improved muscle power (both concentric and eccentric), isometric strength, and balance ($p < 0.05$). In contrast, there was no statistically significant difference in muscle endurance between group B at two separate intervals (0 week and 6th week) at $p > 0.05$, as shown in Fig. 4.

Table 1 Description of conventional rehabilitation protocol

Phases in weeks	Criteria for progression	Details of the protocol
Phase 1 Week 1	–	• Control of pain and inflammation (i.e., through cryotherapy and exercises) • Obtain ROM of 0–90*, emphasizing achievement of full extension (i.e., through CPM and exercises: patellar mobilization in all directions, heel slides and leg elevation with a pillow under the heel) • Regain muscle control, with safe isometric and isotonic OC (ROM 90*–40*) and CC (ROM 0*–60*) strength exercises without additional weight (i.e., SLR, mini squads, shifting body weight) • Improve gait pattern. If pain is tolerated, aim at walking without crutches from day 4. Sufficient neuromuscular control and a non-limping gait pattern are criteria for walking without crutches
Phase 2 Week 2 to week 9	• Pain knee is equal to previous week or less (VAS-score pain) • Minimal swelling (measurement with measuring tape) • Full extension and 90 flexion are possible (ROM goniometer) • Good patellar mobility compared with contralateral side • Sufficient quadriceps control to perform a mini squad 0–30 and SLR in multiple directions • Ability to walk independently with or without crutches	• Apply cryotherapy in case of pain or swelling (if necessary, after each therapy session) • Work toward full ROM (maintain full extension, 120* flexion from week 2 and 130* flexion from week 5) with remaining attention for good patellar mobility • Walking without crutches from day 4 to 10. Normalize gait pattern with walking exercises (treadmill from week 3 and jogging in a straight line from week 8) • Isometric and isotonic strength training increasing in intensity (quadriceps, hamstring, gastrocnemius, and soleus), with increasing ROM for OC and CC exercises without extra weight. For OC exercises: weeks 2, 3, and 4 from 90* to 40*, afterward 10* toward extension to be added every week. For CC exercises: weeks 2–7 from 0* to 60* and from week 8 from 0* to 90* • Start neuromuscular training by slowly increasing from static stability to dynamic stability. Work toward confidence on the vestibular and somatosensory system for balance, with increasing surface instability and decreasing visual input • Start from week 3 with cycling on an ergometer and swimming • Start from week 4 with stepping on a stair-stepping machine • Start from week 8 with outdoor cycling Caution: act adequately in case of persisting pain, inflammation, or limited ROM. There is a risk of developing arthrofibrosis (in case of doubt consult the orthopedic surgeon)
Phase 3 Week 9 to week 16	• Minimal pain and swelling (VAS-score pain, measurement of knee swelling with measuring tape) • Full extension and at least 130* flexion possible (ROM goniometer) • Normal gait pattern • Exercises of previous week are carried out properly • Administer the IKDC questionnaire	• Obtaining and maintaining full ROM • Optimizing muscle strength and endurance. Add increasing weights from week 9 both for OC and CC exercises • Neuromuscular training with increasing emphasis on dynamic stability and plyometric exercises, slowly increasing duration and speed. Start with two-legged jumping and work slowly toward one-legged jumping. Normalize running with outdoor jogging from week 13
Phase 4 Week 16 to week 22	• No pain or swelling in the knee (VAS-score pain, measuring knee swelling with measuring tape) • Full flexion and extension of the knee (ROM goniometer) • Administer the IKDC questionnaire again • Quadriceps and hamstring strength > 75% compared to the contralateral side. Difference in hamstring/quadriceps strength ratio is < 15% compared to the contralateral side (optional isokinetic strength testing of knee flexors and extensors at 180 per second) • Hop tests > 75% compared to the contralateral side • Exercises of previous week are carried out properly	• Maximizing muscle endurance and strength • Maximizing neuromuscular control with emphasis on jumping, agility training, and sport-specific tasks. Variations in running, turning, and cutting maneuvers are allowed. Duration and speed to be increased and maximized

Table 1 (continued)

Phases in weeks	Criteria for progression	Details of the protocol
–	Criteria for returning to sports • No pain or swelling (VAS-score pain, measuring knee swelling with measurement tape) • Full flexion and extension of the knee is possible (ROM goniometer) • Quadriceps and hamstring strength > 85% compared to the contralateral side. Difference in hamstring/quadriceps strength ratio is < 15% compared to the contralateral side (optional isokinetic strength testing of knee flexors and extensors at 60*, 180*, and 300* per second and an endurance test at 180* per second) • Hop tests > 85% compared to the contralateral side • Exercises of previous week are carried out properly, and the patient tolerates sport-specific activities and agility training with maximal duration and speed • Administer the IKDC questionnaire again	Exercises of previous week are carried out properly, and the patient tolerates sport-specific activities and agility training with maximal duration and speed

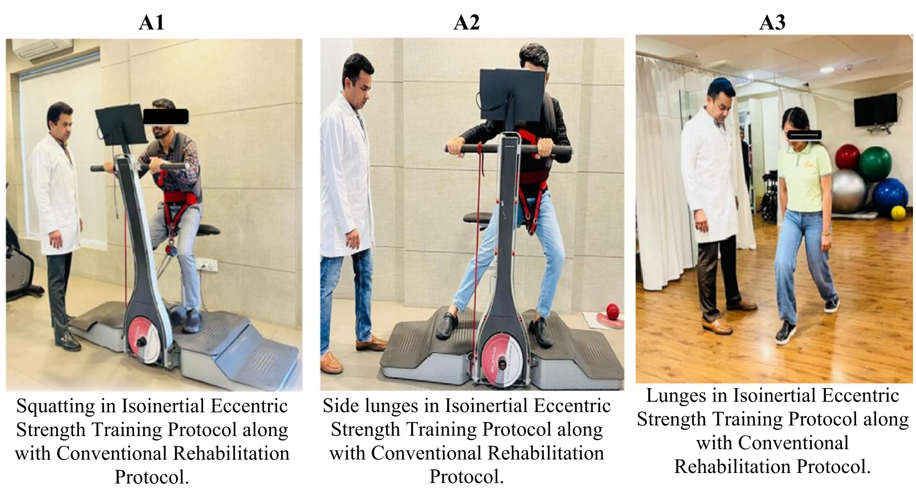


Fig. 2 Group **A** on regimen on the flywheel ergometer with conventional rehabilitation protocol (A1 to A3)

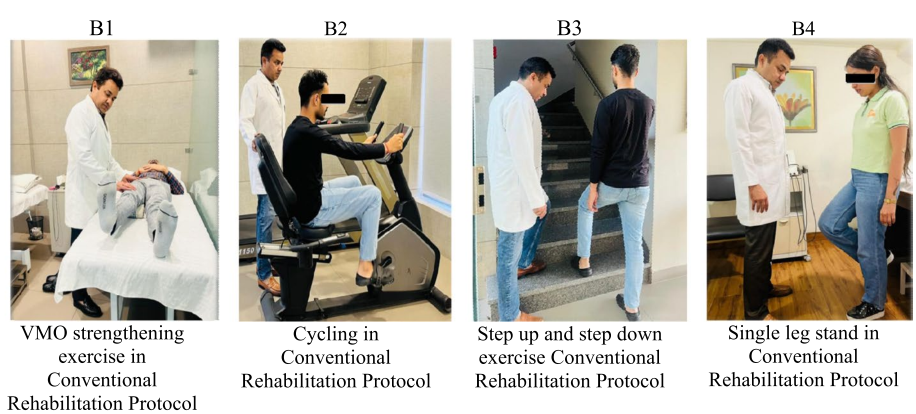


Fig. 3 Group B on conventional rehabilitation protocol (**B1** to **B4**)

Table 2 The demographic characteristics of age, height, weight, and gender

Parameter	Group A (n = 47)	Group B (n = 49)	*t* value	*p* value
Age (years)	29.94 ± 6.78	30.20 ± 7.45	− 0.179	0.858
Height (cm)	170.65 ± 4.63	172.13 ± 5.54	− 1.423	0.158
Weight (kg)	78.28 ± 9.94	77.84 ± 10.44	0.212	0.833
Gender (M/F)	36 M/11 F	39 M/10 F	X^2 = 0.145	0.703

Furthermore, there was no statistically significant difference between groups A and B ($p > 0.05$) based on the study of the improvement of mean values of muscle power (concentric), isometric strength, and balance (refer Table 4). The improvement of the mean value of muscle power (eccentric) in group A, however, showed a statistically significant difference ($p < 0.0001$).

W watt, *kg* kilogram, *s* seconds.

Note: Statistical tests: The independent *t*-test was used for comparisons between groups, while the paired *t*-test was used for comparisons within groups.

W watt, *kg* kilogram, *S.D* standard deviation.

Discussion

In this research, patients who underwent ACL reconstruction surgery were monitored for 6 weeks to assess the effects of combining an isoinertial training program with a conventional rehabilitation program compared to a conventional rehabilitation program alone on muscle power, endurance, isometric strength, and balance. While the group that followed the isoinertial training alongside conventional rehabilitation showed improvements in endurance, no such advancements were noted in the group that received only the conventional rehabilitation. Both patient groups those who engaged in isoinertial

Table 3 Comparison of mean values of muscle power, endurance, isometric strength, and balance before and after the intervention within the two groups

Parameters	Group A (experimental group)				Group B (control group)			
	Week 0 Mean ± S.D	Week 6 Mean ± S.D	*t* value	*p* value	Week 0 Mean ± S.D	Week 6 Mean ± S.D	*t* value	*p* value
Muscle power concentric (W)	79.00 ± 19.35	173.53 ± 49.91	16.42	< 0.0001*	80.61 ± 25.78	172.51 ± 50.32	18.109	< 0.0001*
Muscle power eccentric (W)	68.19 ± 15.37	178.40 ± 41.96	25.88	< 0.0001*	89.20 ± 18.57	163.10 ± 36.11	24.780	< 0.0001*
Endurance (s)	10.98 ± 3.28	14.85 ± 3.87	9.499	< 0.0001*	11.10 ± 2.39	11.65 ± 2.26	1.826	0.0740
Isometric strength (kg)	166.70 ± 33.15	216.33 ± 36.6	7.210	< 0.0001*	161.30 ± 41.08	211.93 ± 42.71	22.630	< 0.0001*
Balance (%)	6.54 ± 2.71	3.23 ± 2.10	7.313	< 0.0001*	7.16 ± 2.08	4.00 ± 2.50	7.210	< 0.0001*

*Significant (*p* value < 0.05 considered statistically significant)

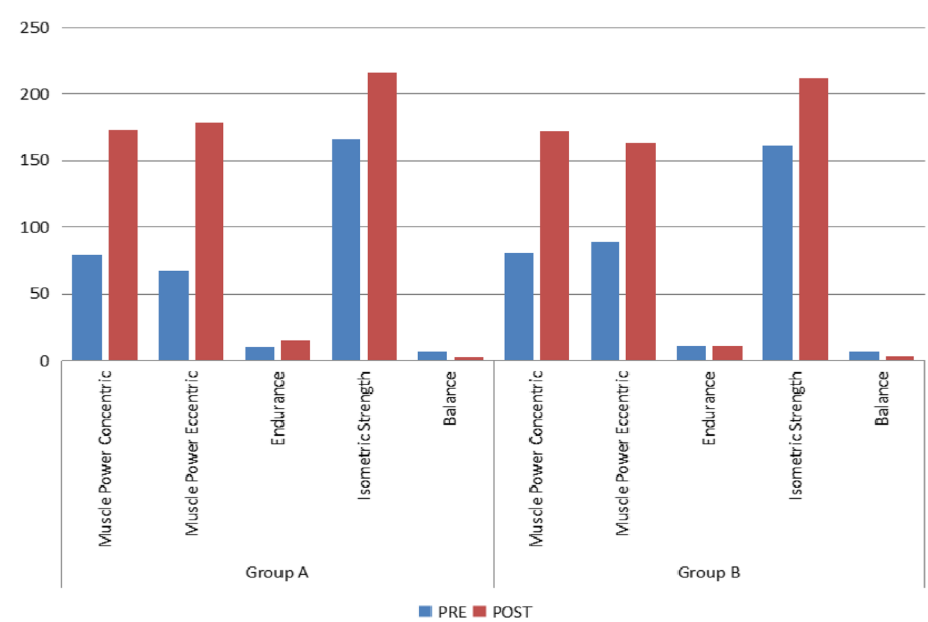


Fig. 4 Graphical representation of comparison of mean values of muscle power, endurance, isometric strength, and balance

Table 4 Comparison of improvement in the mean values of muscle power, isometric strength, and balance

Parameters at 0 week vs 6 weeks	Group A Mean ± S.D	Group B Mean ± S.D	*t* value	*p* value
Muscle power concentric (W)	94.53 ± 39.47	91.90 ± 35.52	0.344	0.731
Muscle power eccentric (W)	110.21 ± 29.19	73.90 ± 20.8	7.032	< 0.001*
Isometric strength (kg)	49.63 ± 19.88	50.62 ± 15.66	0.271	0.786
Balance (%)	− 3.311 ± 3.10	− 3.16 ± 3.07	0.233	0.815

*Significant

training plus conventional rehabilitation and those who participated in only conventional rehabilitation experienced enhancements in muscle power during both concentric and eccentric phases, as well as improvements in isometric strength and balance. The study did not consider participants' dietary intake. Although participants were advised to maintain their usual eating habits, future studies should incorporate the evaluation and adjustment of diet, as nutritional intake may influence recovery.

After surgery for ACL reconstruction, muscle power that includes both concentric and eccentric components is essential for recovery. Muscle shortening and concentration are necessary for restoring joint stability and functional strength. Muscular lengthening or eccentric contractions are essential for regulated movement during tasks like stair climbing, improving muscular flexibility, and accelerating tendon repair. In the current study, both group A and group B showed increases in muscle power during the concentric and eccentric phases. These results are in line with those published by Lorenz and Reiman[18] and Gokeler et al.[17]

The mean eccentric power improvement showed that conventional therapy plus isoinertial training is more effective than conventional rehabilitation alone. In the study by de Hoyo et al.,[19] it was found that flywheel exercises have a higher eccentric load because the subject performs a high velocity movement (usually maximal) during the positive (extension) phase of a squat, while the subject must break the load accumulated during the negative (flexion) phase. The main benefit of EOL is therefore associated with an enchained mechanical load. A positive transfer in motor unit recruitment, force, and power output may have been ensured by the authors' earlier research, which hypothesized that a high eccentric load may have better stimulated higher order motor units (which need the use of high load).[16, 20]

Muscle endurance is essential for reestablishing regular gait patterns, strengthening joints, and increasing general functional ability, all of which help patients carry out everyday tasks with less discomfort. Participants in the current study showed a significant increase in muscle endurance, rising from a mean value of 10.98 to 14.85, when they received isoinertial exercise in addition to traditional therapy. On the other hand, the group that only underwent conventional rehabilitation protocol showed no discernible improvement. The improved ability of eccentric muscle activities, a crucial part of isoinertial training, to generate torque may be the reason for the better results seen in the combined intervention group.[21] However, maximal electromyographic (EMG) activity, which may be lower than in concentric activities, suggests that neural activation is not greater with eccentric muscle action. Conversely, eccentric muscular actions may improve protein synthesis in muscles and contractile tissues by increasing muscle tension. The first week of consistent training will reduce the soreness following eccentric activity.[22] Muscle endurance is increased because many natural movement patterns involve eccentric muscle activation, particularly when the stretch–shortening cycle is employed.

Rehabilitation following ACL reconstruction should include both balance and isometric strength training. With little mechanical strain on the knee, isometric exercises which include static muscle contractions without joint movement are useful for improving joint stability, reducing muscle atrophy, and regaining periarticular strength. They also help to enhance neuromuscular control, which is necessary for motor coordination and the avoidance of compensatory movement patterns. Training for balance is equally important since it improves joint position awareness and proprioception, which lowers the chance of falls and re-injuries. The results of the current study showed that the isometric strength and balance improvements of the two intervention groups those undergoing conventional rehabilitation and those receiving isoinertial training were equivalent. Regarding effectiveness, there were no discernible variations between the two methods.

Direct comparisons with the existing body of research are challenging due to the limited number of studies exploring the impact of these therapies on isometric strength and balance in postoperative ACL populations. The improvement noted in group A may be attributed to isoinertial training, which employs flywheel devices to provide varying resistance during both concentric and eccentric phases. This training modality's close resemblance to dynamic loading and functional movement patterns may lead to greater enhancements in isometric strength and balance. Additionally, isometric exercises focused on joint stabilization and the development of static strength were included in the typical rehabilitation protocol, which may account for the neuromuscular improvements observed in this group. The distinct yet complementary effects of the various training methods likely contribute to the observed enhancements in strength and balance in both groups.

This study has few limitations. The nature of the intervention prevented therapists from being blind to group assignments, which could have led to performance bias. Further restricting the capacity to separate the effects of each intervention was the inability to directly compare the isoinertial training protocol with the traditional rehabilitation treatment alone. Furthermore, it is more difficult to evaluate long-term results and the longevity of the noted changes when there is no long-term follow-up. The effectiveness of isoinertial eccentric-oriented training in conjunction with a traditional rehabilitation strategy was supported by this study despite these limitations. The small sample size prevented subgroup analysis by age, which could have impacted statistical power. It is important to investigate age-specific outcomes in future research using larger cohorts. The study's future scope entails performing long-term follow-up evaluations 4 to 5 months after rehabilitation to look at the long-term effects on activity levels and lifestyle modifications. This prolonged observation period would yield important information about the long-term impacts of the rehabilitation procedures and how they affect the patients' everyday routines and way of life in general.

Conclusion

This research indicated that both treatment protocols—combining isoinertial training with conventional rehabilitation and using conventional rehabilitation alone—were successful in improving muscle power during both concentric and eccentric phases, as well as isometric strength and balance over a duration of 6 weeks. Conversely, group A that underwent isoinertial training in conjunction with conventional rehabilitation demonstrated enhancements in endurance, while group B, which only participated in conventional rehabilitation, did not exhibit any progress. Further investigations revealed that an isoinertial training program combined with a traditional rehabilitation approach can significantly boost power in the eccentric phase of muscle contraction.

Abbreviations

ACL	Anterior Cruciate Ligament
CC	Close Chain
CONSORT	Consolidated Standards of Reporting Trials
DOMS	Delayed Onset Muscular Soreness
EMG	Electromyographic
IKDC	International Knee Documentation Committee
ISOMET	Isometric Strength Test
OC	Open Chain
ROM	Range of Motion
SLR	Straight Leg Raising
VAS	Visual Analogue Scale

Acknowledgements

We express our sincere appreciation and gratitude to the Department of Orthopaedics, Joint Replacement and Arthroscopic Surgery, Fortis Hospital, Ludhiana, Punjab, India; Lovely Professional University, Phagwara, Punjab, India; and the Physiotherapy Department of the School of Allied Medical Sciences for their invaluable support in this study.

Authors' contributions

RCP contributed to conceptualization, data curation, formal analysis, investigation, methodology, supervision, validation, writing—original draft, and writing—review and editing; SG did the data curation, formal analysis, methodology, investigation, validation, and writing—review and editing; SM contributed to data curation, formal analysis, investigation, methodology, validation, and writing—review and editing; **AY** contributed to data curation, formal analysis, investigation, methodology, validation, and writing—review and editing; **SM** uo.

Funding

The authors did not receive funding for this article's research, writing, and publication.

Data availability

The data will be available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Institutional Review Board (IRB). The ethics approval number is LPU/IEC/2018/01/09. It was filed in the Clinical Trials Registry of India under CTRI/2019/06/019858. Written informed consent was obtained from all subjects involved in the study to publish this article.

Consent for publication

The participants were provided with informed consent before publishing any information.

Competing interests

The authors disclosed no potential conflicts of interest regarding this article's research, authorship, and publishing.

Author details

[1]Department of Physiotherapy, School of Allied Medical Science, Lovely Professional University, Phagwara, Punjab, India. [2]Fortis Hospital, Ludhiana, Punjab, India.

Received: 22 June 2024 Accepted: 2 July 2025
Published online: 25 July 2025

References

1. Lam MH, Fong DT, Yung PS, Ho EP, Chan WY, Chan KM. Knee stability assessment on anterior cruciate ligament injury: clinical and biomechanical approaches. BMC Sports Sci Med Rehabil. 2009;1(1):1–9.
2. Bailey AK. Enhancing Rehabilitation Following Anterior Cruciate Ligament Reconstruction. University of Exeter (United Kingdom). 2015.
3. Medvecky MJ, Zazulak BT, Hewett TE. A multidisciplinary approach to the evaluation, reconstruction and rehabilitation of the multi-ligament injured athlete. Sports Med. 2007;37(2):169–87.

4. Wiese-Bjornstal DM, Smith AM, Shaffer SM, Morrey MA. An integrated model of response to sport injury: psychological and sociological dynamics. J Appl Sport Psychol. 1998;10(1):46–69.
5. Harrison EL, Duenkel N, Dunlop R, Russell G. Evaluation of single-leg standing following anterior cruciate ligament surgery and rehabilitation. Phys Ther. 1994;74(3):245–52.
6. Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physically active individuals. Phys Ther. 2000;80(2):128–40.
7. Chmielewski TL, Hurd WJ, Rudolph KS, Axe MJ, Snyder-Mackler L. Perturbation training improves knee kinematics and reduces muscle co-contraction after complete unilateral anterior cruciate ligament rupture. Phys Ther. 2005;85(8):740–9.
8. Pezzullo DJ, Fadale P. Current controversies in rehabilitation after anterior cruciate ligament reconstruction. Sports Med Arthrosc Rev. 2010;18(1):43–7.
9. Lepley LK, Palmieri-Smith RM. Effect of eccentric strengthening after anterior cruciate ligament reconstruction on quadriceps strength. J Sport Rehabil. 2013;22(2):150–6.
10. Parmar P, Perry R, Cesarz G, Roberts A, Hardman H, Caruso JF. Physiological effects of spaceflight/unloading and the mitigating effects of flywheel-based resistive exercise. Gravitational & Space Research. 2016;4(1).
11. Tesch PA, Fernandez-Gonzalo R, Lundberg TR. Clinical applications of iso-inertial, eccentric-overload (YoYo™) resistance exercise. Front Physiol. 2017;27(8):241.
12. Norrbrand L, Pozzo M, Tesch PA. Flywheel resistance training calls for greater eccentric muscle activation than weight training. Eur J Appl Physiol. 2010;110(5):997–1005.
13. Odeleye OO. A comparative study on the effects of eccentric flywheel overload and traditional resistance training on the physiological/functional performance in healthy older adults. PhD thesis, University of Saskatchewan. 2020.
14. Stojanović MD, Mikić M, Drid P, Calleja-González J, Maksimović N, Belegišanin B, Sekulović V. Greater power but not strength gains using flywheel versus equivolumed traditional strength training in junior basketball players. Int J Environ Res Public Health. 2021;18(3):1181.
15. Van Grinsven S, Van Cingel RE, Holla CJ, Van Loon CJ. Evidence-based rehabilitation following anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc. 2010;18:1128–44.
16. Beato M, Stiff A, Coratella G. Effects of postactivation potentiation after an eccentric overload bout on countermovement jump and lower-limb muscle strength. J Strength Cond Res. 2021;35(7):1825–1832.
17. Gokeler A, Bisschop M, Benjaminse A, et al. Quadriceps function following ACL reconstruction and rehabilitation: implications for optimisation of current practices. Knee Surg Sports Traumatol Arthrosc. 2014;22(5):1163-1174. 25.
18. Lorenz D, Reiman M. The role and implementation of eccentric training in athletic rehabilitation: tendinopathy, hamstring strains and ACL reconstruction. Int J Sports Phys Ther. 2011;6(1):27–44.
19. de Hoyo M, de la Torre A, Pradas F, Sañudo B, Carrasco L, Mateo-Cortes J, et al. Effects of eccentric overload bout on change of direction and performance in soccer players. Int J Sports Med. 2014;36:308–14.
20. Docherty D, Hodgson MJ. The application of postactivation potentiation to elite sport. Int J Sports Physiol Perform. 2007;2:439–44.
21. Westing SH, Seger JY, Thorstensson A. Effects of electrical stimulation on eccentric and concentric torque-velocity relationships during knee extension in man. 1990.
22. Fridén J, Seger J, Sjöström M, Ekblom B. Adaptive responses in human skeletal muscle subjected to prolonged exercise training. Int J Sports Med. 1983;4:177–83.

Publisher's Note

JOREP xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Orthopaedic Reports

journal homepage: www.journals.elsevier.com/journal-of-orthopaedic-reports

Impact of isoinertial training on muscle power, endurance, isometric strength, and balance: An experimental trial in post-ACL reconstruction patients

Ramesh Chandra Patra [a,c,*], Som Gupta [a,c], A. Yashudas [a], Sanjeev Mahajan [b]

[a] Lovely Professional University, Phagwara, Pumjab, India
[b] Joint Replacement and Arthroscopic Surgery, Fortis Hospital, Ludhiana, Punjab, India

ARTICLE INFO

Keywords:
ACL reconstruction
Isoinertial training
Conventional rehabilitation
Muscle power

ABSTRACT

Background: Rehabilitation post Anterior Cruciate Ligament (ACL) reconstruction often results in temporary deficits in strength, endurance and neuromuscular control, Isoinertial training, with its emphasis on eccentric overload, may provide additional benefits beyond conventional rehabilitation. This study evaluated the efficacy of combining isoinertial and conventional rehabilitation on neuromuscular outcomes.

Methods: A randomized controlled trial was conducted with 96 participants (aged 18–45years) three weeks of post ACL reconstruction, participants were randomized to Group A (n = 47; received intervention of Isoinertial and conventional rehabilitation) and Group B (n = 49; undergone intervention of conventional rehabilitation only). Both groups completed 6-week intervention program. Outcome measures were evaluated through flywheel ergometer for endurance, isometric strength and balance at pre- and post-intervention.

Results: Both groups showed significant improvements in concentric and eccentric muscle power, isometric strength and balance ($p < 0.05$; effect sized = 1.25–2.45). Only Group A showed significant improvement in endurance ($p < 0.001$; d = 1.18). Eccentric muscle power improved more in Group A than Group B ($p < 0.001$; d = 3.74).

Conclusion: Adding isoinertial training to conventional rehabilitation improved eccentric power and endurance beyond conventional therapy alone. These results support its integration into early ACL rehabilitation. However, the absence of long-term follow-up limits' conclusions on sustained benefits.

1. Introduction

The anterior cruciate ligament (ACL), which serves as the principal static and dynamic stabilizer of the knee joint, is essential to preserving knee stability.[1] Limiting anterior tibial translation in relation to the femur and regulating rotational movements are two of its biomechanical functions, particularly during high demand exercises.[2] Rapid direction changes in sports like football, basketball, handball, volleyball, and skiing put a lot of strain on the ACL and raise the risk of injury.[3] ACL injuries make up around 40 % of all knee ligamentous trauma, making them one of the most common ligament injuries seen in sports medicine. Furthermore, around 70 % of ACL injuries happen in non-contact situations, usually when a person is braking or making sudden direction changes.[4,5] Joint instability, reduced functional performance, and increased vulnerability to related injuries like meniscal tears and early onset osteoarthritis are just a few of the short and long-term consequences that can arise from untreated or poorly managed ACL ruptures.[6]

ACL reconstruction (ACLR) results have significantly improved thanks to developments in surgical methods and organized rehabilitation regimens. For example, research has indicated that following successful ACLR, up to 89 % of professional football players can resume their pre-injury level of play.[6] However, successful return to sport (RTS) depends on thorough rehabilitation that takes into account deficiencies in proprioception, neuromuscular control, psychological preparedness, and strength.[7,8]

Traditionally, Return to Sport (RTS) choices were made mostly on the amount of time that had passed since surgery, using benchmarks like 6–12 months after reconstruction to determine when a patient was

* Corresponding author. School of Physiotherapy and Paramedical Sciences, Lovely Professional University, Phagwara, Punjab, 144001, India.
E-mail address: rameshpatra2208@gmail.com (R. Chandra Patra).
[c] First author.

https://doi.org/10.1016/j.jorep.2025.100746
Received 10 June 2025; Received in revised form 10 July 2025; Accepted 21 July 2025
Available online 22 July 2025

cleared to return. In favour of function based decision making, which uses objective performance tests to assess preparedness, this time-based approach has come under growing criticism.[9] Tests of isokinetic and isometric strength, single-leg hops, vertical jumps, and crossover hops are examples of functional evaluations.[10] These instruments aid in assessing power, neuromuscular coordination, reactive strength, and limb symmetry indices all of which are closely related to safe and effective RTS.

ACL rehabilitation now includes perturbation training as a beneficial element. It includes proprioceptive exercises designed to promote joint stabilization and restore neuromuscular reflexes.[11,8] Assuring that athletes are ready for intricate sport specific movements, perturbation training is frequently coupled with progressive, load based exercises and functional bracing, which is particularly pertinent in the later phases of recovery.[12]

Eccentric oriented training has demonstrated encouraging results among the many training methods investigated for post-ACL rehabilitation. Muscles extend under tension during eccentric activities, which causes special neuromuscular adaptations such as increased muscle hypertrophy, better recruitment of motor units, altered muscle architecture, and improved tendon compliance.[13,14] These modifications help athletes who want to return to high performance activities by improving joint control and lowering their risk of reinjury.

In the early to mid-stages of rehabilitation, the combination of plyometric and eccentric training has shown particularly beneficial. Enhanced explosive performance, better balance, and stronger quadriceps are among the advantages.[10,15] There is still a lack of information in the literature, nevertheless, about how these therapies affect athletes who compete or perform well in the latter stages of recovery. Research indicates that initial strength levels may have an impact on results, with those starting rehabilitation with lower strength levels benefiting more significantly from eccentric modalities.[13]

Using flywheel based resistance technology, isoinertial training (IT) is one of the more innovative methods of eccentric training. This modality, which was initially created to help astronauts prevent muscle atrophy in microgravity, provides gravity independent resistance that enables maximal concentric effort followed by instantaneous eccentric overload.[16,17] In contrast to conventional resistance training, this technique has been associated with increased muscle growth, improved power development, and enhanced neuromuscular activation.[18]

In ACL rehabilitation, IT has demonstrated potential to enhance both functional results and life quality. According to some research, people who engage in isoinertial exercises see notable improvements in their knee strength, proprioception, and RTS preparedness.[15] It is possible even in advanced phases of rehabilitation because it is well tolerated and has not been linked to substantial delayed onset muscle soreness (DOMS) or muscle damage.[19]

There is still a dearth of high calibre studies evaluating the effectiveness of IT in the later stages of rehabilitation, despite these positive results. This is especially problematic for athletes, whose shift from clinical recuperation to sport specific performance necessitates specialized, research based strategies. The majority of research that has already been done either concentrates on early recovery or ignores verified functional outcome measures such neuromuscular control, limb asymmetry, or jump performance relevant to a sport.[13,20] Furthermore, it is uncertain if these physiological advantages translate to sport specific situations, even though meta-analyses indicate that IT may be more effective than traditional resistance training at increasing maximal strength and power.[16]

This study aims to address this gap by examining how key neuromuscular outcomes muscle power, endurance, isometric strength, and balance are affected in patients recovering from ACL repair when isoinertial training is paired with traditional rehabilitation. Late-stage rehabilitation, where performance-based sport preparedness is crucial, receives particular attention. With the aid of a flywheel ergometer, force output and balance shifts may be precisely measured, providing unbiased information about the efficacy of interventions.

We hypothesized that isoinertial training, when added to traditional therapy, will produce better gains in neuromuscular function, especially in muscle endurance and eccentric power. Competitive athletes hoping to safely and successfully return to high demand activities may find a more effective and efficient route with such a strategy.

2. Materials and methods

2.1. Study design and ethics

This study was single-blind, randomized controlled experiment with parallel groups carried out in com-pliance with the standards of CONSORT 2010. After anterior cruciate ligament reconstruction (ACLR), it assessed the effectiveness of incorporating isoinertial eccentric overload (EOL) exercise into standard therapy. This study was carried out at Fortis Hospital in Ludhiana, Punjab, India from July 2020 to September 2023. The Institutional Human Ethics Committee granted ethical permission, and the study was listed on Clinical Trials.gov (CTRI/2021/09/036933). In accordance with the Declaration of Helsinki (2013) and the Good Clinical Practice recommendations of the Indian Council of Medical Research, all subjects gave written informed consent.

2.2. Participants and recruitment

Using G*Power 3.1 software, 95 participants were enrolled out of 130 individuals who underwent ACLR. Sample size was calculated assuming the effect size $f = 0.25$, $\alpha = 0.05$, power = 80 %, and a projected droupout rate of 15 %, based on prior studies evaluating eccentric training in ACL rehabilitation.The study was ultimately finished by 96 participants (Group A: $n = 47$; Group B: $n = 49$). The CONSORT diagram (Fig. 1) incorporates the documented dropout rates and attrition reasons. There were no recorded negative incidents. A computerized random number generator with block randomization (block size = 4) was used to allocate participants at random (1:1) to maintain group balance. Sequentially numbered, opaque, sealed envelopes were used to preserve allocation concealment, and an independent researcher who was not engaged in outcome evaluations or intervention administration opened them.

Inclusion and Exclusion criteria Age, gender, sport, and injury mechanism were the baseline variables that were matched and statistically compared between groups. Football, kabaddi, basketball, and other semi-professional and recreational athletes made up the cohort. Stratified randomization was used during allocation to guarantee age matching.

Inclusion Criteria The study's participants were eligible to participate, if they were three weeks after anterior cruciate ligament reconstruction (ACLR), between the ages of 18 and 45, and had been given the all-clear by a physician to perform eccentric overload exercises. To guarantee that instructions and procedures were understood, they also had to be fluent in at least one of the following languages: Punjabi, Hindi, or English.

Exclusion Criteria Participants were excluded on the basis of whether they had a history of lower limb functional limitations or prior knee surgery. Additionally, those with systemic or neurological disorders that can impede rehabilitation were not included. The inability to understand research procedures because of language challenges, reluctance to give informed consent, or any other reason that prevented adherence to the intervention protocol including the difficulty to complete isoinertial (eccentric) exercises safely were further exclusion criteria.

2.3. Blinding and bias control

Participants blinding was not feasible due to the nature of the intervention, which may have introduced the performance bias,

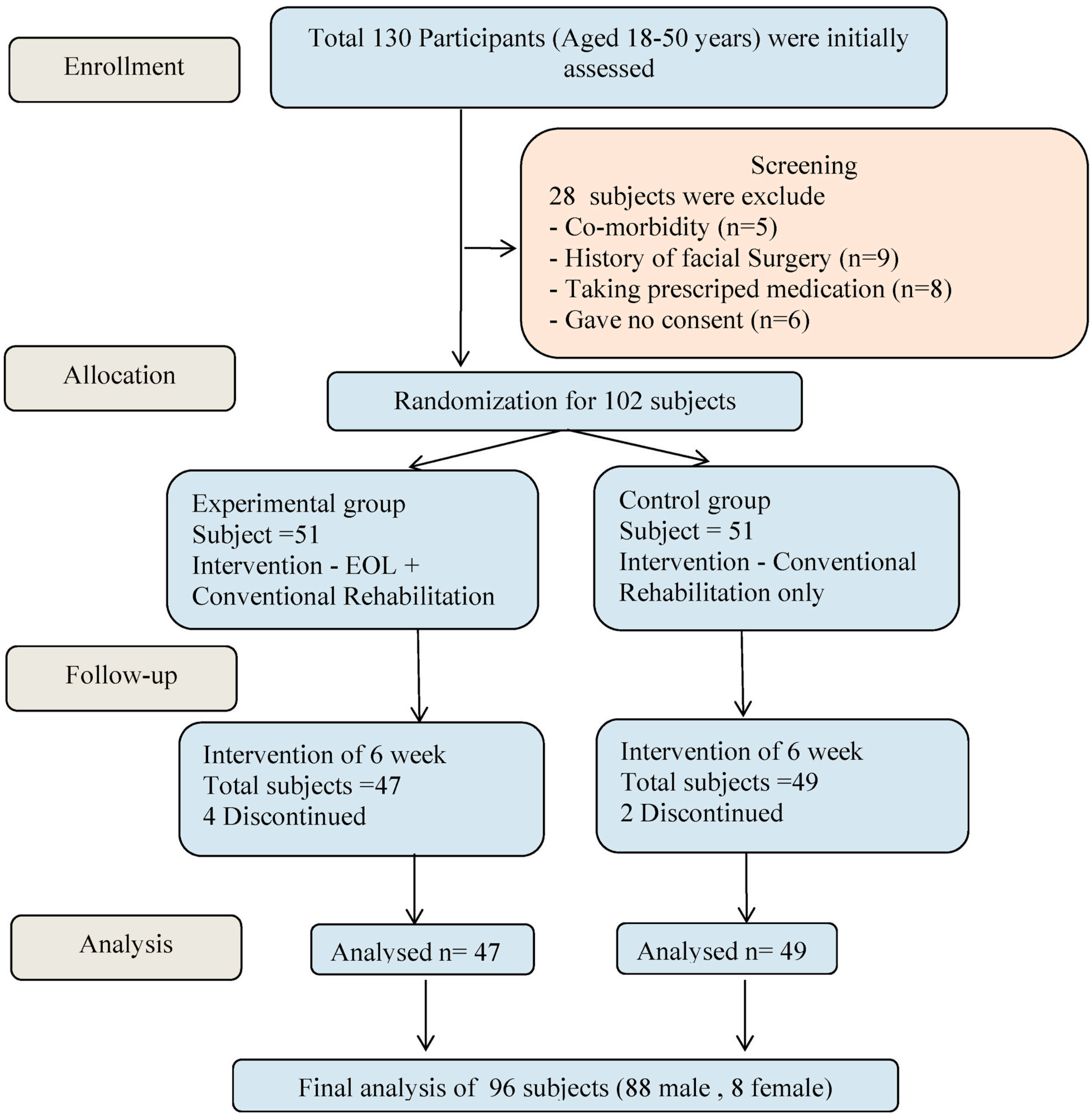


Fig. 1. CONSORT flow diagram depicting participant recruitment, randomization, and study completion.

particularly in subjective outcomes such as balance. To minimize detection and analysis bias, outcome asessors and data analystswere blinded to group allocation. Assessors were unaware of participants' group assignments and were instructed not to inquire, while participants were asked not to disclose their assigned intervention.

2.4. Adherence and monitoring

Every intervention session's attendance was noted. There was no discernible difference in adherence across groups ($p = 0.46$), and participants in Group A completed an average of 11.4 ± 0.9 EOL sessions (out of 12).

2.5. Baseline assessment protocol using flywheel ergometer

All participant from Group A (Experimental) and Group B (Control) were evaluated on a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy) for muscle power, endurance, isometric strength, and balance. Participants were asked to semi-squat (knees flexed approximately 100°), place their hands on their hips, and wear a waist strap to test their isometric strength in the lower limbs. Participants executed a maximal voluntary isometric contraction for 10 s at the examiner's signal. Contact panels were used to record force output, which was then shown using Desmotec's D.Soft software. This allowed for the analysis of strength, endurance, and both eccentric and concentric power. Standing on the platform with weighted plates in the same location, balance was evaluated. To represent postural stability, deviations from the center were noted and presented as a percentage.

2.6. Intervention

2.6.1. Group A (EOL + conventional rehabilitation)

Participants in the experimental group received daily traditional therapy for six weeks, along with two weekly sessions (30 min each) of

EOL training on a flywheel ergometer (D11 Plus; Desmotec, Biella, Italy). Flywheel squats and lunges were among the EOL exercises. Every session consisted of three sets of ten repetitions for each exercise, separated by 1 min of rest. By modifying the flywheel inertia (starting at 0.02 kg/m^2 and increasing by 0.005–0.01 kg/m^2 every week) in response to power output recorded by D.Soft software, load progression was customized.

2.6.2. Group B (conventional rehabilitation only)

Participants in the control group followed a standardized rehabilitation protocol for 6 weeks, comprising 30-min sessions, 6 days/week, without EOL training.

2.6.3. Rehabilitation protocol

The protocol consist of four phases and then return to sport.

2.6.3.1. Phase 1 (Week 1). **Standards for Advancement:** Regain muscular control with isometric and isotonic OC (90°–40°) and CC (0°–60°) exercises, manage pain and inflammation, reach ROM 0–90° with full extension, and, if tolerated, establish a normal gait to walk without crutches by day 4. **Procedure:** Use CPM, leg elevation, heel slides, patellar mobilizations, and cryotherapy. Start with safe strength training such as weight shifting, small squats, and SLR. Once gait is non-limping and pain permits, encourage self-sufficient walking.

2.6.3.2. Phase 2 (Weeks 2). **Standard for achievement:** Includes complete extension, 90° flexion, stable or decreased pain/swelling, adequate quadriceps control (mini squat 0–30°, SLR), satisfactory patellar mobility, and autonomous walking. **Procedure:** If necessary, continue cryotherapy. By week two, increase ROM to 120°, and by week five, to 130°. Return to a normal gait by week three, walking on a treadmill, and running by week eight. Strength training should be gradually increased each week with increased range of motion. Commence swimming, stair-stepping, cycling, neuromuscular balance training, and outdoor cycling in weeks three and eight. Look for signs of arthrofibrosis.

2.6.3.3. Phase 3: (Weeks 3–4). **Standard for advancement:** Include complete extension, 130 flexion, minimal discomfort or swelling, normal gait, a nd appropriate workout performance. **Procedure:** Keep your ROM full. Use more weights to improve muscle endurance and strength. Using plyometrics and dynamic stability, advance neuromuscular training by beginning with two-legged jumping and working your way up to one-legged jumping. Start jogging outside again in week 13. Use the IKDC questionnaire to reevaluate.

2.6.3.4. Phase 4 (Weeks 5–6). **Standard for advancement:** full range of motion, no pain or swelling, quadriceps/hamstring strength greater than 75 % compared to the contralateral side, a difference of less than 15 % in the hamstring/quadriceps ratio, hop tests greater than 75 %, and appropriate exercise performance. **Procedure**: Optimize neuromuscular control, strength, and endurance. Place a focus on jumping, agility exercises, and sport-specific activities that gradually increase in intensity and speed.

Requirements for Returning to Sports:

Full range of motion, quadriceps/hamstring strength greater than 85 % of the contralateral side, a strength ratio difference of less than 15 %, hop tests greater than 85 %, appropriate exercise performance, and tolerance to full-speed sport-specific activities are all indicators of good health. For confirmation, administer the IKDC questionnaire.

2.7. Outcome measures

A blinded physiotherapist performed pre and post intervention assessment.

2.7.1. Isometric strength

The flywheel ergometer (D11 Plus; Desmotec) was used to test the lower limb's isometric strength. Peak force was collected using D.Soft software after participants executed a 10-s maximal voluntary contraction from a semi-squat position (knee angle 100°).

2.7.2. Muscle power and endurance

The flywheel ergometer was used to track total work and eccentric and concentric power outputs during EOL training.

2.7.3. Balance

During a 10-s semi-squat stance on the flywheel platform, postural sway was measured to evaluate balance; deviations from the center were expressed as a percentage.

2.8. Statistical analysis

SPSS v20 was used for the statistical analysis. Because n > 50, the Kolmogorov–Smirnov test was used to assess the normality of the data. When necessary, independent t-tests or chi-square tests were used to examine baseline differences between groups. The effects of the intervention were evaluated using a 2 × 2 repeated measures ANOVA (group × time). Effect sizes were given using Cohen's d for pairwise comparisons and partial eta-squared for ANOVA. Multiple comparisons were subjected to a Bonfer-roni adjustment. For every outcome, 95 % CIs were provided, and $p < 0.05$ was considered statistically significant.

3. Results

3.1. Demographic and baseline characteristics of participants of group A and group B

Table 1 shows the demographic and baseline data for participants in Groups A (experimental) and B (control). Participants in Group A were 29.94 ± 6.78 years old on average, while those in Group B were 30.20 ± 7.45 years old ($p = 0.858$). Age, height, weight, endurance, isometric strength, balance, and concentric muscular power did not differ statistically significantly between the two groups ($p > 0.05$). Eccentric muscular power, on the other hand, showed a significant baseline difference (Group A: 68.19 ± 15.37 W vs. Group B: 89.20 ± 18.57 W, $p < 0.001$), which was statistically adjusted in further between-group analyses using ANCOVA. Between groups, there was no significant difference in the distribution of genders ($\chi^2 = 0.0035$, $p = 0.953$). Table 1, presents the demographic and baseline characteristics of participants across the study groups. The age, sex distribution, and baseline clinical

Table 1
The demographic characteristics and baseline outcome measure for Group A and B.

Particular	Group A	Group B	t-value	p-value
Age in years	29.94 ± 6.78	30.20 ± 7.45	−0.179	0.858
Height in cm	171.65 ± 4.64	172.12 ± 5.56	−0.45	0.654
Weight in kg	78.27 ± 9.93	77.80 ± 10.46	0.226	0.822
Muscle Power Concentric (W)	79.00 ± 19.35	77.80 ± 10.46	−0.347	0.73
Muscle Power Eccentric (W)	68.19 ± 15.37	89.20 ± 18.57	−6.05	< 0.001
Endurance (sec)	10.98 ± 3.28	11.10 ± 2.39	−0.204	0.839
Isometric strength (kg)	166.70 ± 33.15	161.30 ± 41.08	−0.709	0.48
Balance (%)	6.54 ± 2.71	7.16 ± 2.08	−1.255	0.213
Gender (Male/Female)	43M/4F	45M/4F	X^2 = 0.0035	0.953

cm = centimeter, kg = kilogram, W = watt.

score were comparable between groups, indicatiing no significant differences prior to intervention. Fig. 2 summarizes these characteristics, highlighting the balanced distribution across key variables (see Fig. 3).

3.2. Within-group comparisons (pre and post intervention)

Table 2 presents the within-group comparison of outcome measures before and after the intervention from Week 0 to Week 6, both groups showed statistically significant gains in the majority of outcome measures:

Group A showed, significant increases with ($p < 0.0001$) in endurance (d = 1.18), isometric strength (d = 1.53), concentric power (d = 2.45), eccentric power (d = 3.74), and balance (d = 1.36).

Group B also made significant improvements, the decrease in endurance was not statistically signifi-cant (p = 0.074, d = 0.24), however there was a change in concentric power (d = 2.19), eccentric power (d = 2.98), isometric strength (d = 1.25), and balance (d = 1.37).

3.3. Between-group comparisons (post-intervention improvement)

The following outcomes were noted following ANCOVA's adjustment for baseline eccentric power differences:

Eccentric Muscle Power Group A experienced a substantially higher improvement than Group B (adjusted mean difference = 36.7 W, 95 % CI [24.5, 48.8], $p < 0.001$, partial = 0.29). The improvements in concentric power (p = 0.731, $\eta^2 = 0.004$), isometric strength (p = 0.786, $\eta^2 = 0.002$), and balance (p = 0.815, $\eta^2 = 0.001$) did not show statistically significant differences between groups, suggesting similar gains. The change in outcomes(from Week 0 to Week 6) are compared between groups in Table 3 presents a comparison of outcomes between the intervention and control groups atboth pre- and post-intervention time points. Fig. 4 illustrate the magnitude of post-intervention improvement between the group.

4. Discussion

This study investigated the effects of two rehabilitation approaches following anterior cruciate ligament (ACL) reconstructio standard rehabilitation versus rehabilitation augmented with isoinertial training on muscle power, endurance, isometric strength and balance. Over a six-week period, both group demonstrated statistically significant within-group improvements across multiple neuromuscular outcomes. However, ANCOVA-adjusted between-group comprisons reveled asubstantially greater increase in eccentric muscular strength in the group receiving adjunctive isoinertial training, with a large associated effect size. Additionally, significant improvements in muscular endurance were observed exclusively in the isoinertial training group, suggesting enhanced neuromuscular adaptation during the early postoperative phase. Nervertheless, a statistically significant baseline difference in accentric muscle power between groups (p < 0.001) raises concerns about the adequacy of randamization. Although ANCOVA was used to adjust for this imbalance, the magnitude of the discrepency may have influenced the between-group comparisons.

Eccentric muscle power, become a crucial area for group distinction. With a substantial effect size (Cohen's d = 3.74), While the large effect sizes (Cohen's d = 3.74) were observed for eccentric power, the small sample size and short duration may have inflated these estimates. Without stratification by initial performance levels or sport type, the generalizability of such large effects remains questionable. Future studies with large cohort are need to validate these finding. Group A showed noticeably larger improvements than Group B (p < 0.001). This confirms earlier findings that eccentric-oriented training regimens, like flywheel-based isoinertial training, enhance mechanical load through variable resistance, leading to superior eccentric adaptations. This, in turn, promotes neuromuscular recruitment and mechanical tension across muscle fibers.[13,14,18] The observed increase in power production is probably explained by the type of eccentric overload that is inherent in flywheel systems. The advantages of this type of training in enhancing tendon remodelling, motor unit recruitment, and joint stability have also been demonstrated in earlier studies.[21,13].

Concentric muscle power, both groups showed improvement, with no discernible difference be-tween them (Group A: d = 2.45; Group B: d = 2.19). This implies that concentric phase recovery in the initial phases following ACL surgery can be achieved with standard rehabilitation. Although concentric force is important for mobility tasks like getting out of a chair or climbing stairs,[17,22] both therapies seem to address it equally.

The improvement in muscle endurance in the isoinertial group alone

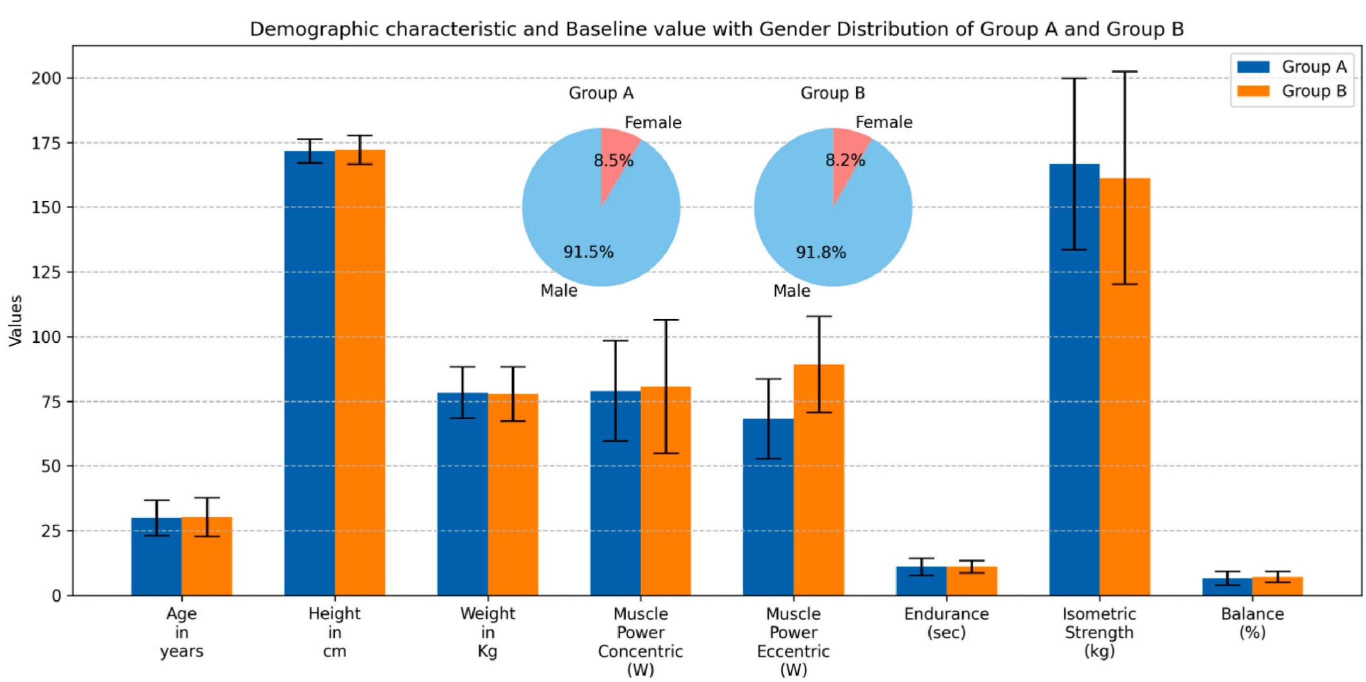


Fig. 2. Baseline demographic and outcome measure for group a and B.

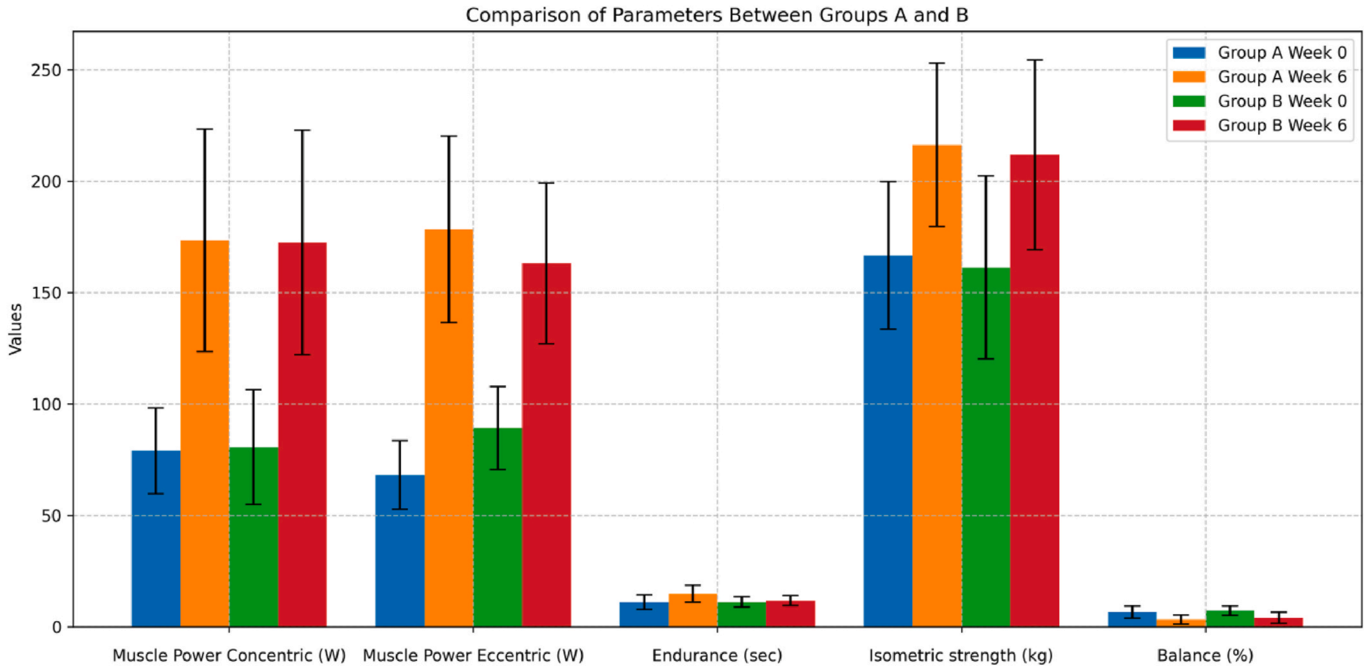


Fig. 3. Group A and B, pre and post intervention comparison of Muscle Power, Endurance, Isometric strength and Balance.

Table 2
Within-group comparisons of mean outcome measures at Week 0 and Week 6 with effect sizes (Cohen's d).

Parameters	Week 0 Mean ± S.D	Week 6 Mean ± S.D	t value	p value	Cohen's d
GROUP A (EXPERIMENTAL) **Muscle Concentric power (W)**	79.00 ± 19.35	173.53 ± 49.91	1	< 0.0001**	2.45
Muscle Power Eccentric (W)	68.19 ± 15.37	178.40 ± 41.96	25.880	< 0.0001**	3.74
Endurance (sec)	10.98 ± 3.28	14.85 ± 3.87	9.499	< 0.0001**	1.18
Isometric Strength (kg)	166.70 ± 33.15	216.33 ± 36.60	7.210	< 0.0001**	1.53
Balance (%)	6.54 ± 2.71	3.23 ± 2.10	7.313	< 0.0001**	1.36
GROUP B (CONTROL) **Muscle Power Concentric (W)**	80.61 ± 25.78	172.51 ± 50.32	18.109	< 0001**	2.19
Muscle Power Eccentric (W)	89.20 ± 18.57	163.10 ± 36.11	24.780	< 0.0001**	2.98
Endurance (sec)	11.10 ± 2.39	11.65 ± 2.26	1.826	0.0740	0.24
Isometric Strength (kg)	161.30 ± 41.08	211.93 ± 42.71	22.630	< 0.0001**	1.25
Balance (%)	7.16 ± 2.08	4.00 ± 2.50	7.210	< 0.0001**	1.37

cm = centimeter, kg = kilogram, W = watt.
Note * denotes significant difference; ** denotes highly significant difference.

Table 3
Post-intervention comparison between groups.

Measure	Mean Diff	p-value	Cohen's d	CI (95 %)
Muscle Concentric Power (W)	2.63	0.731	0.07	[-12.61, 17.87]
Muscle Eccentric Power (W)	36.31	< 0.001 * *	1.43	[25.98, 46.64]
Isometric Strength (kg)	−0.99	0.786	−0.06	[-8.26, 6.28]
Balance (%)	−0.15	0.815	−0.05	[-1.40, 1.10]

Note * denotes significant difference; ** denotes highly significant difference.

was the most clinically significant outcome ($p < 0.001$; d = 1.18). It has previously been demonstrated that eccentric focused treatments improve muscle tendon stiffness and oxidative enzyme activity, two processes that support fatigue resistance and long-term performance.[23,24].

Endurance and eccentric power, eccentric exercise tends to increase endurance capacity and protein synthesis while decreasing electromyographic activity.[10,22] The endurance gains observed in Group A but not in Group B may be explained by these physiological advantages, highlighting the importance of isoinertial regimens in thorough post-ACL rehabilitation. The significant gains that are anticipated to facilitate early functional recovery are indicated by the large effect sizes that were noted (d = 1.18 for endurance and d = 3.74 for eccentric power). These magnitudes imply possible clinical relevance even though direct functional tests were excluded.

Balance and isometric strength had similar effect sizes and showed significant improvement in both groups (Group A strength: d = 1.53; balance: d = 1.36; Group B strength: d = 1.25; balance: d = 1.37). According to these results, regaining joint stability and neuromuscular control in six weeks can be accomplished with traditional rehabilitation protocols, which usually involve static exercises and proprioceptive training.[25,26] Although there were no differences between the groups, prior research indicates that isoinertial training might offer further advantages by simulating dynamic tasks in real life that activate stabilizing muscles and improve proprioception.[17,27] Therefore, even if the improvements were comparable in size, a lengthier follow-up could show different impacts.

A significant baseline difference despite the use of opaque, sealed envelopes for allocation concealment and appropriate randomization

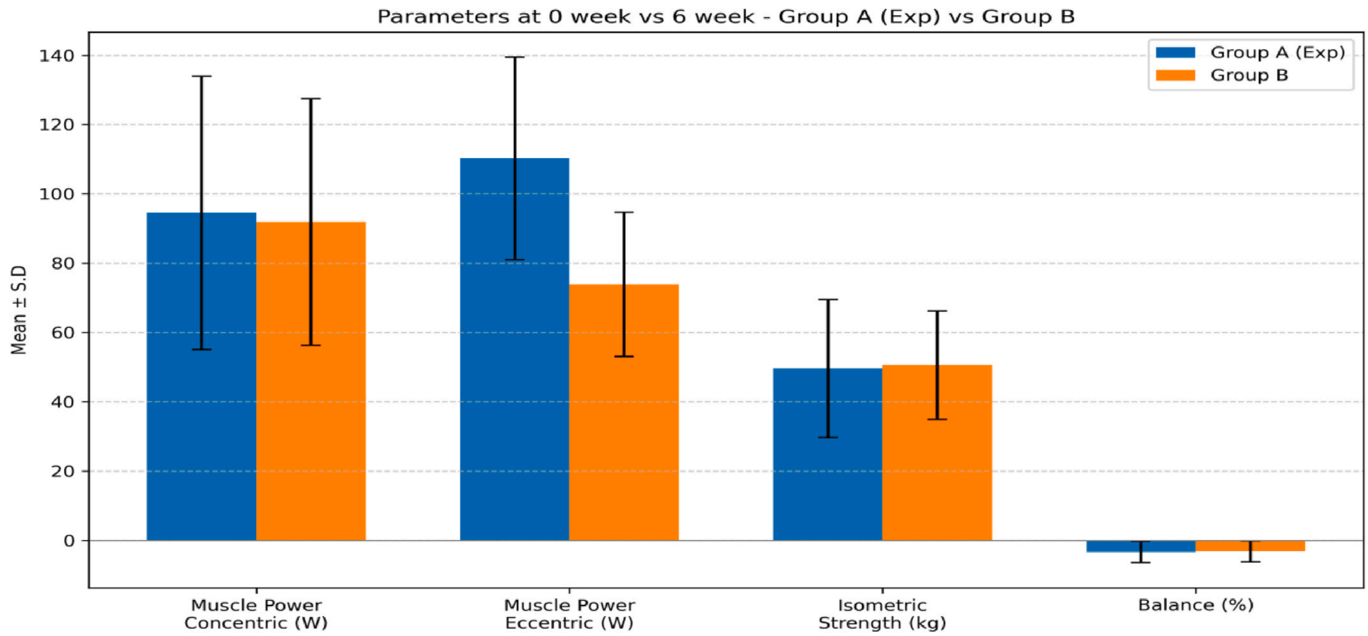


Fig. 4. Post Intervention comparison of improvement of Muscle Power, Isometric Strength and Balance.

using computer-generated block sequences, an increase in eccentric power was noted. We used ANCOVA, a statistical technique that has been proven to increase the precision of treatment effect estimates, to account for baseline differences in order to address this. Although confounding cannot be totally eliminated by any statistical adjustment, ANCOVA lessens its impact. In addition, every other baseline characteristic, such as gender, age, and functional measures, was evenly distributed among the groups. The observed post-intervention differences between the groups are more credible, and this reinforces the validity of our randomization. The study produced a more precise estimate of the training impact attributed to the intervention by controlling for this baseline variable. Blinding participants was not possible due to the nature of the intervention, which is a common limitation in trials involving physical rehabilitation. Participants were specifically told not to reveal their group assignment, and outcome assessors and data analysts were completely blinded to reduce performance bias. Sequentially numbered, opaque, sealed envelopes were used to maintain allocation concealment; only a separate researcher who was not involved in the intervention or assessment could open them. These protocols were put in place to guarantee methodological integrity and are in line with CONSORT guidelines.

Previous RCTs and meta-analyses have shown that isoinertial training is beneficial for strength development after ACL reconstruction. However, especially among Indian athletes, there is little data on short-term neuromuscular changes using high-precision flywheel ergometers. The majority of current research focuses on elite athletes, long-term results, or Western cohorts, and flywheel technology is used inconsistently as an intervention and evaluation tool. In order to fill these gaps, this study uses standardized flywheel ergometry to assess early-phase rehabilitation outcomes in a semi-professional Indian athletic cohort over a six-week period. By doing this, it helps ascertain the wider significance of isoinertial training in ACL recovery by validating current findings and evaluating their suitability in a different clinical and demographic context.

Despite of these encouraging results, it is important to recognize the many methodological constraints of the study. First, Early-phase neuromuscular adaptations are essential for moving on to mid- and late-stage rehabilitation, and the 6-week intervention period was specifically chosen to evaluate these adaptations. For safe progression through rehab phases, early improvements in eccentric strength, endurance, and balance are crucial, even though full functional recovery and return to sport usually take 6–12 months. The results are meant to supplement long-term results by providing information about the short-term gains that can be made through isoinertial training, not to replace them.

Second, another significant omission is the absence of individuals reported outcome measures (PROMs). The stydy did not included validated PROMs such as IKDC, KOOS scales. Since subjective perception, functional recovery and psychological readiness are key components of rehabilitation, this omission limits the holistic understanding of patient outcomes. The study mainly examined objective neuromuscular outcomes (such as power, endurance, strength, and balance) in the early post-operative period. When patients are participating in higher-level activities during the mid-to-late stages of rehabilitation, PROMs are more appropriate measuring the entire spectrum of recovery, including the patient's functional perception and quality of life.

Third, the study did not stratify data by sport type or functional load, despite its focus on neuromuscular outcomes. Future studies should take into account sport-specific subgroup analyses because different athletic profiles may call for distinct rehabilitation objectives (e.g., sprinters' explosive power versus soccer players' endurance). This study consisting mainly of semi-professional and recreational athletes from a single center in northern India also limits generalizability to elit athletes, sedentary and healthcare setting. Findings may not be applicable to elite athletes, sedentary individuals, or populations in different geographic and cultural settings.

Lastly, a crucial result of ACL rehabilitation is return to sport (RTS), which reflects not only functional and psychological recovery but also physical preparedness. Due to the brief 6-week intervention period, this study did not monitor RTS rates or timelines, despite its focus on neuromuscular improvements during early rehabilitation. This restricts the findings' clinical generalizability because successful RTS may not always be correlated with gains in eccentric strength and endurance. Future research should evaluate reinjury risk, sport readiness, and long-term functional outcomes using validated RTS criteria, sport-specific performance tests, and follow-up periods of six to twelve months.

This study adds to the increasing amount of data that supports the use of eccentric-biased isoinertial training in post-ACL rehabilitation. The addition of isoinertial training generated greater results in eccentric power and endurance, two factors crucial to safe return-to-sport performance, even though both standard and combined regimens improved strength and balance.

5. Conclusion

Post-ACL reconstruction patients' concentric and eccentric muscle power, isometric strength, and balance were enhanced by both isoinertial exercise in conjunction with traditional rehabilitation and conventional rehabilitation alone. Nonetheless, the isoinertial group demonstrated much higher increases in eccentric power and muscle endurance, with substantial effect sizes suggesting a transient benefit. Improvements in strength and balance were similar between groups. These results provide credence to the use of isoinertial training in early rehabilitation, especially when it comes to improving eccentric capacity and endurance. However, the data' clinical generalizability is diminished by restrictions such the brief intervention time, lack of blinding, and lack of long-term follow-up. To validate and improve isoinertial protocols in ACL healing, future studies should evaluate patient reported metrics, return-to-sport preparedness, and long-term outcomes.

Statements and declarations ethical approval

The study was approved by the Institutional Review Board (IRB). The Ethics Approval Number is LPU/IEC/2018/01/09. It was filed in the Clinical Trials Registry of India under CTRI/2019/06/019858.

Informed consent

Written informed consent was obtained from all subjects involved in the study and to publish this article.

Author contributions

1. Ramesh Chandra Patra (RCP) Contributed to Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft and Writing – review, editing.
2. Som Gupta (SG) Data curation, Formal analysis, Methodology, Investigation, Validation, and Writing – review and editing.
3. A Yashudas (AY) Data curation, Formal analysis, Investigation, Methodology, Validation and Writing – review and editing.
4. Sanjeev Mahajan (SM) Data curation, Formal analysis, Investigation, Methodology, Validation and Writing – review and editing.

The final draft has undergone critical examination and approval by all the authors, who are also in charge of the manuscript's content and similarity index.

Funding

The authors did not receive funding for the research, writing, and/or publication of this article.

Declaration of competing interest

The authors disclosed no potential conflicts of interest regarding this article's research, authorship, and/or publishing.

Acknowledgements

We express our sincere appreciation and gratitude to Lovely Professional University, Phawara-Punjab, India, and the Physiotherapy Department of the School of Allied Medical Sciences for their invaluable support in this study.

References

1. Diermeier TA, et al. Treatment after ACL injury: panther symposium ACL treatment consensus group. *Br J Sports Med.* 2021;55:14–22.
2. Hurley ET, Fried JW, Kingery MT, Strauss EJ, Alaia MJ. Antero-lateral ligament reconstruction improves knee stability alongside anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2021;29:764–771.
3. Budhkar, D. A. & Kumar, N. A Review on Rehabilitation and Return to Sport Criteria Post ACL Reconstruction in Athletes.
4. Neal BS, et al. Variables associated with successful outcome after anterior cruciate lig- ament reconstruction in recreational athletes: a prospective cohort study. *Knee.* 2022;39:29–37.
5. Marmura H, Bryant DM. Evaluation of outcomes after anterior cruciate ligament reconstruction: what we know, what we have, and what to consider. *Clin Sports Med.* 2024.
6. Byrne L, et al. The effect of meniscal pathology and management with ACL reconstruction on patient-reported outcomes, strength, and jump performance ten months post-surgery. *Knee.* 2021;32:72–79.
7. Bregenhof B, et al. The effect of targeted exercise on knee-muscle function in patients with persistent hamstring deficiency following ACL reconstruction–study protocol for a randomized controlled trial. *Trials.* 2018;19:1–13.
8. Gangwani N, Kaur G, Phansopkar P. Reviving movement and stability: a case series on different innovative rehabilitation strategies post-anterior cruciate ligament Recon- struction. *Cureus.* 2024;16.
9. Petersen W, Taheri P, Forkel P, Zantop T. Return to play following ACL reconstruction: a systematic review about strength deficits. *Arch Orthop Trauma Surg.* 2014;134:1417–1428.
10. Kasmi S, et al. The effects of different rehabilitation training modalities on isokinetic muscle function and Male athletes' psychological status after anterior cruciate ligament reconstruc- tions. *BMC Sports ScI Med Rehabilitation.* 2023;15:43.
11. Nawasreh Z, Failla M, Marmon A, Logerstedt D, Snyder-Mackler L. Comparing the effects of mechanical perturbation training with a compliant surface and manual perturba- tion training on joints kinematics after ACL-Rupture. *Gait Posture.* 2018; 64:43–49.
12. Mendez-Bouza M, Alonso-Calvete A, Abalo-Nuñez R. Efficacy of perturbation-based balance training in anterior cruciate ligament tears. A systematic review. *Apunts Sports Med.* 2023;58, 100411.
13. Stojanovic MD, et al. Effects of eccentric-oriented strength training on return to sport criteria in late-stage anterior cruciate ligament (acl)-reconstructed professional team sport players. *Medicina.* 2023;59:1111.
14. Vidmar MF, et al. Isokinetic eccentric training is more effective than constant load eccen- tric training for quadriceps rehabilitation following anterior cruciate ligament reconstruc- tion: a randomized controlled trial. *Braz J Phys Ther.* 2020;24: 424–432.
15. Wang K, Cheng L, Wang B, He B. Effect of isokinetic muscle strength training on knee muscle strength, proprioception, and balance ability in athletes with anterior cruciate ligament reconstruction: a randomised control trial. *Front Physiol.* 2023;14, 1237497.
16. Hu Z, et al. Comparing the effect of isoinertial flywheel training and traditional resistance training on maximal strength and muscle power in healthy people: a systematic review and meta-analysis. *Life.* 2024;14:908.
17. Burileanu H-A, Cosma MA, Cosma GA, Burileanu I, ZĂVĂLEANU M. The importance of isoinertial training and evaluation for func- tional recovery in athletes with acl injuries. *J Sport Kinetic Movement.* 2023;1.
18. Stojanovic MD, et al. Greater power but not strength gains using flywheel versus equiv- olumed traditional strength training in junior basketball players. *Int J Environ Res Publ Health.* 2021;18:1181.
19. Monajati A, Larumbe-Zabala E, Goss-Sampson M, Naclerio F. Injury prevention programs based on flywheel vs. body weight resistance in recreational athletes. *J Strength Condit Res.* 2021;35:S188–S196.
20. Oliveira M, et al. Unilateral versus bilateral resistance exercise in postoperative rehabili- tation after ACL reconstruction with bone–patellar tendon–bone graft: a randomized controlled trial. *Orthopaedic J Sports Me.* 2022;10, 23259671221088830.
21. Beato M, Stiff A, Coratella G. Effects of postactivation potentiation after an eccentric overload bout on countermovement jump and lower-limb muscle strength. *J Strength Condit Res.* 2021;35:1825–1832.
22. Chen J, Wu T, Guo Y. Nordic hamstring exercises in functional knee rehabilitation after anterior cruciate ligament reconstruction: a prospective, randomised, controlled study. *Sci Rep.* 2023;13, 19039.
23. Fauziansyah A, Hidayatullah MF, Riyadi S, et al. Literature review: Pen- garuh eccentric exercise terhadap peningkatan kekuatan otot quadriceps pada cedera anterior cruciate ligament (acl): litera- ture review: the effect of eccentric exercise on increasing quadriceps muscle strength in anterior cruciate ligament (ACL) injuries. *ASSYIFA: Jurnal Ilmu Kesehatan.* 2024;2:174–188.
24. Kasmi S, et al. The effects of eccentric and plyometric training programs and their combi- nation on stability and the functional performance in the post-ACL-surgical rehabilitation period of elite female athletes. *Front Physiol.* 2021;12, 688385.
25. Melyana B, et al. Terapi latihan fungsional di air meningkatkan kekuatan kontraksi isometrik otot paha pasien post rekonstruksi cedera anterior ligamentum cruciatum phase 2 di RSPAD Gatot Soebroto Jakarta. *Sport Fit J.* 2021;9:55–66.
26. Kotsifaki R, et al. Aspetar clinical practice guideline on rehabilitation after anterior cruciate ligament reconstruction. *Br J Sports Med.* 2023;57:500–514.
27. Obradovic M, et al. Tubularization of bone-tendon-bone grafts: effects on mechanical strength and postoperative knee stability in anterior cruciate ligament reconstruction. *Medicina.* 2023;59:1764.

PHYSIO CONNECT
SPREADING KNOWLEDGE

CERTIFICATE
OF PARTICIPATION

THIS CERTIFICATE IS PROUDLY PRESENTED TO

Som Gupta

FOR HIS PRESENTATION

Titled : "Impact of Isoinertial Eccentric Strength Training on Knee Related Quality of Life and Function: An Experimental Trial in Post ACL Reconstruction Patients"

PHYSIOCONNECT 4

National Conference held on 30-31 March 2024 at Panjab University, Chandigarh
Organised By: The Mayra Foundation

DR. SARVOTAM CHAUHAN (PT)
CHAIRMAN

THE MAYRA FOUNDATION
A Move Towards Life

DR. SHWETA SHARMA (PT)
SECRETARY

CHITKARA UNIVERSITY | SCHOOL OF HEALTH SCIENCES

2ND INTERNATIONAL CONFERENCE ON ADVANCES IN PHYSIOTHERAPY AND REHABILITATION - AIPR-23

GLRA INDIA

CERTIFICATE

of Appreciation

This is to certify that

Dr. /Mr. /Ms **Som Gupta**

has participated in Oral Paper Presentation titled **Impact of Isoinertial Training on Muscle Power Endurance, Isometric Strength and Balance : An Experimental Trial in Post - ACL Reconstration Patients** in the on theme **'Emergent Trends and Evolving Practices in Electrotherapeutic and Diagnostic Approaches: A Bottomless Ocean of Possibilities'** held on 17th – 18th November, 2023 organised by **Department of Physiotherapy, Chitkara School of Health Sciences, Chitkara University, Punjab.**

Dr. Sonika Bakshi	Dr. Gurbir Singh	Dr. Amandeep Singh
Dean	Prof. Emeritus	Principal
Chitkara School of Health Sciences, Chitkara University, Punjab	Chitkara School of Health Sciences, Chitkara University, Punjab	Chitkara School of Health Sciences, Chitkara University, Punjab