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EFFECTIVENESS OF ELECTRICAL MUSCLES STIMULATION VERSUS STRENGTHENING EXERCISES IN ATHLETES WITH ACUTE ANTERIOR CRUCIATE LIGAMENT INJURY

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Abstract

Introduction: Anterior cruciate ligament injury was a condition in which tibia externally rotated and femur moved internally due to contact or non-contact injury. In ACL injury, ligament was stretched causing partially or completely tear. ACL was more common in athletes as compared to general population. This injury was presenting in the individuals over 16 years old and was more common in females due to hormonal and biomechanical factors. EMS and Strengthening exercises were used as interventions and showed greater effects to maintaining muscle strength, reducing muscle atrophy, restoring muscle function, reducing pain and improving tissue healing. Aims and Objectives: This study compared the effectiveness of EMS versus Strengthening exercises in athletes with acute ACL injury. It focused on evaluating the effects of EMS on ACL patients to reduce pain, improve function and mobility as well as the effects of strengthening exercises on ACL patients to improve knee stability and reduce function disability. Materials and Methodology: This study was a Randomized Clinical trial conducted on 78 patients who were athletes diagnosed with ACL injury. Participants were randomly allocated into two groups each group contained 39 individuals. Group A received EMS and Group B received strengthening exercises. Treatment sessions were conducted two times per week for six one month. Outcome measures included the Lysholm Knee Scoring Scale (LKSS) and numeric pain rating scale (NPRS). Statistical Analysis: Data Analyzed by using Statistical Package for Social Sciences (SPSS) software.

INTRODUCTION

CHAPTER # 1

The band of connective tissue called the ACL attaches to the anterior portion of the tibia after emerging from the lateral femoral condyle. ACL injuries are any damage to this ligament. Ligaments play a crucial and significant part in the neuro-muscular system which stabilizes joints and serves to communicate sensory feedback about any stress, strain, tension and discomfort in the ligaments to the central nervous system. One of the most common ligament tears in the knee joint in sports is an ACL injury. The audible "popping" and "cracking" sound at the site of injury is the clinical definition of an ACL injury. ADL performance is challenging there is pain and there is effusion. Ligament laxity, medially or laterally joint line pain and reduced knee movement are typical clinical findings. The study's primary goal is to analyze the literature and compare the benefits of electrical muscle stimulation (EMS) and strengthening activities for treating acute ACL injuries by reducing pain and increasing mobility(Larsen, 2020).

The femur, tibia and fibula are the three bones that make up the knee joint which is protected by a cap known as the patella. Reduced quadriceps leverage, increased joint susceptibility to pressure and lower knee stability would all result from the patella's absence. Several ligaments including the ACL, MCL, LCL and PCL attach to the knee joint. Ankle stability is provided by the ACL which attaches anteriorly to the

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tibia. With its origin medially to the lateral femoral condyle and its introduction at the tibial medial differentiation, the ACL is the most significant ligament in the knee. Like other connective tissues, the ACL ligament has mechanical characteristics. The stability and supporting criteria of bone-bone articulation are significantly influenced by both viscoelasticity and stress-strain(Zantop et al., 2005).

Covering around two-thirds of the top internal section of the lateral femoral condyle, the anterior cruciate ligament (ACL) begins proximally on its inner surface. In relation to four reliable arthroscopic landmarks, the exact location of its femoral insertion can be determined: it is approximately 6.1 mm anterior to the lateral intercondylar ridge,

1.7 mm distal to the bifurcate ridge, 8.5 mm from the posterior cartilage boundary and 14.7 mm distal to the distal cartilage edge. This anatomical arrangement aids in determining the placement of the femoral footprint of the ACL. An average length of 25 to 35 mm and a normal thickness of about 3.9 mm are the dimensions of the ACL's triangular cross-sectional form(Banovetz et al., 2023).

ACL injury has mechanism of contact and non-contact injury. Contact injury includes direct blow, accidents, force on lateral side of knee that lead to valgus moment leads to ACL injury. In non-contact injury tibia externally rotates on planted foot and other mechanism include forceful hyperextension of knee. Females are generally at a higher risk than males for ACL injuries that occur without physical contact. These injuries often happen due to certain movement patterns such as when the knee is slightly bent and turns inward (valgus) especially if the quadriceps muscles apply a strong force. Sports such as football, netball, basket-ball, soccer, gymnastics, downhill skiing involved the pivoting movement and cause the ACL injury. These sports are also known as pivoting sports(Akoto et al., 2024).

The ACL begins in the front inner area of the tibia just behind where the medial meniscus attaches. It runs upward and to the side connecting to the back inner part of the lateral femoral condyle. This ligament is key to keeping the knee stable by limiting the forward movement and inward twisting of the tibia. It is the most commonly injured ligament in the knee. ACL injuries often happen during motion where the thigh moves toward the body's center known as femoral adduction. Made of dense connective tissue, the ACL links the femur to the front of the tibia and is more vulnerable to damage than the PCL, MCL and LCL. Whether the knee is bearing weight or not, the ACL is exposed to several types of stress like forward-backward sliding, twisting forces and side-toside pressure. Its blood flow mainly comes from the middle genicular artery along with branches from the fat pad under the knee cap and nearby synovial tissue. These vessels form a network that supplies the ligament with small arteries entering it and joining up with longer ones. The lower part of the ACL also gets blood from branches of the lower medial and lateral genicular arteries(Fleming et al., 2001).

ACL injuries are some of the most common knee problems seen in soccer players especially in situations where there is no physical contact. Female soccer players are generally more at risk for these non-contact ACL tears than males. To create effective prevention methods and identify what increases the risk, it's important to understand how the ACL experiences stress during movement. Research shows that movements in the sagittal plane especially those with shallow knee bends, strong backward forces from the ground and intense quadriceps activity can place significant pressure on the ACL. When the quadriceps contract forcefully and are met with large backward ground forces they can create strong forward-directed stress at the knee, increasing the chance of injury. A smaller knee bend is also linked with steeper angles

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of the ACL and the patellar tendon in relation to the tibia, both of which put more load on the ligament. However newer studies suggest that side-to-side (valgus-varus) and twisting (rotational) forces aren't mainly controlled by the ACL alone. This means that if the ACL is torn, it's likely that other nearby knee structures are also affected(Yu & Garrett, 2007).

The ACL plays a key role in keeping the knee stable, allowing for smooth movement and preventing the tibia from shifting forward in relation to the femur. Many individuals who suffer an ACL tear struggle to return to sport (RTS) and getting back to their previous level of performance can be challenging. A combination of internal (intrinsic) and external (extrinsic) factors often contribute to the risk of ACL injuries. Joint laxity more than normal, decreased lower limb strength, biomechanical factors such as altered trunk and knee mechanics, neuromuscular control and motor functions are slightly compromised as compare to people who have no any injury. These risk factors contribute in the injury of ligament(Cronström et al., 2021).

Various internal and external elements can increase the risk of injury. Internal (intrinsic) factors include loose joints, hormonal influences, the alignment of the limbs, the size of the ligaments, the width of the intercondylar notch, landing and pivoting mechanism. Intrinsic factors are modifiable (strength, core stability, body awareness) and nonmodifiable (anatomy, genetics and medical history). Extrinsic factors include irregular surface of ground, weather conditions, lateral blow to knee and tackle during game. Modifiable factors are participation in game per week and field condition, nonmodifiable factors are the level of competition(Apseloff et al., 9900).

Female young athletes who are active in sports are more likely to get injured than the males because of the hormonal changes, deficiencies of calcium and vitamin D. In order to stay slim and smart the female athletes moving ahead toward the malnutrition so that they have decreased estrogen level, declined in vitamin D and calcium level that make the decrease in bone density. This decrease cause the weak bones, tendons, muscles strength and any twisting, pivoting, blow cause the injury. Women athletes compromised their diet to participate in sports. Osteoarthritis and limited participation in daily activities are two long term end result of ACL injury. Risk factors which include anatomical differences, neuro-muscular short fall or loss, biomechanical factors and hormonal changes lead to higher risk of injury(Acevedo et al., 2014).

After the confirmation of ACL injury it is necessary to decide either patient will get post-operative treatment or operative management and it will totally depend on patient's age, gender, how much instability he/she get, either patient have any other abnormality or not before, during and after injury, taking history regarding any pivoting movement occur during playing, ask about patient's occupation and social factors that individual have enough resources to get treatment or not. Diagnosis of acute ACL injury made by anterior drawer test, lachman test and pivot shift test.

MRI is radiological diagnosis of ACL injury but acute phase easily diagnosed by orthopedic special tests. It is important for the patient to take conservative treatment to prevent from chronic stage and surgery. Measures that are taken for return to sports (RTS) play a golden role to prevent from further damage. After conservative treatment of Grade-I injury patient start to participate in sports such as a term is used called return to performance which is defined as participant is able to resume and start their preinjury level of athletic performance. It is used to characterize victorious RTS process as patient recover from their injury. Conservative management of ACL include a lot of protocols, strengthening exercises, knee immobilizers,

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EMS, improvement of proprioceptive properties of damaged ligament and squatting of different types. The three main outcomes after ACL treatment are: RTS, risk of re-injury and risk of joint damage.

People who have again and again ACL injury are responsible for other knee abnormalities such as MCL get intact, meniscal tear and iliotibial band issues. In most chronic and ACLR re-injuries occur in first twelve months. There is 80 percent of chances that cartilage, joint and meniscus get damaged(Meredith et al., 2020).

On the basis of structural and functional failure of ACL ligament it is divided into three grades of injury. Acute ACL injury include grade I in which there is swelling, pain and discoloration of affected knee. Gade II include the same symptoms if 1st grade but have soft endpoint of orthopedic tests. Grade III have similar symptoms of above two grades but orthopedic tests reveal no end point. RICE therapy which constitutes of rest, icing, compression and elevation is the immediate treatment of acute ACL injury after any mechanism of injury to the knee. Medications like ibuprofen and naproxen which are the part of the non-steroidal anti-inflammatory drug (NSAID) group, may assist in easing discomfort and managing swelling. For individuals with an acute ACL injury, conservative approaches such as physical therapy, the use of a hinged knee brace, basic patient guidance and RICE (rest, ice, compression, elevation) therapy can be considered. These methods might help slow down the progression toward a more serious or chronic condition, potentially reducing the need for surgical intervention(Papaleontiou et al., 2024).

Joint trauma has been associated with an increased risk of developing post-traumatic osteoarthritis (PTOA) particularly in individuals who have experienced an anterior cruciate ligament (ACL) injury. This review explores how frequently PTOA occurs following ACL damage considers the potential role of ACL reconstruction in lowering that risk and discusses various biological and mechanical factors that might contribute to the onset of PTOA. It also examines the current tools available for detecting early signs of osteoarthritis and reviews possible approaches that could help delay or prevent the condition from progressing. Additionally, we point out crucial avenues for further study. Many elements including structural, biochemical, mechanical and neuromuscular aspects are believed to have a role in the underlying mechanism. Because PTOA has a distinct "start point," early detection and treatments are crucial. Early detection of PTOA is currently possible thanks to several biomarkers and imaging techniques. None of them are easily available, sensitive and though. In order to prevent excessive loading and restore joint stability, many patients who have suffered an ACL injury have their ACLs surgically rebuilt(Wang et al., 2020).

It is important to diagnose ACL injury because there are other ligaments at knee which can undergoes to the injury. Authentic knee assessment should be necessary. Most precise diagnostic test in domain of physical therapy to diagnose ACL injury is Lachman test. The pivot shift and anterior drawer tests are commonly utilized to help identify potential ligament damage. In radiology, magnetic resonance imaging (MRI) is often employed to gain a clearer view of the injury and confirm the diagnosis(Cimino et al., 2010). Prevalence of injury is about 85 per 100 000 having age between sixteen to thirty-nine years. Anterior tibial translation and internal rotation is compromised in ACL injury so management will be conservative in acute and pre-surgical phase. In case of chronic ligament rupture or tear individual moving ahead toward operative treatment. Immediately following the injury, applying RICE therapy which includes rest, ice

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application, compression with bandages and keeping the affected area elevated above heart level can be helpful in managing initial symptoms(Diermeier et al., 2020).

Individual experiences pain, inflammation, crepitations, atrophy of quadriceps and weakness. Due to decreased quadricep strength there is variation in gate pattern followed by loading response or weight bearing activities. In acute ACL injury implementation often includes the use of EMS that is then supported by targeted strengthening exercises(Moran et al., 2019).

Strengthening exercise is resistance training in which muscles enhanced their strength and endurance with a proper exercise plan. Every exercise is performed by providing resistance of different type such as resistance band and bodyweight exercise to gain range of motions (ROMs), endurance, strength, stability and power. There are a lot of strengthening exercises that play crucial role to rehab the ACL some of them are quadriceps drills, double-leg calf raises, bridging, assisting knee bending movements, performing hip abduction exercises with elastic tubing, carrying out hip extension exercises using elastic bands, hamstrings curl and squatting(Potts et al., 2022).

Physiotherapy focuses on the muscle strength around the knee, improving proprioception (body awareness), balance and restoring normal movement patterns. Activity modification involves avoiding activities that stress the ACL such as pivoting and cutting movements. While conservative management can be effective for some patients with partial ACL tears. It might not sufficiently address the underlying instability of the ligaments which could result in early onset of osteoarthritis, recurring periods of instability and chronic discomfort(Yao et al., 2021).

In the initial phase of recovering from an ACL injury, performing “quad sets” can be a helpful way to gently strengthen the quadriceps muscles. This exercise involves the patient contracting the front thigh muscles as forcefully as possible to attempt full knee extension. However, many individuals experience a peculiar challenge at this stage— they are unable to voluntarily engage their quadriceps muscles despite conscious effort. This inability is often due to significant muscle inhibition which commonly occurs after knee injuries, surgeries and in the presence of joint swelling. Such inhibition leads to noticeable quadriceps weakness, hindering progress in rehabilitation if not properly addressed(Millett).

Above exercises increased the muscle strength, bone density, athletic performance and improved overall health of patient. Exercise criteria which used for acute ACL injury come up with 45 minutes session twice a week. Knee mobilization increases mobility, self-directed learning is helpful and necessary for patient to perform at home at least once time a week(Abel et al., 2023).

EMS is an electrotherapeutic modality that used to generated impulses, reduced pain, strengthen week muscles, increase the ability to contract the muscle and improve muscle atrophy in short, it makes the muscle healthy and strong. Electrodes are placed on muscle belly to activate the motor nerves by repetitive electrical stimuli and promote the muscle recovery(Cho et al., 2023).

EMS is a gentle non-invasive method often used to help improve muscle function and relieve pain. It can assist in rehabilitation by encouraging more muscle fibers to activate, which may lead to better muscle strength and coordination. On the other hand, TENS mainly focuses on reducing pain by targeting certain nerve fibers and modifying how pain signals are processed. Although TENS shows potential for helping people with chronic pain particularly those using opioids, many studies so far have been limited by small participant numbers and varying treatment details, making the results less certain. Besides pain relief,

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TENS might also affect automatic bodily functions like sympathetic nervous activity and blood flow, which could widen its possible uses(Patel et al., 2025).

ACL is often seen as a serious problem for the knee, especially among young people and athletes involved in sports that demand intense physical activity. The ACL is an important ligament inside the knee that helps control the forward movement and rotation of the shinbone (tibia) relative to the thighbone (femur). It helps to keep the knee stable during movements like jumping, turning or sudden changes in direction, as well as in cases of impact or trauma. ACL injuries frequently occur in sports such as football, rugby, basketball, and soccer, where quick twisting motions, awkward landings and sharp cuts can place a lot of stress on this ligament(Koutures, 2024). Although most ACL injuries happen without direct contact, sometimes a blow to the side of the knee while the foot is firmly planted can also cause a tear, especially if the knee is pushed into an unnatural position like hyperextension or bending inward. People who injure their ACL often describe hearing or feeling a sharp "pop" right when it happens followed by sudden pain and difficulty continuing their activity. Swelling usually develops within a few hours often because of bleeding inside the knee joint which is a common sign of ligament damage. Many also feel like their knee is unstable or may give way, particularly when twisting or turning. If left untreated, this instability can worsen over time and increase the chance of damaging other parts of the knee such as the meniscus or cartilage potentially leading to early arthritis. MRI scans are often used to get a clearer look at the soft tissues and confirm whether the ACL is torn as well as to spot any additional injuries(Koutures, 2024).

When the anterior cruciate ligament (ACL) is suddenly injured it usually leads to knee pain and swelling and some individuals may hear or feel a popping sound at the time of injury. However, patients might not always realize how severe the damage is. These signs often appear after incidents like falls, jumps, direct impacts, trauma and twisting movements. In physical therapy, examining the patient carefully is important for early identification of ACL injuries especially before using imaging tools like MRI. Three common tests used to check the ACL are the Lachman test, anterior drawer test, and pivot shift test and the anterior drawer test often considered one of the more dependable methods for finding acute ACL tears. These assessments are generally done while the patient lies on their back(Avasthi et al., 2024).

The Lachman test is performed with the knee slightly bent at about 15°, where the examiner stabilizes the femur from lateral side of thigh with one hand and applies an anterior force to the medial side of tibia with the other to assess joint stability. The anterior drawer test involves bending the knee to 90°, stabilizing the foot and pulling the tibia forward to check for increased movement compared to the uninjured side. Both tests are considered positive if there is greater forward displacement of the tibia on the affected side. The pivot shift test is used to detect rotational instability by medially rotating the tibia while flexing and then extending the knee; a noticeable clunk or shift as the tibia reduces indicates a positive result. While MRI provides confirmation, these clinical tests are essential tools for diagnosing ACL injuries in their early stages(Avasthi et al., 2024).

ACL injuries can significantly affect a person's mobility and often require surgical intervention followed by a structured and intensive rehabilitation process. The main goal of rehab is to help individuals regain knee strength, stability and normal function so they can return to daily activities or sports safely. Both open kinetic chain (OKC) and closed kinetic chain (CKC) exercises are commonly used during recovery. OKC exercises such as seated leg extensions involve moving the end part of the limb freely without supporting

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body weight, making them useful for isolating specific muscle groups. OKC exercises can improve strength and range of motion (ROM) but may put strain on the ACL graft. CKC exercises involve fixed distal segment with weight bearing, e.g. squats and lunges. OKC exercises promote co-contraction of muscles, stabilizing and controlling joint movements. In result, findings studies have conflicting findings on the effect of OKC exercises on knee laxity(Sigit et al., 2024).
Athletes suffering from acute ACL injuries often face challenging rehabilitation. Restoring muscle strength is critical to regain knee stability and prevent future complications. Conventional strengthening exercises are commonly used but may not always deliver optimal results in the early recovery phase. Electrical Muscle Stimulation (EMS) has emerged as a promising method to support muscle activity without putting stress on the joint. Despite the growing use of both approaches, there is limited research comparing their effectiveness in athletic populations especially in local settings like Gujranwala and Lahore. This study aims to assess which method provides better outcomes in terms of strength recovery and functional performance. The results may help guide more effective rehabilitation strategies tailored to athletes' needs in our region.

CHAPTER #2
LITERATURE REVIEW

This randomized controlled crossover study explored how different pre-exercise EMS protocols might influence recovery and performance in male soccer players. Nineteen participants all with a background in aerobic training were selected and the sample size was calculated using G*Power software (version 3.1.9.4; Düsseldorf, Germany). The players were randomly divided into three groups each assigned a specific EMS routine before exercise. One group (Group A) followed a muscle-strengthening program using a frequency of 104 Hz while another group (Group B) received stimulation designed to boost explosive strength at 75 Hz. The final group (Group C) acted as a control and received a placebo treatment at 15 Hz. The results showed that the 75 Hz protocol was the most effective leading to noticeable improvements in lower body strength and anaerobic performance. These findings suggest that this type of EMS may offer valuable support for athletes during pre-exercise preparation(Sofuoğlu et al., 2025). Researchers looked into whether using passive EMS before surgery could help athletes who were about to have ACL reconstruction. They worked with 47 male athletes and out of those, 28 showed lower activity in their quadriceps muscles, which was measured using EMG. Of those, 14 athletes received a 10-day course of passive EMS prior to surgery. Following ACLR, all participants engaged in postoperative EMS and initiated active rehabilitation beginning in the third week. Findings demonstrated that those who received preoperative EMS experienced significantly greater improvements in quadriceps muscle contraction and functional recovery reaching levels comparable to participants who had normal EMG readings at baseline(Akhmetyanov & Davydova, 2025).
A meta-analysis was conducted using data from 11 randomized controlled trials (RCTs), involving a total of two hundred and two participants. These individuals were drawn from separate studies and divided into two groups: one received Neuromuscular Electrical Stimulation (NMES) as the intervention while he other served as the control group undergoing either standard rehabilitation or a placebo treatment. The number of participants in each group varied across the included studies bur overall, around 101 patients were assigned to each group. The findings revealed that NMES significantly improved quadriceps strength in

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both the short term (with a standardized mean difference or SMD of 0.53) and the long term (SMD of 0.59). Notably, the benefits were most pronounced when NMES was initiated within the first week after surgery showing an SMD of 1.48(Li et al., 2025).
A randomized controlled study was conducted to explore how radial extracorporeal shock wave therapy (rESWT) might support recovery after an ACL injury. A total of 72 participants took part, split evenly into two groups of 36. One group received standard rehabilitation along with rESWT while the other group followed the same rehab program but with a placebo (sham) version of the therapy. Over a 24 week period researchers observed that those in the rESWT group experienced a noticeable improvement between the third and sixth weeks of treatment compared to the control group(Song et al., 2024).
A randomized clinical trial explored the impact of incorporating blood flow restriction (BFR) training into rehabilitation following ACL surgery. Fifty patients took part in the study and were randomly assigned to one of two equal groups. The first group followed a rehab plan that included BFR techniques while the second group engaged in conventional strengthening exercises. The results clearly indicated that those who completed the BFR-based program showed more substantial improvements in muscle function and overall recovery progress. This suggests that BFR may be a more effective strategy for post-surgical ACL rehabilitation compared to traditional strengthening methods(Akash et al., 2024).
In another trial, researchers investigated whether whole-body electrical muscle stimulation (WB-EMS) could help reduce knee pain and boost physical function in overweight individuals suffering from symptomatic knee osteoarthritis. Seventy-two participants with an average age of 58 were randomly split into two groups: one received WB-EMS therapy while the other continued with their usual care routines. Over the course of the study, those undergoing WB-EMS experienced greater pain relief and more noticeable improvements in mobility and physical performance. These findings suggest that WB-EMS may be a valuable alternative to standard care for managing knee osteoarthritis(Kast et al., 2024).
A cross-sectional study focused on patients who had undergone ACL reconstruction five years earlier and were now experiencing anterior knee pain possibly related to osteoarthritis. Those who reported pain were brought in for follow-up evaluations. The assessments revealed that discomfort in the patellofemoral joint was often linked to weakness and atrophy in the quadriceps muscles. Interestingly, the non-injured leg also showed changes specifically a thinner vastus medialis and increased stiffness in the vastus lateralis, likely due to overcompensation during daily activities. To address these issues, ultrasound therapy was used to improve muscle condition. The study emphasizes the need to monitor and treat both limbs after ACL surgery, not just the affected one(Girdwood et al., 2024).
A randomized clinical trial was designed to examine the effects of open kinetic chain exercises (OKCE) versus close kinetic chain exercises (CKCE) on quadriceps femoris muscle strength in patients of varying ages following anterior cruciate ligament (ACL) surgery. The study included 16 participants who attended postoperative rehabilitation sessions and were evenly divided into two groups. Group A (n=8) received OKCE protocols while Group B (n=8) followed CKCE programs. The primary objective was to assess the impact of each exercise type on muscle strength recovery. The findings indicated that CKCE produced more favorable outcomes in terms of quadriceps strength improvement compared to OKCE, suggesting that closed kinetic chain exercises may be a more effective approach for enhancing lower limb function after ACL reconstruction.(Sigit et al., 2024).

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A study was conducted to evaluate the impact of the Nordic hamstring curl training (NHCT) program on athletic performance in male football players. Forty injury-free athletes actively engaged in regular training were randomly assigned to either a training group (TG, n=20) or a control group (CG, n=20). Over an eight-week period the TG completed the NHCT protocol twice weekly while the CG continued with their standard football training routines. Upon completion of the intervention the analysis showed no statistically significant interaction effects between the two groups. These findings suggest that within the duration and frequency applied the NHCT program did not produce measurable performance improvements beyond those achieved through regular football training alone(Adıgüzel et al., 2024).

A study was conducted to determine whether the sequence of knee and ankle joint training influences knee extension and flexion torques during rehabilitation following anterior cruciate ligament (ACL) reconstruction. Forty-two male participants who had undergone ACL surgery were randomly assigned to two groups: Group A received knee joint training followed by ankle joint exercises while Group B began with ankle training followed by knee exercises. The intervention lasted for eight weeks with a one week washout period between phases. Results demonstrated that knee extension torque improved significantly in both groups; however, a significant increase in knee flexion torque was observed only in Group B. Moreover, Group B showed greater overall post training improvements across all measured variables compared to Group A. These findings suggest that initiating ACL rehabilitation with ankle joint training prior to knee focused exercises may be more effective in enhancing knee torque during gait. Further research is recommended to explore these effects in diverse populations and across different types of ACL reconstruction procedures(Ashour et al., 2024)

A randomized controlled trial was carried out to assess how effective core stability training could be for male athletes aged 20 to 30 who had undergone ACL reconstruction. Twenty-six participants were randomly split into two equal groups. One group started supervised core workouts a week before beginning guided rehab sessions while the other followed a structured home-based exercise plan. The eight-week program was evaluated using the McGill core endurance test for stability, manual strength testing and video analysis to observe endurance and control. Results showed that those who received supervised training achieved greater gains in strength, stability and muscular endurance compared to those who exercised at home without supervision. This highlights the added value of early and professionally guided core training during ACL recovery(Saki et al., 2023).

A randomized controlled trials having impact of combining blood flow restriction training (BFRT) with electrical muscle stimulation (EMS) during low-intensity resistance workouts. Their study included 40 participants who were relatively new to exercise and were randomly assigned to one of four groups: BFRT alone, EMS alone, a combination of BFRT and EMS and a control group. Over a period of six weeks all participants performed light-load squats at 25% of their one repetition maximum five times per week. The group that received both BFRT and EMS demonstrated the greatest improvements in muscle strength and activation. Their results even surpassed the BFRT-only group and were comparable to the EMS-only group. These outcomes suggest that pairing BFRT with EMS can be an effective strategy to enhance muscle performance, especially in situations where high-load resistance training is not feasible(Li et al., 2023).

In another clinical trial, researchers compared the effects of adding EMS to standard rehab exercises following ACL reconstruction. Thirty patients took part and were randomly assigned to one of two groups.

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The first group performed rehab exercises with EMS support while the second completed the same exercises without EMS. The group that used EMS showed more noticeable progress, suggesting that combining EMS with rehabilitation may lead to better outcomes in ACL recovery(Cho et al., 2023).

Additionally, a trial involving 26 professional team sport athletes both male and female examined the benefits of flywheel resistance training versus traditional strength routines. Athletes were randomly assigned to two different training programs. One group focused on eccentric-based flywheel workouts while the other followed a more conventional strength regimen which included isometric holds, semi-squats, vertical jump assessments and single-leg hops. Over six weeks, with sessions held two to three times weekly, the flywheel group showed greater performance improvements. These results suggest that eccentric flywheel training may offer a more effective approach for enhancing athletic performance in high-level sports settings(Stojanović et al., 2023). In 2023, a comparative study examined how combining traditional lower-limb strength exercises with EMS affects quadriceps activation in soccer players. Participants were split into two groups: one performed standard strengthening workouts while the other added EMS to the same routine. After an eight-week intervention, the EMS group showed notably greater improvements in quadriceps activity than the standard-training group, suggesting that integrating EMS into familiar training protocols could more effectively boost muscle activation and may hold promise for sports rehabilitation and performance enhancement(Uhm et al., 2023).

A systematic review and meta-analysis focusing on individuals aged 18–40 years post-ACL injury assessed hip and lower-leg muscle strength. The study compared injured limbs with the uninjured side and healthy controls, measuring hip abductors, extensors, external rotators and calf muscles. Results showed no significant deficits in hip or calf strength but there were clear weaknesses in knee flexors and extensors. The authors concluded that while hip and calf muscles often remain strong after an ACL injury, restoring knee flexor and extensor strength should be a key focus of rehabilitation(Ong et al., 2023).

Another randomized controlled trial explored whether exercising the contralateral (non-injured) knee following ACL reconstruction could improve balance, function and pain in male athletes. Thirty participants received standard physiotherapy, with one group also performing neuromuscular exercises on their non-operative side. Post-rehab assessments revealed that this group achieved better static and dynamic balance and reported less pain than the control group, demonstrating that training both limbs may offer broader recovery benefits(Karimijashni et al., 2023).

In a separate study, combining EMS with resistance training during ACL recovery was tested for its impact on muscle hypertrophy markers. Twenty male athletes were randomized into two groups: one underwent a 12-week strength regimen alone while the other group also received EMS (35–70 Hz). Blood tests taken before and after the intervention revealed significantly higher levels of SIRT1 and nitric oxide—biomarkers associated with muscle regeneration—in the EMS group. Visfatin levels rose too, though without statistical significance. These findings suggest that EMS alongside resistance training might amplify molecular pathways important for muscle growth and aid ACL rehabilitation(Kababi et al., 2022).

A meta-analysis looking at ACL injury prevalence among teens reported that female athletes especially those playing soccer had higher injury rates than males. The risk was substantially greater during competitive matches about eight times higher-compared to practice sessions which still carried a six-fold

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increase in risk. These results underscore both gender differences and sport-specific factors in adolescent ACL injury risk(Bram et al., 2021).

A parallel-group randomized trial investigated the impact of a six-week strengthening program versus no intervention in young male soccer players aged 12 to 15. Out of 134 players screened, 45 met the criteria and participated; unfortunately, eight dropped out (six from the control group, two from the exercise group), three due to injury. The study found some benefits for the exercise group but also highlighted the high attrition challenge common in youth sports research(Wilczyński et al., 2021).

Another controlled trial examined whether adding EMS to resistance training could reduce serum levels of atrogin-1 and MuRF1, proteins linked to muscle atrophy in athletes recovering from ACL injury. Twenty participants followed a twelve weeks exercise protocol one group with EMS (35–70 Hz) and the other without. Results showed that the EMS group had significantly lower levels of atrogin-1 than the non-EMS group suggesting that EMS may help preserve muscle proteins during rehabilitation(Alavi et al., 2022).

A cross-sectional study involving 320 Saudi male athletes aged 15–40 investigated ACL injury risk factors. Data collected from various playing surfaces—including artificial turf, natural grass, playgrounds, and dirt fields—revealed that injuries were more common among overweight athletes those who were training over 10 hours per week and those playing on irregular surfaces like turf or dirt, suggesting that these variables may heighten ACL injury risk(Alqarni et al., 2022).

In another randomized controlled trial, the effects of EMS on quadriceps activity in healthy young men were measured. The experimental group (n=18) received EMS on their lower limbs while the control group (n=14) did not. After the intervention EMS group demonstrated significantly increased quadriceps activation compared to controls, confirming EMS's effectiveness in boosting neuromuscular activity(Nishikawa et al., 2021).

Finally, a randomized trial in Denmark evaluated bodyweight exercise effects on quadriceps and hamstring performance following ACL injury. Twenty athletes (nine women), aged 18–35 participated in local club training. Surface electromyography recordings from hamstrings and quadriceps showed no overall increase in hamstring activity but different responses between semitendinosus (8–45%) and biceps femoris (11–54%). Quadriceps activation however, was consistently high, reinforcing the value of bodyweight exercises in post-ACL rehabilitation(Zebis et al., 2019)

A preliminary randomized controlled trial was carried out involving individuals who had undergone ACL surgery. The study included a total of 28 participants who were then evenly divided into two groups of 14. Group A received Functional Electrical Stimulation (FES) while Group B was given Neuromuscular Electrical Stimulation (NMES) as part of four weeks rehabilitation program. At the end of 4-week, those in the FES group regained approximately 82% of their quadriceps strength compared to their pre-surgery levels, whereas participants in NMES group showed a recovery of only about 47%(Moran et al., 2019).

A randomized controlled trial was conducted involving 70 male athletes who had previously undergone anterior cruciate ligament reconstruction (ACLR). Participants were randomly divided into two groups. Group A, the intervention group, received high- frequency transcutaneous electrical nerve stimulation (TENS) along with their standard rehabilitation exercises while Group B, the control group, followed only the routine rehabilitation protocol without any TENS intervention. The TENS therapy, operating at a frequency of 80-100 Hz was applied consistently throughout the initial four weeks post-surgery alongside

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therapeutic exercises. Both groups showed improvements in the knee range of motion (ROM), functional performance based on the International Knee Documentation Committee (IKDC) scores and pain levels assessed through the Visual Analog Scale (VAS). However, after the 4-week period no statistically significant differences were observed between the two groups across these outcome measures(Forogh et al., 2019).

CHAPTER # 3

MATERIALS AND METHODS

3.1: Study Design:

A randomized clinical trial framework was adopted as the basis for conducting this research.

3.2: Study setting:

The study was conducted on athletes by explored branches of shapes exceuative sport club in lahore johar town and gullberg and explore the local tournaments in ground of gujranwala's for local athletes and gyms.

3.3: Duration:

The time period in which our study was carried out is six month after the approval of committee.

3.4: Sampling Technique:

Participants were selected using a convenience sampling approach, based on availability and ease of access rather than random selection.In this not every individual was allowed to participate, we selected athlete's population to make the research easy.

3.5: Sample Size:

To determine the appropriate sample size for comparing the means of two independent groups, a priori power analysis was conducted using G*Power software. The analysis was set up for a two-tailed t-test with an effect size (d) of 0.65, a significance level (α) of 0.05 and a desired statistical power of 0.80 meaning there is an 80% chance of detecting a true effect if one exists. The groups were assumed to be of equal size with an allocation ratio of 1:1. Based on these criteria, the software calculated that each group should include 39 participants resulting in a total sample size of 78. The corresponding critical t-value was found to be approximately 1.9917 and the actual achieved power with this sample size was slightly above the target at 0.8089. This ensures a reasonable balance between minimizing Type I and Type II errors in the hypothesis testing.

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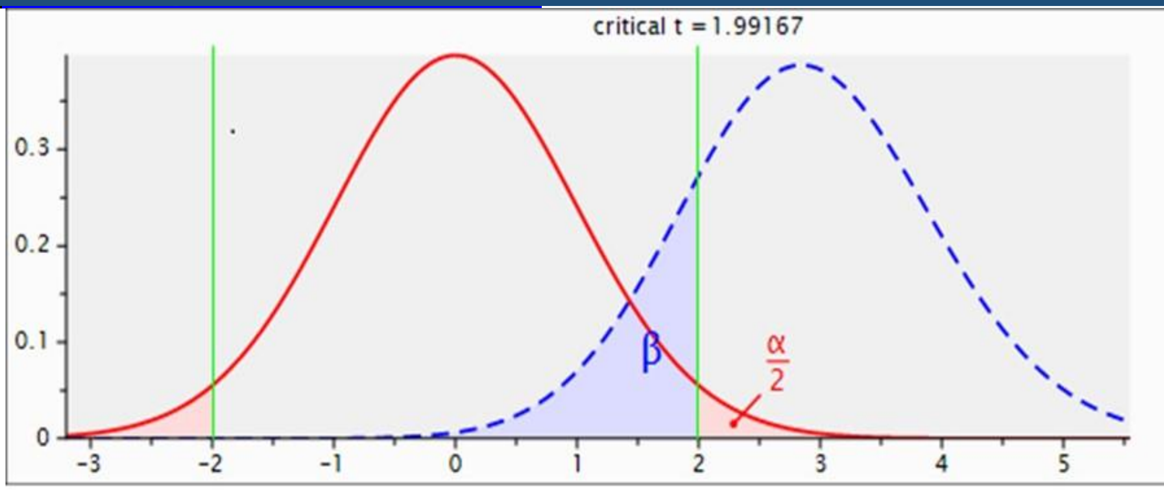

t tests – Means: Difference between two independent means (two groups)

Analysis:	A priori: Compute required sample size		
Input:	Tail(s)	=	Two
	Effect size d	=	0.65
	α err prob	=	0.05
	Power (1−β err prob)	=	0.80
	Allocation ratio N2/N1	=	1
Output:	Noncentrality parameter δ	=	2.8703223
	Critical t	=	1.9916726
	Df	=	76
	Sample size group 1	=	39
	Sample size group 2	=	39
	Total sample size	=	78
	Actual power	=	0.8089174

Fig: Sample size calculated through G-power software

3:6: Target Population:

The population was Athletes of Gujranwala and Lahore District.

3:7: Study Groups:

Group A received strengthening exercise

Strenthening exercise provide resistance to the targeted muscle to work against through resistance bands and other resistive machines.

1. **Quardricep sets** (for vastus lateralus, medialis, intermedius and rectus femoris)

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Procedure:
- Place the knee roller under the knee asked the patient to apply force on it
- Then hold the postion for three to five seconds and tha relax the knee
- Asked the patient to bend his knee and placed the roller between two bend knees, patient applied force at the roller and sustained the position for same time as given above
- Bended knee apply force laterally on the roller therapist resisted it and these set improved the muscle strength

2. **Bridging** (to target hamstrings, low-back and glutes)

Essentials: yoga mat

Procedure:
- Patient was in supine position.
- We instructed the patient to lying supine on mat
- Then flexed the knee at 90 degree and asked to raise the hip or lower back • We sustained this position for minimum three and maximum five second and asked the patient to relax.

3. **Hamstring curls:**

There are three procedures to perform this exercise in which curling on floor, curling with machine and curling with ball are included but we used curling on floor.

Essentials: yoga mat

Procedure:
- Patient was in prone position.
- Patient was on the yoga mat
- Hands were in front of his and wider than the shoulder
- Bending of knee with feet out off the mat, closer knees with straight back while performing exercise
- Take the knee to normal position then apply the weight at ankle and asked patient to flex the knee

4. **Wall squats with ball:**

Squats are type of strengthening exercise that is indispensable in rehabilitating fitness programme of athletes.

Essentials: ball

Procedure:
- Patient hold back, shoulder and thigh against wall and his face toward the therapist
- Basketball sized ball placed between his back and wall
- Patient came down toward floor with 45 degree angle while maintained back
- Thighs were parallel to the ground

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- Sustained the position for five seconds

The study was randomized clinical trials in which we randomly allocate two groups and provide them the two different interventions.

1. Group A:

Participants of group A will get strengthening exercises that increased their mobility, endurance, power and strength.
Each exercise was performed with 10 repetitions of three sets by athelete or participants.

2. Group B:

Individuals of group B applied EMS in acute ACL injury. This mode of therapy increased the quadriceps performance, manage the weaken quadriceps and avoid from quards atrophy.
Intensity was according to patient's tolarence level
Frequency was 3 Hz **3.8: Eligibility Criteria:**

Inclusion Criteria:
1: Age 16 to 50 years (depending on study population or treatment type).
2:Confirmed ACL Injury Diagnosis by:Clinical tests (e.g., Lachman, anterior drawer, pivot shift) and MRI findings.
3:Injury occurring within 3–6 weeks (may vary by study; "acute" often defined as <6 weeks).
4: No major comorbidities that would affect healing or participation.
5:Willingness to participate and provide informed consent(Osterberg et al., 2012).
Exclusion Criteria:
1: Chronic Injuries older than the specified acute period (>6 weeks).
2: ACL reconstruction or significant surgery on the same knee.
3: injury to knee ligaments (e.g., PCL, LCL, MCL) requiring separate intervention.
4: Presence of associated fractures (e.g., tibial plateau fracture).
5:Infections of skin in or around the knee(Müller et al., 2023).

3.9: TOOLS/SCALES:

- Lysholm knee scoring scale (LKSS)
- Numeric pain rating scale (NPRS)
- Goniometer

Lysholm Knee Scoring Scale:

Eight questionnaires are used in this scoring scale to assess the knee function and ligament injury. Each point will be scored range 0-100 scoring 91-100 scoring indicates the good knee functions. Questionnaire consists of following points.

- Limp
- Using cane or crutches

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- Locking sensation
- Giving way sensation
- Pain
- Swelling
- Climbing stairs
- Squatting(Çakar et al., 2025).

Numeric Pain Rating Scale:

The NPRS is a frequently used tool for assessing the level of pain experienced by patients who have had ACL injuries. On an 11 point scale where 0 denotes no discomfort and 10 denotes the worst pain suffering possible in functions perform(Kahl & Cleland, 2005).

Goniometer:

A goniometer is a widely used tool for assessing joint range of motion. When a patient presents with restricted or abnormal movement in a specific joint clinicians can utilize the goniometer during the initial evaluation to document baseline measurements. It can then be applied in follow-up sessions to monitor progress and evaluate the effectiveness of therapeutic interventions(Svensson et al., 2019).

3.10: DATA COLLECTION PROCEDURE

Enrollment:

Participants was assessed for eligibility and assessment will be based on inclusion and exclusion criteria.

Allocation:

The participants were assigned to two separate groups through a random allocation process:

Group A received electrical muscle stimulation (EMS), while **Group B** engaged in a program focused on strengthening exercises.

Follow up:

Participants was continue their treatment but some was drop out.

Analysis:

Effects of both groups will be analyzed and it will conclude that either EMS gives more effects or strengthening exercises.

DATA ANALYSIS

To carry out the data analysis, IBM SPSS Statistics (version 27.0.1) for Windows was utilized. A significance level of p = 0.05 was applied in interpreting the results. Descriptive tools such as frequency tables and bar graphs were employed to present a general overview of the gathered information.

CHAPTER # 4
RESULTS

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The outcomes observed in this study suggested that individuals suffering from recent ACL injuries showed certain patterns or trends worth noting, particularly among the athlete population and improved their pain, mobility, swelling and weakness of quadricep muscles with both electrical muscle stimulation (EMS) and strengthening exercise in which quadricep drills, bridging, hamstring curl and wall squat with ball were included. Participants of both groups had improved range of motion and pain. In EMS group, individuals had marked decline in pain and swelling that is due to acute ACL injury. It also increased the quadricep muscles strength and knee stability. On the other hand, strengthening exercises increased overall stability of knee and resulted in greater outcomes than EMS. In most cases, one or two component of RICE therapy was used to overcome swelling prior to exercise. The findings obtained from the analysis aimed to explore how electrical muscle stimulation (EMS) and strengthening exercises differently impacted athletes with recent ACL injuries, belonging to various sports clubs in Gujranwala and Lahore. A brief summary of the outcomes is provided, incorporating results from a non-parametric test used to compare independent groups

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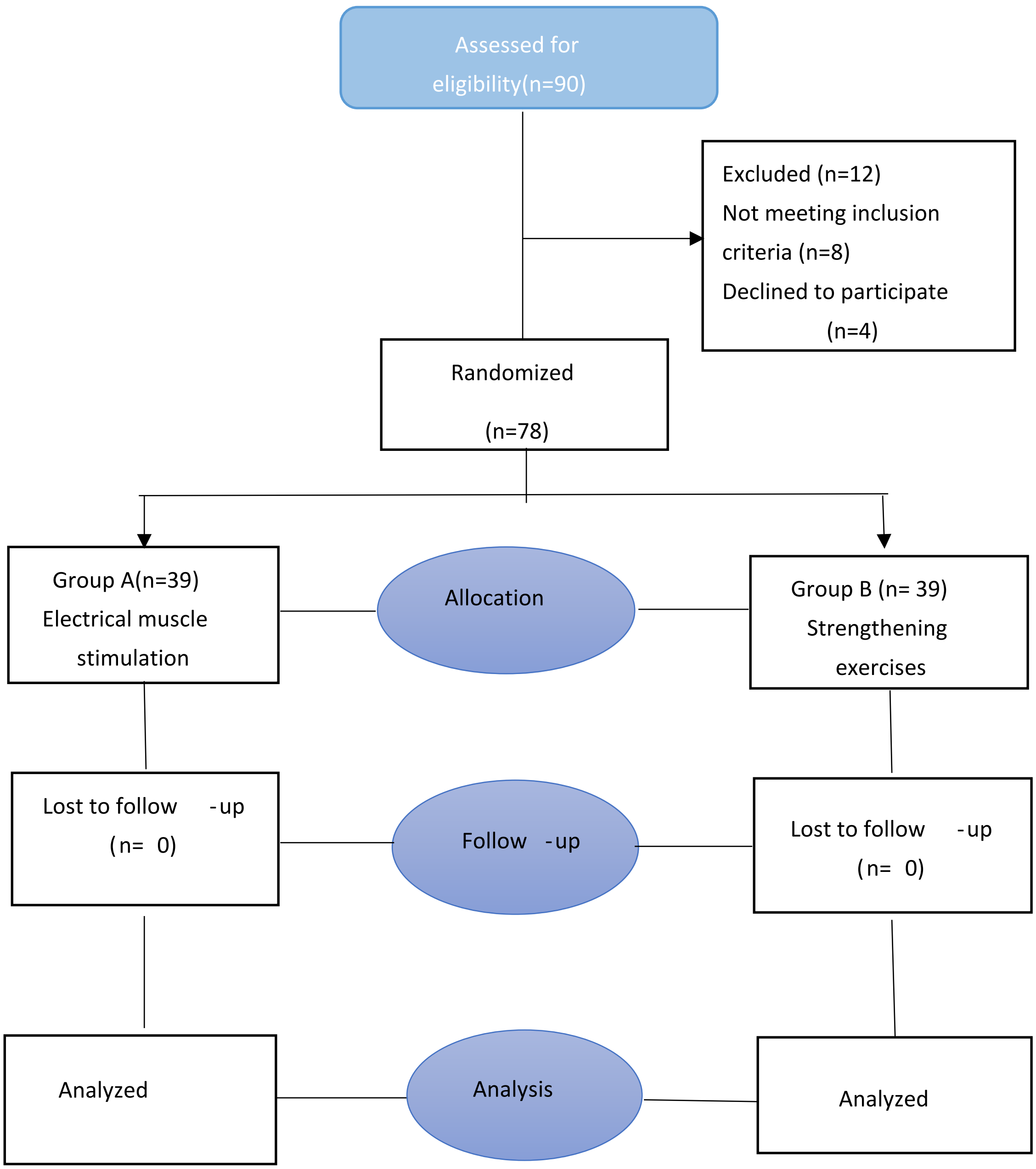
Consort Diagram



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Demographic characteristics

This chapter presents the demographic profile of the participants involved in the study. A total of 78 individuals took part and were equally assigned to two intervention groups. The distribution of participants across groups, age ranges, and gender is detailed in the following subsections.

Table 4.1: Group Distribution

Groups	frequency	Percent %
EMS	39	50.0
Strengthening exercise	39	50.0
Total	78	100.0

Participants were randomly divided into two equal groups to ensure a fair comparison between the interventions. As shown in Table 4.1, one group received Electrical Muscle Stimulation (EMS), while the other engaged in traditional strengthening exercises. Each group consisted of 39 participants, representing 50% of the total sample. This even allocation supports the reliability of the comparative analysis between the two interventions.

Table 4.2: Age Distribution

Age	Frequency	Percent %
16-25	32	41.0
26-35	40	51.3
36-45	6	7.7
Total	78	100

The age profile of participants was grouped into three categories: 16–25 years, 26–35 years and 36–45 years. As illustrated in Table 4.2, the largest proportion of participants (51.3%) were between 26-35 years old totaling 40 individuals. The second most represented age group was 16–25 years comprising 32 participants or 41% of the sample. Only 6 participants (7.7%) were in the 36–45 age range. The data indicates that the study predominantly involved young to early middle-aged adults.

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Table 4.3: Gender Distribution

Gender	Frequency	Percent %
Male	48	61.5
Female	30	38.5
Total	78	100.0

Gender representation within the study was moderately uneven, with a greater number of male participants. As shown in Table 4.3, 48 of the
participants were male accounting for 61.5% of the sample. Female participants numbered 30 making up 38.5% of the total. Although the male population was slightly larger, both genders were sufficiently represented to allow meaningful analysis of intervention effects across sexes.

Table 4.4: Comparison of preNPRS

Variable	Group	Mean rank	Z-value	p-value
preNPRS	1	40.10	_.244	<.001
	2	38.90		

Table showed that there was no significant difference in preNPRS having p value <.001

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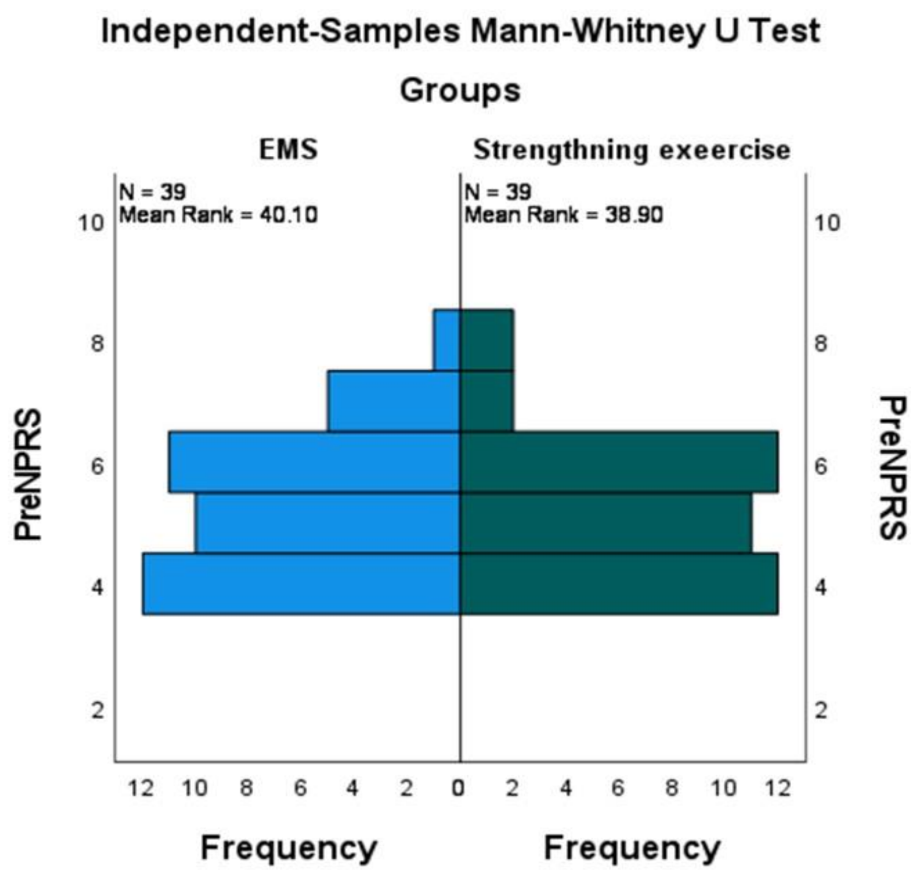

Figure 4.1: Independent-sample Mann-Whitney U Test

Figure showed the frequency of preNPRS on Y-axis EMS group have sample size of n=39 and mean rank is equal to 40.10 and the other group is strengthening n=39 having mean rank= 38.90

Table 4.5: Comparison of preLKSS

Variable	Groups	Mean rank	Z-value	p-value
preLKSS	1	37.97	_.599	.549

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	2	41.03		

Table demonstrated that there was no significant difference before intervention having p= .549

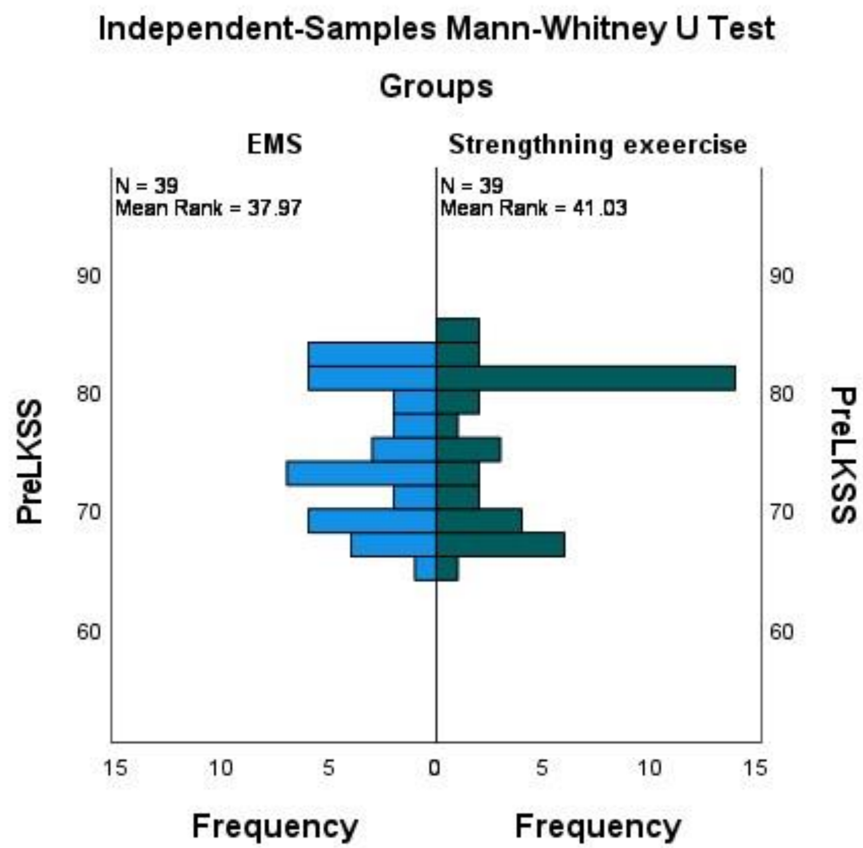

Figure 4.2: Independent-sample Mann-Whitney U Test

Figure showed comparison of preLKSS between two groups, EMS n=39 have mean rank = 37.97 and strengthening exercise n= 39 have mean rank = 41.03 using MannWhitney U Test.

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Table 4.6: Comparison of pre-flexion

Variable	Groups	Mean rank	Z-value	p-value
pre-flexion	1	37.38	_.827	.408
	2	41.62		

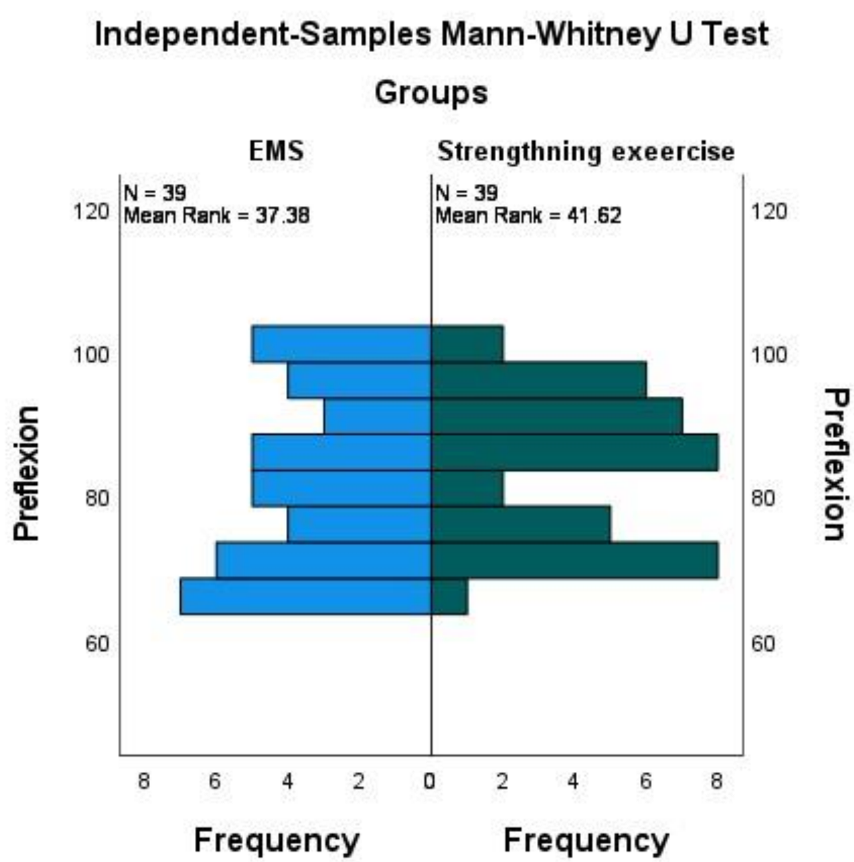

Figure 4.3: Independent-sample Mann-Whitney U Test

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Figure showed comparison of frequency of pre-flexion in EMS n=39 and have the mean rank= 37.38 and strengthening group n= 39 having the
mean rank 41.62 by using independent Mann-Whitney U test.

Table 4.7: Comparison of pre-extension

Variable	Groups	Mean rank	Z - value	p - value
pre - extension	1	37.23	_.930	.353
	2	41.77		

table demonstrated that there was no significant difference in pre-extensionand value is equal to .353

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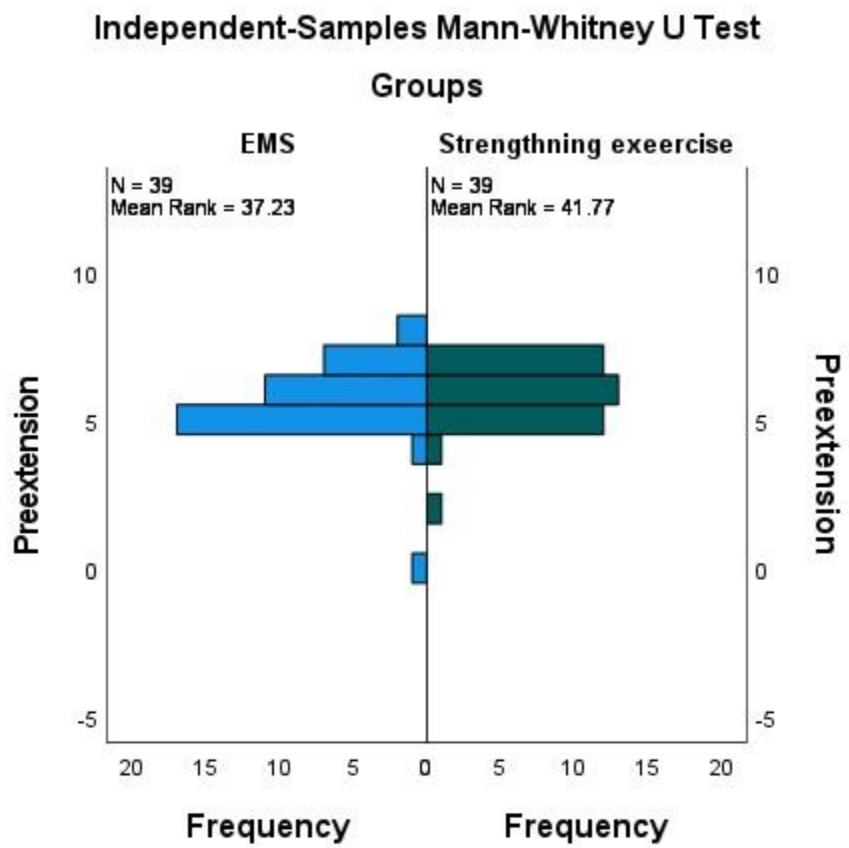

Figure 4.4: Independent-sample Mann-Whitney U Test

Figure showed the comparison between pre-extension frequency of EMS n=39 and have mean rank =37.23 and strengthening group n=39 have mean rank= 41.77, strengthening group has better

results than EMS group. **Table 4.8: Comparison of postNPRs**

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Table 4.8: Comparison of post-NPRS

	Groups	Mean rank	Z -value	p-value
postNPRS	1	51.47	_ 4.887	.807
	2	27.53		

Table presented that there had a significance difference in postNPRS. Although groupI had a higher mean rank and the p-value of 0.807 indicated that difference is not statistically significant.

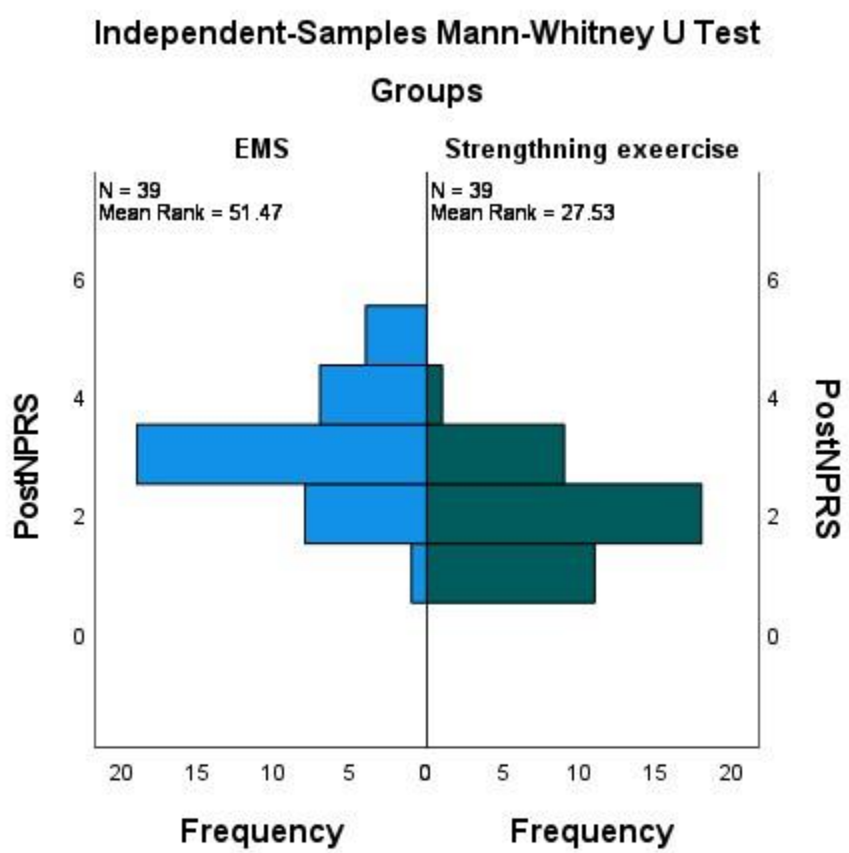

Figure 4.5 : Independent-sample Mann-Whitney U Test

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Figure showed the frequency comparison of postNPRS of EMS group n=39 having mean rank=51.47 and strengthening group n= 39 having mean rank= 27.53 gives the more better results than

the strengthening group according to the Mann-Whitney U test.

Table 4.9: Comparison of postNPRS

Variable	Groups	Mean rank	Z -value	p-value
postLKSS	1	27.05	_4.874	<.001
	2	51.95		

There was a highly significant difference in post-treatmeant having p=<.001 as compared to the significance of pre-treatment.

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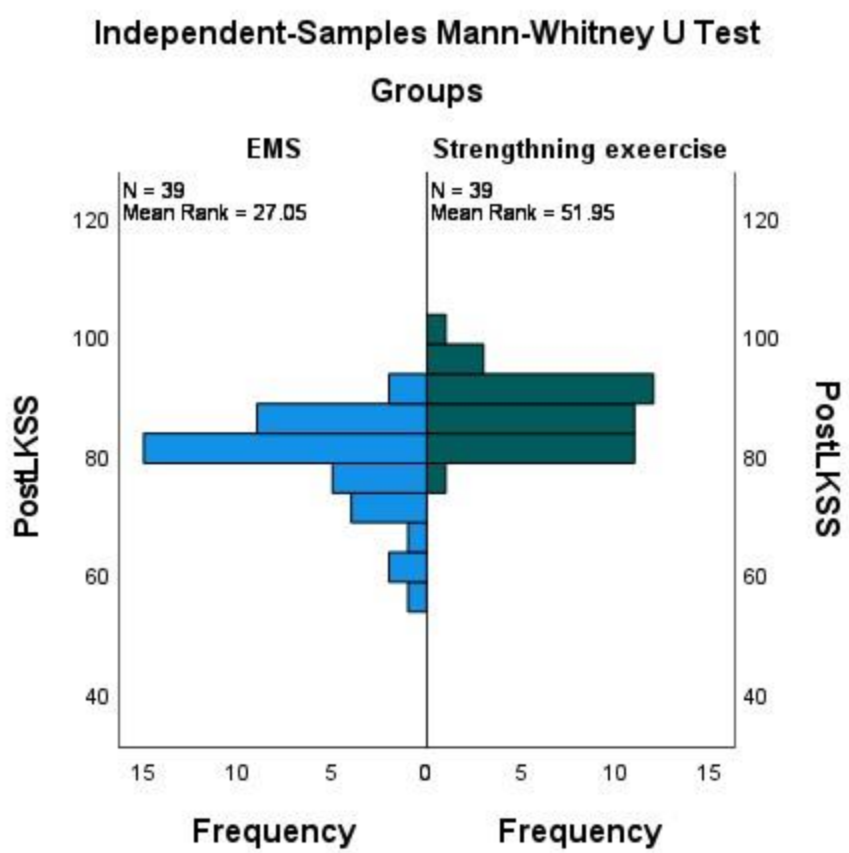

Figure 4.6: Independent-sample Mann-Whitney U Test

Figure showed the frequency comparison of postLKSS in EMS group n=39 having mean rank= 27.05 and strengthening group n=39 have mean
rank= 51.95 gives that strenthening group had better result in postLKSS than EMS group.

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Table4.10: Comparison of post-flexion

Variable	Groups	Mean rank	Z -value	p-value
Post -flexion	1	42.83	_.1.307	.191
	2	36.17		

Table presented that results of comparison between two groups for post-flexion variable. Group 1 had a high mean rank than group 2 but the difference was not statistically significant.

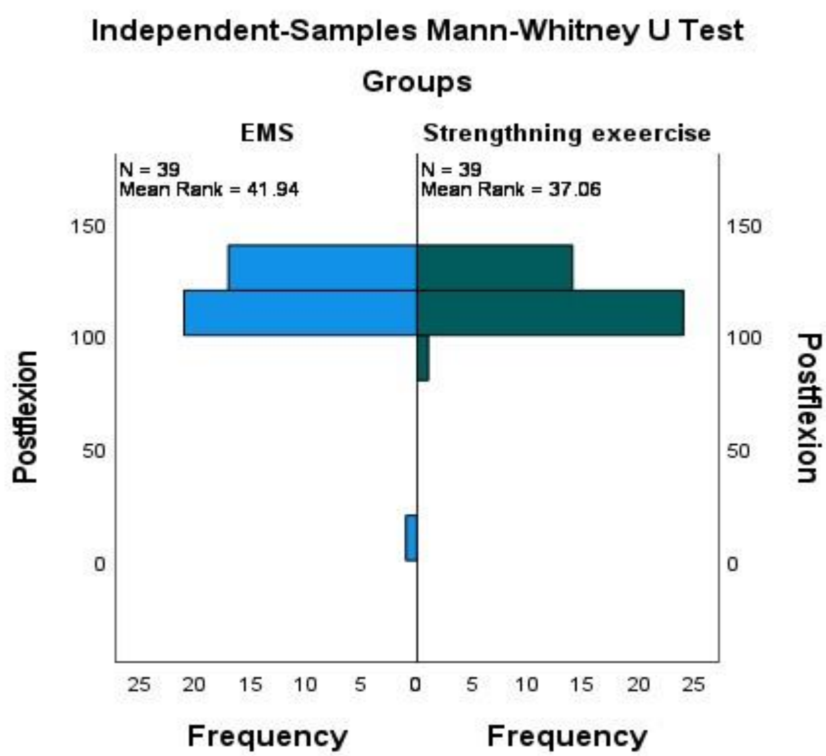

Figure 4.7: Independent sample Mann-Whitney U Test

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Figure showed comparison of post knee flexion between EMS group n=39 have the mean rank= 41.94 and strengthening exercises n=39 have mean rank=37.06 by using the Mann-Whitney U Test. EMS group shows a higher mean rank gives better

posttreatment knee flexion outcomes compared to strengthening group.

Table 4.11: Comparison of post-extension between group-I and group-II

Variable	Groups	Mean rank	Z - value	p - value
Post - extension	1	53.82	5.933	<.001
	2	25.18		

Table presented the comparison of two groups on the post-extension variable. Group 1 had higher mean rank than group 2 with Z-value of 5.933 and highly significant p-value of less than 0.001 indicated that a strong difference between the group.

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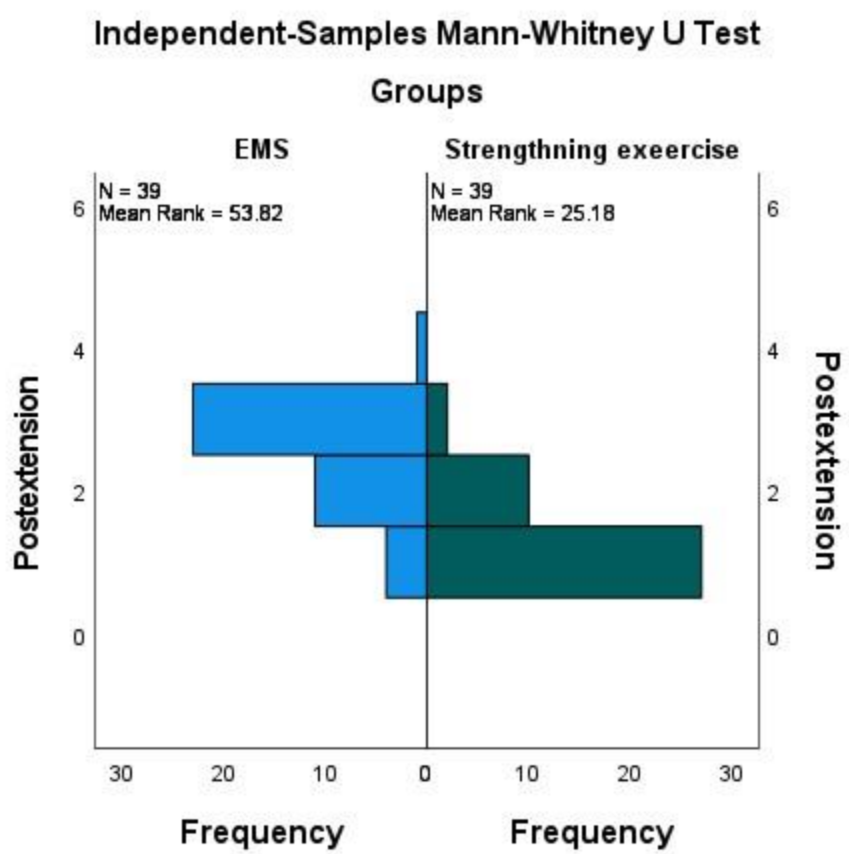

Figure 8: independent sample Mann-Whitney U test

EMS group having n=39 shows a higher mean rank as compared to the strengthening exercise group indicated the better post-extension performance.

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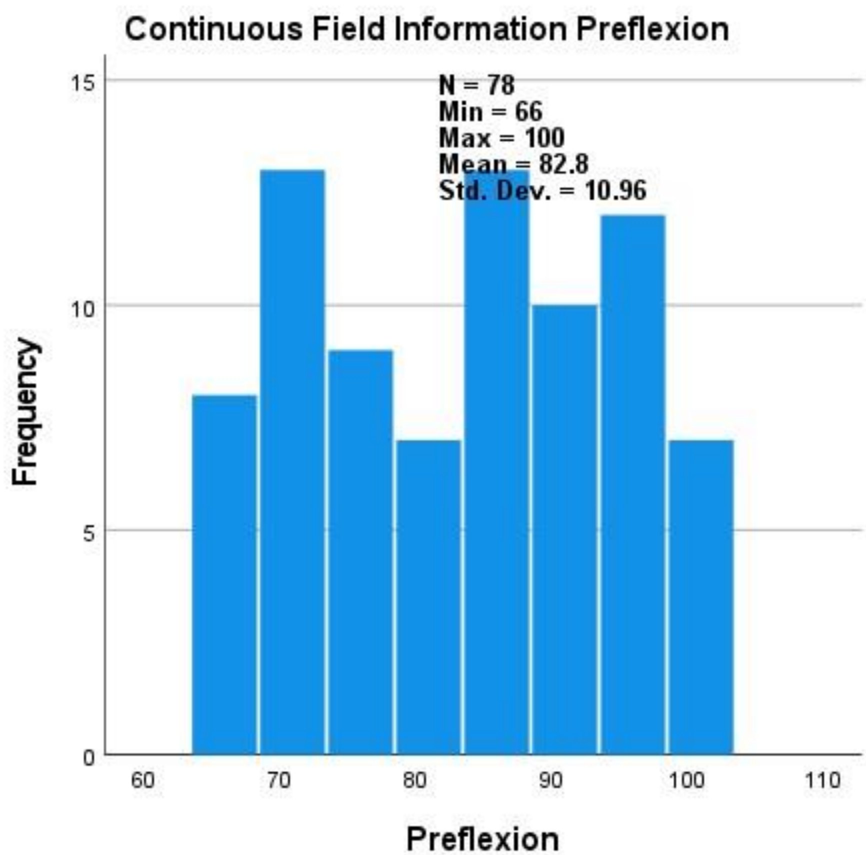

FIGURE 4.9: Bar-chart of preflexion

Histogram shows the ddistribution of preflexion scores for 78 individuals (n=78). The score range from 66 to 100 as a mean of 82.8 and standard deviation of 10.96.

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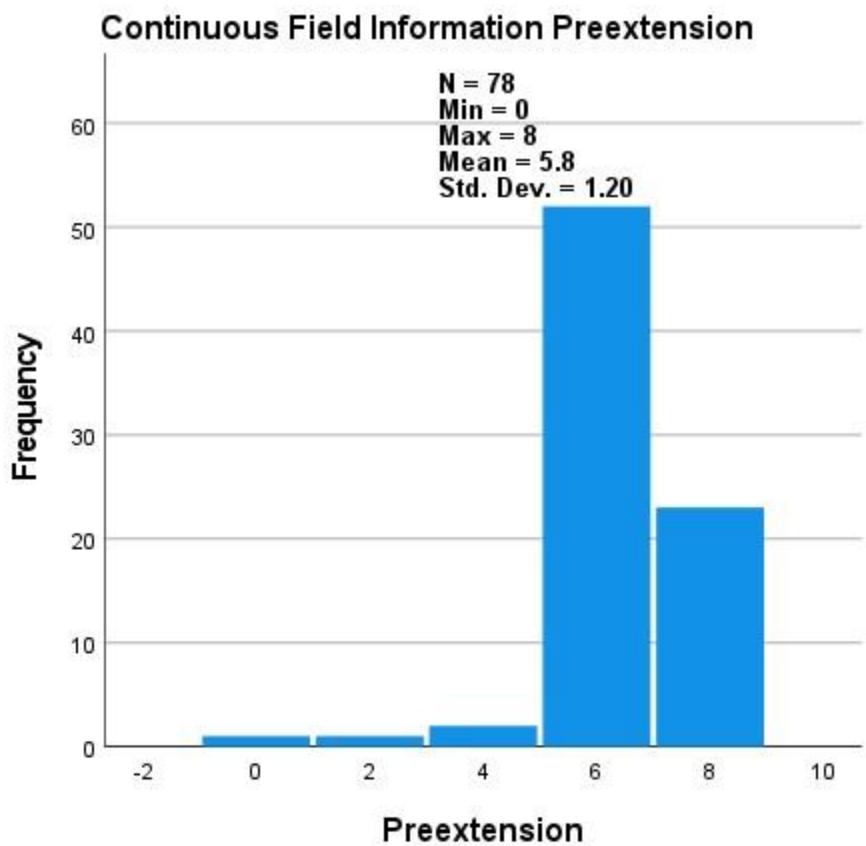

Figure 4.10: bar-chart of preextension

Figure shows the pre-extension scores for 78 individuals ranging from 0 to 8 having mean= 5.8 and a standard deviation = 1.20. Most of the values
cluster around 6 indicating low variability and right – skewed distribution.

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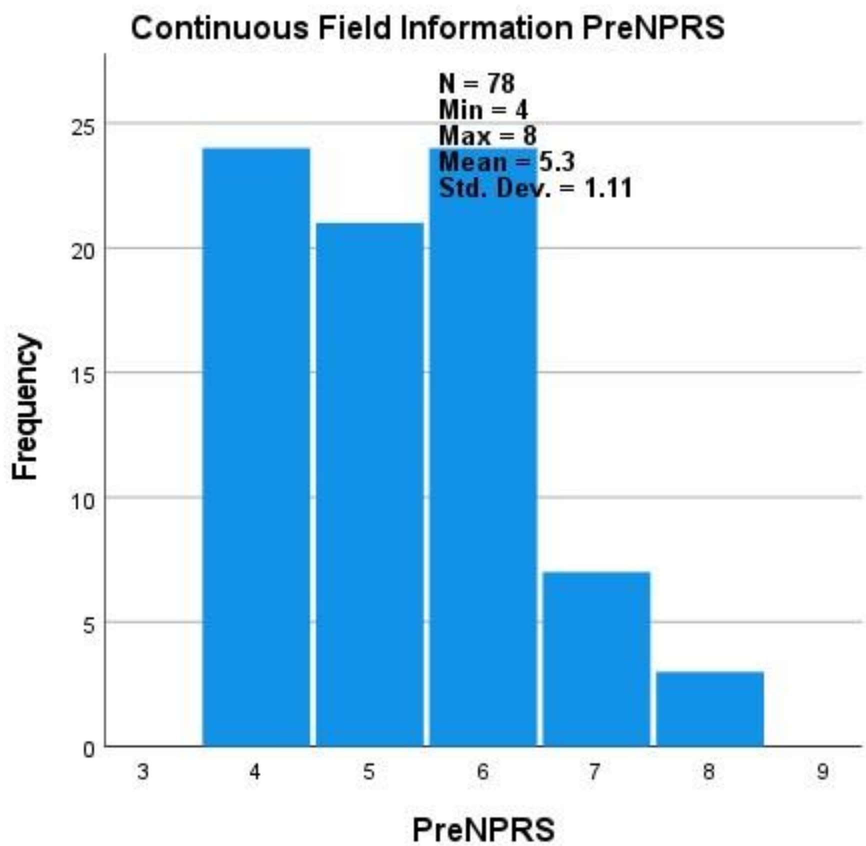

Figure 4.11: bar-chart of preNPRS

Histogram of preNPRS indicates that the individual n=78 with values that range from 4 to 8. The mean = 5.3 and the standard deviation = 1.11. Most of the participants scored between 4 and 6 indicate a moderately clustered distribution around the mean.

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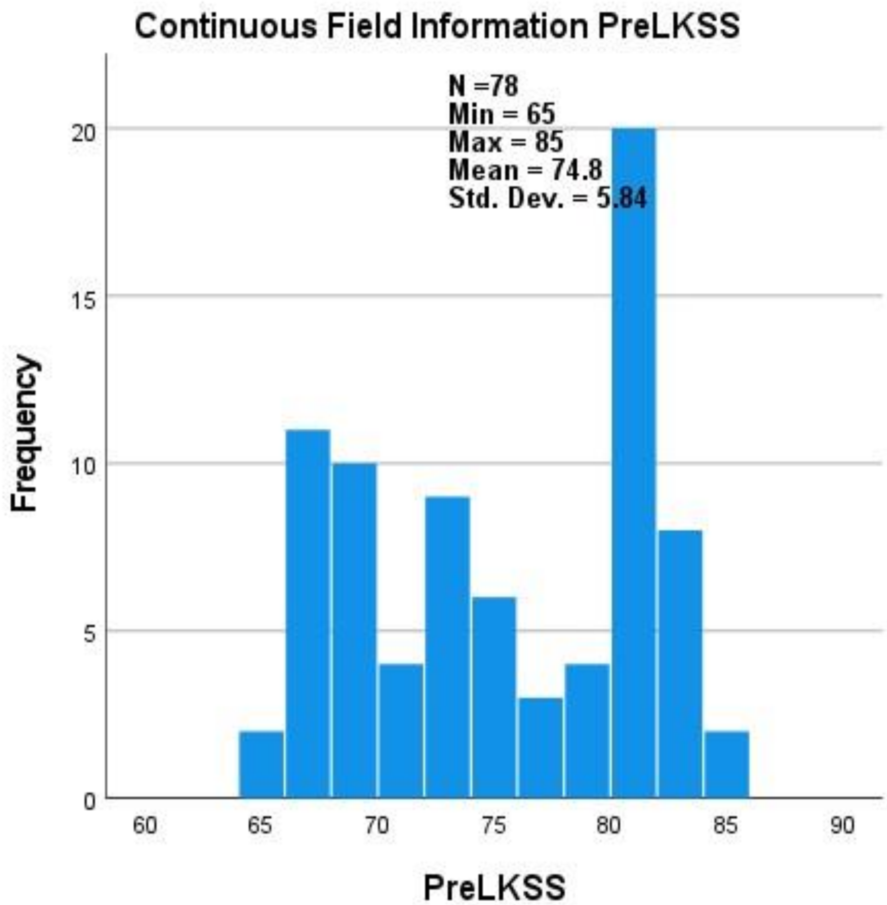

Figure 4.12: Bar-chart of preLKSS

Histogram of preLKSS presents the sample size n=78 that are ranging from 65 to 85. The mean = 74.8 with the standard deviation of 5.84. The distribution shows a peak near the upper end that indicate a concentration of scores between 80 and 85.

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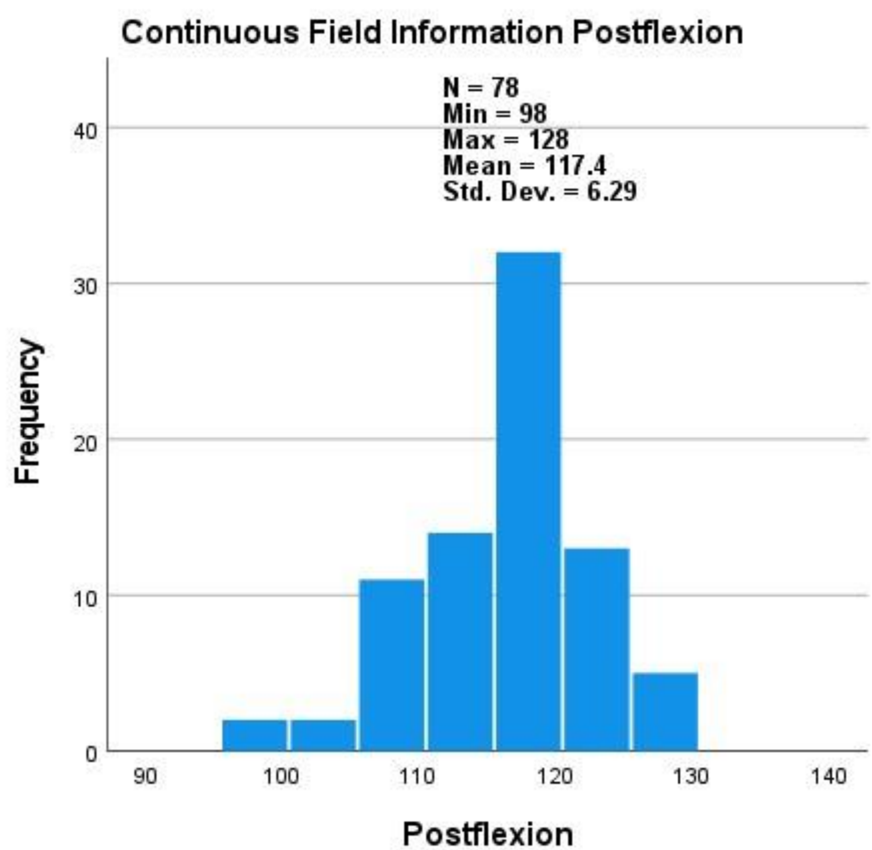

Figure 4.13: Bar-chart of post-flexion

The histogram of post-flexion displays the 78 individuals having flexion range from 98 to 128. The mean score I equal to 117.4 and standard deviation is equal to 6.29. Most of the scores are concentrated around the mean that indicate a normal distribution centered near 117.

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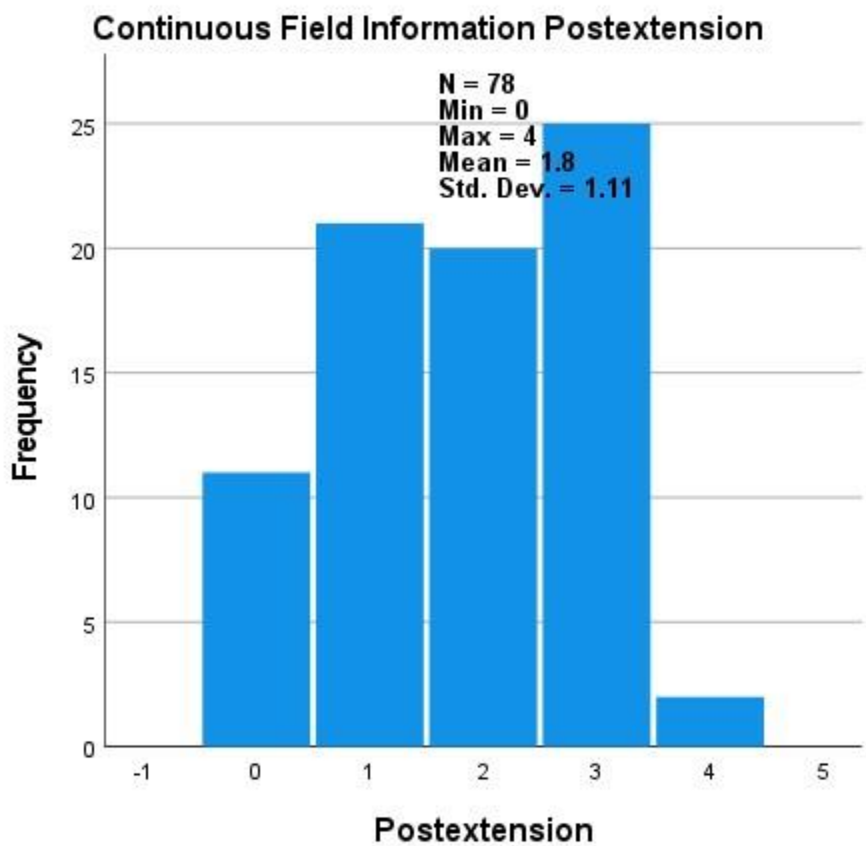

Figure 4.14: Bar-chart of postextension

Graph of postextension has the score n = 78 with values range from 0 to 4. The mean is about 1.8 and the standard deviation is 1.11. The distribution slightly right-skewed with most of the scores are clustered between 1 and 3.

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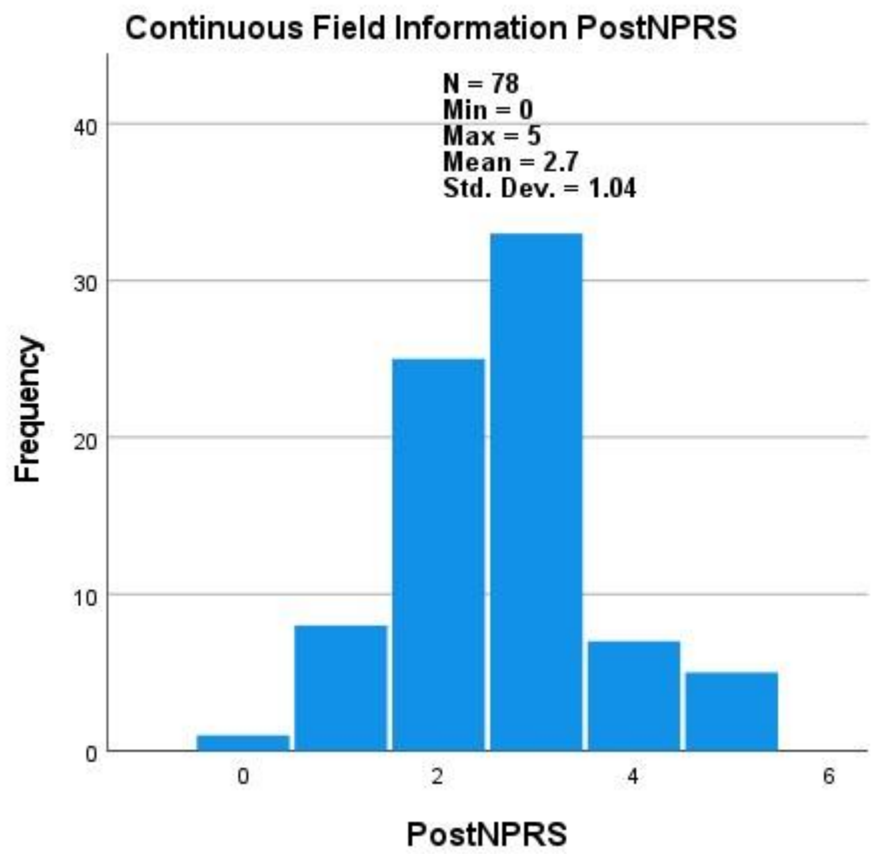

Figure 4.15: Bar-chart of postNPRS

Graph of postNPRS indicates that there are 78 individuals (n=78) having values range from 0 to 5. The mean score is 2.7 and the standard deviation is equal to 1.04. The scores are concentrated between 2 and 3 that showing a slightly left-skewed distribution and a general reduction.

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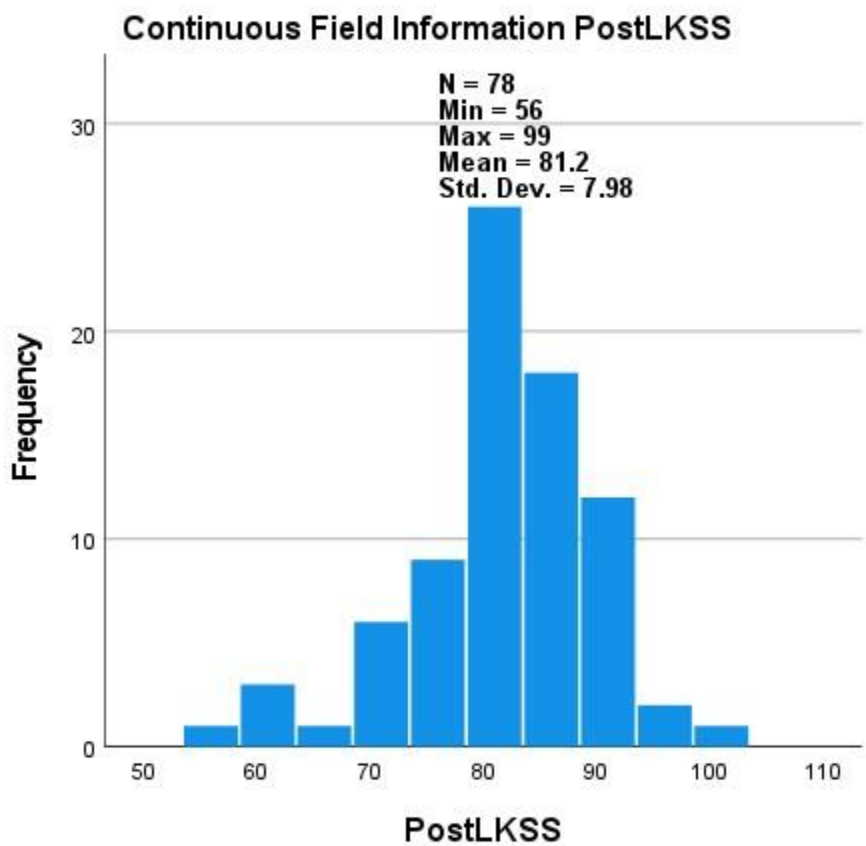

Figure 4.16: bar-chart of postLKSS

The graph shows the frequency of postLKSS in which there is individuals are 78. The values are ranging from 56 to 99. The histogram gives the mean that is 81.2 and standard deviation is 7.98. Most of the scores are concentrated between 75 and 90 that
indicating the improved and moderately clustered outcomes after intervention.

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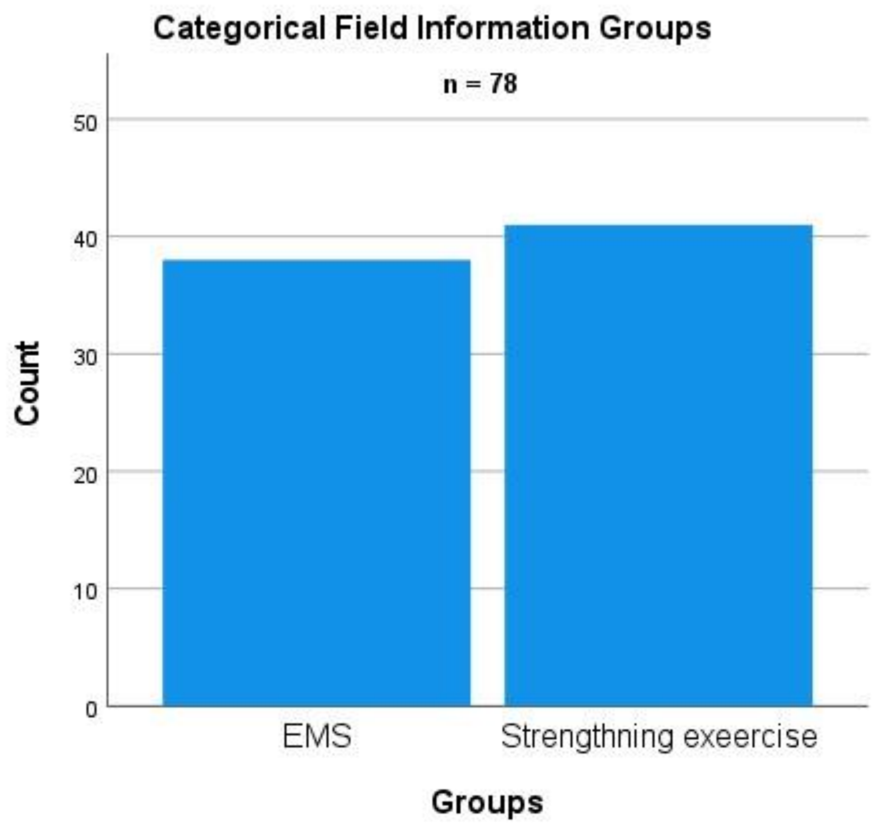

Figure 4.17: bar-chart of EMS group and Strengthening group

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The bar chart displays the distribution of participants across two groups. One is EMS group and second one is strengthening group. Out of 78 total participants, both groups have nearly equal represented strengthening exercise group have slightly better results then EMS group.

DISCUSSION

A study was conducted to evaluate the effectiveness of passive EMS as a preoperative intervention for athletes scheduled to undergo anterior cruciate ligament reconstruction (ACLR). Findings demonstrated that those who received preoperative EMS experienced significantly greater improvements in quadriceps muscle contraction and functional recovery, reaching levels comparable to participants who had normal EMG readings at baseline. Our

study is conducted to evaluate the effectiveness of EMS vs strengthening exercises in athletes with acute ACL injury. And the results of this study is Strengthening exercises are more effective than the EMS in athletes that are affected with ACL injury during sports.

As we choosed randomized clinical trial for our research in which we randomly allocated the two groups and both groups had 39 number of participants. To group 1 participants received treatment of EMS. There were four pads of EMS that were placing to vastus lateralis, vastus medialis, rectus femorus and below the knee to gain the strength of weak quadriceps due to acute ACL injury. We applied EMS that provide electrical stimulation to muscles that was usefull to reduce pain and gain strength. On the other hand, group-II underwent strengthning exercises aimed at gaining stability and mobility. Strengthening exercises played important role in the rehabilitation of acute ACL injury. Quadricep sets, hamstring curl, squat and bridging were included in the exercise protocol. We visited shapes sport club of the two districts Gujranwala and Lahore for data collection, local tournament in grounds and different gyms of Gujranwala. We explored different sport clubs of Gujranwala to get the data of acute ACL injury in athletes.

First of all, we take consent from participants and assessed them according to the knee evaluation form. We performed anterior drawer test, pivot shift test and lachman test. Based on these test, along with history of individual and inclusion/exclusion criteria we diagnosed acute ACL injury.

EMS which is electrical therapy used to reduce pain, chance of quardricep atrophy and swelling, applied for 10 minutes with 3 Hz frequency and intensity that patient tolerated. Strengthening exercises improved the stability, mobility of knee and we performed 2 sets of 10 repetitions of each selected exercise. There were two sessions of interventions per week for one month.

We provided intervention two days per week for one month and then evaluate the post condition of patient. We entered the data in SPSS which is Statistical Package for Social Sciences, for analysis of the outcomes of EMS and strenthening group.

We applied parametric test first that did not give the normal distribution of data as data was not normaly distrubute due to ordinal data we applied nonparametric test in which we used Mann-Whitney U test and get the results of pre-flexion, pre-extension, preNPRS, preLKSS, postflexion, postextensiom, postNPRS and postLKSS and have the significance level of 0.05. U test was used for two independent samples and also known as Mann-Whitney U statistics. In this test SPSS output

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gave the mean rank which was the average of scores of each group. To calculate the significance value (p value) their was the standarized version of U statistics called the Z-value. p-value (sig.) defined that significance level of data whether the difference was statistically significant or not. According to the non-parametric, Mann-Whitney U test patients who got strengthening exercises had better outcomes as compared to EMS group.

When treating patients with ACL injuries, it's helpful to use a combination of questionnaires and clinical tests to fully understand their current condition. In different studies, researchers used different evaluation form, clinical tests and functional tests and we use different electronic databases such as PubMed, google scholar and EMBASE for this purpose(Swain et al., 2014).

CHAPTER # 5
SUMMERY

ACL injury was the injury of connective tissue band that originated from medial side of the lateral femoral condyle and inserted to tibia anteriorly. Acute phase of ACL injury was three to six weeks after injury but in acute phase many individuals unaware that they had injury. They had pain, swelling and popping sound at the time of event. In RCT we had 78 participants after dividing into the two groups each had 39 individuals. Group 1 got EMS protocol and group 2 got strengthening exercise protocol. After taking consent participants filled the knee evaluation form we assessed the patient and performed the special tests. In case of positive testing we gave the follow up of two days per week for one month. After post-evaluation we enter the data and analyzed from SPSS, non-parametric test. We analysed that the group get strengthening exercise have more better effects as compared to EMS group.

RECOMMENDATION AND LIMITATION
RECOMMENDATION:

- Use both EMS and physical exercises together in rehab programs to speed up recovery and reduce the risk of re-injury.
- Design rehab plans that are tailored to the individual athlete's needs rather than using a uniform protocol for everyone.
- Organize educational sessions or workshops for athletes, coaches and trainers to explain the correct use and timing of EMS and exercise therapies.
- Encourage routine follow-ups with physiotherapists to fine-tune treatment plans based on how the athlete is responding.
- Future research should include athletes from different cities or provinces to better understand regional differences in recovery outcomes.
- Future research should explore long-term outcomes such as return to play, ongoing knee function and overall quality of life.
- Efforts should be made to provide affordable EMS equipment and increase access to trained physiotherapists particularly in local clinics and community sports centers.

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LIMITATION:

- The research was only conducted in Gujranwala and Lahore, so the findings may not apply to athletes in other regions with different rehabilitation environments.
- The study observed short-term outcomes, missing long-term results such as return to sport, re-injury risk or sustained recovery.
- Not all athletes may had followed the rehab program consistently which could affected the overall results.
- Participants had varying levels of ACL injury severity which might be influenced how effective EMS or exercises were for them.
- Some athletes had better access to EMS devices or rehab support, potentially leading to differences in treatment quality.
- Some results were based on athletes' personal feedback which can be influenced by bias or inaccurate reporting.
- A limited number of participants may reduced the ability to generalize findings or detect subtle differences between treatments.

ETHICAL CONSIDERATION

- Participants were fully informed about research objecctives, criteria, benefits, risks and must voluntarily agree to participate.
- This was researcher's responsibility to secured sensitive information unless explicit consent was given to disclose it.
- Research was minimized physical, psychological and social risk to participants.

Any potential harm was justified by the potential benefits.

- Data was reported truthfully without fabrication and plagiarism.
- The individuals who took part in the study were treated respectfully, with full acknowledgment of their personal rights including the freedom to leave the study whenever they chose.
- Efforts were made to ensure that both the advantages and responsibilities of the research were shared in a balanced manner avoiding any form of unfair treatment or exclusion.
- Any research that involved people or animals underwent careful review and was granted approval by a recognized ethics board to ensure adherence to proper ethical standards.

REFERENCES

Adıgüzel, N. S., Koç, M., Öztürk, B., Engin, H., Karaçam, A., Canlı, U., Orhan, B. E., & Aldhahi, M. I. (2024). The Effect of the Nordic Hamstring Curl Training Program on Athletic Performance in Young Football Players. *Applied Sciences*, *14*(22), 10249.

Akhmetyanov, R. R., & Davydova, E. V. (2025). [Effectiveness of muscles' preoperative preparation for reconstruction of anterior cruciate ligament of knee]. *Vopr*

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about
Online ISSN 3007-2387
Print ISSN 3007-2379
Jamil et al - 2026
DOI: http://doi.org/

Kurortol Fizioter Lech Fiz Kult, *102*(1), 51-57. https://doi.org/10.17116/kurort202510201151 (Effektivnost' predoperatsionnoi podgotovki myshts k rekonstruktsii perednei krestoobraznoi svyazki kolennogo sustava.)

Apseloff, N. A., Hughes, J. D., Devitt, B. M., & Musahl, V. (9900). Primary Anterior Cruciate Ligament Injury: Extrinsic and Intrinsic Risk Factors. *JAAOS - Journal of the American Academy of Orthopaedic Surgeons*, 10.5435/JAAOS-D-5424-00341. https://doi.org/10.5435/jaaos-d-24-00341

Ashour, A. A., Elhafez, S. M., ElMeligie, M. M., & Hanafy, A. F. (2024). Crossover effect of knee and ankle joint training on knee mechanics after ACL reconstruction: A randomized controlled trial. *Gait & Posture*, *113*, 512-518.

Avasthi, S., Aggarwal, P., Mahapatra, S., Nishat, N., Mishra, M., & Aslam, A. (2024). Diagnostic accuracy of lever sign test in acute and chronic ACL injuries. *Journal of Clinical Orthopaedics and Trauma*, *52*, 102427.

Banovetz, M. T., Familiari, F., Kennedy, N. I., Russo, R., Palco, M., Simonetta, R., DePhillipo, N. N., & LaPrade, R. F. (2023). Anatomy of the anterior cruciate ligament and the common autograft specimens for anterior cruciate ligament reconstruction. *Ann Jt*, *8*, 28. https://doi.org/10.21037/aoj-22-49

Çakar, A., Aktaş, M. A., & Atıcı, A. (2025). Predictors of Donor Site Morbidity Following Osteochondral Graft Harvesting from the Healthy Knee using Lysholm Knee Score. *Istanbul Medical Journal*.

Cho, S.-I., Kim, J.-W., Nam, S.-S., Moon, H.-W., & Jung, W.-S. (2023). Effects of a Rehabilitation Exercise Program Using Electro Muscle Stimulation following Anterior Cruciate Ligament Reconstruction on the Circumference, Activity, and Function of the Quadriceps Muscle. *Applied Sciences*, *13*(7), 4153. https://www.mdpi.com/2076-3417/13/7/4153

Cimino, F., Volk, B. S., & Setter, D. (2010). Anterior cruciate ligament injury: diagnosis, management, and prevention. *American family physician*, *82*(8), 917-922.

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., Hamrin Senorski, E., Rauer, T., Meredith, S. J., & The Panther Symposium, A. C. L. T. C. G. (2020). Treatment after anterior cruciate ligament injury: Panther Symposium ACL Treatment Consensus Group. *Knee surgery, sports traumatology, arthroscopy*, *28*(8), 2390-2402. https://doi.org/10.1007/s00167-020-06012-6

Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about
Online ISSN Print ISSN
3007-2387 3007-2379
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DOI: http://doi.org/

Fleming, B. C., Renstrom, P. A., Beynnon, B. D., Engstrom, B., Peura, G. D., Badger, G. J., & Johnson, R. J. (2001). The effect of weightbearing and external loading on anterior cruciate ligament strain. *Journal of biomechanics*, *34*(2), 163-170.

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-blind clinical trial. *Disabil Rehabil*, *41*(5), 514-522. https://doi.org/10.1080/09638288.2017.1399294

Kahl, C., & Cleland, J. A. (2005). Visual analogue scale, numeric pain rating scale and the McGill pain Questionnaire: an overview of psychometric properties. *Physical therapy reviews*, *10*(2), 123-128.

Koutures, C. (2024). Acute Knee Injuries. In *Pediatric Sports Medicine* (pp. 251-258). CRC Press.

Larsen, M. (2020). Effectiveness of Neuromuscular Electrical Stimulation on Quadriceps Strength After Anterior Cruciate Ligament Reconstruction.

Li, N., Yang, J., & Liao, Y. (2023). The effect of blood flow restriction training combined with electrical muscle stimulation on neuromuscular adaptation: a randomized controlled trial. *Frontiers in Physiology*, *14*, 1182249.

Li, Z., Jin, L., Chen, Z., Shang, Z., Geng, Y., Tian, S., & Dong, J. (2025). Effects of Neuromuscular Electrical Stimulation on Quadriceps Femoris Muscle Strength and Knee Joint Function in Patients After ACL Surgery: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Orthop J Sports Med*, *13*(1), 23259671241275071. https://doi.org/10.1177/23259671241275071

Meredith, S. J., Rauer, T., Chmielewski, T. L., Fink, C., Diermeier, T., Rothrauff, B. B., Svantesson, E., Hamrin Senorski, E., Hewett, T. E., & Sherman, S. L. (2020). Return to sport after anterior cruciate ligament injury: Panther Symposium ACL Injury Return to Sport Consensus Group. *Orthopaedic journal of sports medicine*, *8*(6), 2325967120930829.

Millett, A. A Guide to Early ACL Rehabilitation A Guide to Early ACL Rehabilitation.

Moran, U., Gottlieb, U., Gam, A., & Springer, S. (2019). Functional electrical stimulation following anterior cruciate ligament reconstruction: a randomized controlled pilot study. *J Neuroeng Rehabil*, *16*(1), 89. https://doi.org/10.1186/s12984019-0566-0

Müller, S., Bühl, L., Nüesch, C., Pagenstert, G., Mündermann, A., & Egloff, C. (2023).
Favorable Patient-Reported, Clinical, and Functional Outcomes 2 Years After ACL Repair and InternalBrace Augmentation Compared With ACL
Reconstruction and Healthy Controls. *The American Journal of Sports Medicine*,
51. https://doi.org/10.1177/03635465231194784

Osterberg, A., Kvist, J., & Dahlgren, M. (2012). Ways of Experiencing Participation and
Factors Affecting the Activity Level After Non-Reconstructed ACL Injury: A Qualitative Study. *The Journal of orthopaedic and sports physical therapy*, *43*. https://doi.org/10.2519/jospt.2013.4278

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Pakistan Journal of Medical & Cardiological Review

https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387

Print ISSN 3007-2379

DOI: http://doi.org/

Papaleontiou, A., Poupard, A. M., Mahajan, U. D., & Tsantanis, P. (2024). Conservative vs Surgical Treatment of Anterior Cruciate Ligament Rupture: A Systematic Review. *Cureus*, *16*(3).

Patel, P., Maja, G., Jennifer, T., Eugene, W., Melissa, M., a, A.-E. A., & and Chakravarthy, K. (2025). Latest Advancements in Transcutaneous Electrical Nerve Stimulation (TENS) and Electronic Muscle Stimulation (EMS): Revisiting an Established Therapy with New Possibilities. *Journal of Pain Research*, *18*(null), 137-153. https://doi.org/10.2147/JPR.S493162

Potts, G., Reid, D., & Larmer, P. (2022). The effectiveness of preoperative exercise programmes on quadriceps strength prior to and following anterior cruciate ligament (ACL) reconstruction: a systematic review. *Physical Therapy in Sport*, *54*, 16-28.

Sigit, M., Doewes, M., & Liskustyawati, H. (2024). The effect of open kinetic chain exercise and close kinetic chain exercise on strength quadriceps femoris muscle post anterior cruciate ligament surgery in terms of age. *Advances in Health and Exercise*, *4*(1), 10-16.

Sofuoğlu, C., Fujita, R. A., Keskin, K., Kamiş, O., & Akçay, N. (2025). Acute electrical muscle stimulation effects on strength and anaerobic power in soccer players. *International Journal of Sports Medicine*.

Song, Y., Che, X., Wang, Z., Li, M., Zhang, R., Wang, D., & Shi, Q. (2024). A randomized trial of treatment for anterior cruciate ligament reconstruction by radial extracorporeal shock wave therapy. *BMC Musculoskeletal Disorders*, *25*(1), 57. https://doi.org/10.1186/s12891-024-07177-8

Svensson, M., Lind, V., & Löfgren Harringe, M. (2019). Measurement of knee joint range of motion with a digital goniometer: A reliability study. *Physiotherapy Research International*, *24*(2), e1765.

Swain, M. S., Henschke, N., Kamper, S. J., Downie, A. S., Koes, B. W., & Maher, C. G. (2014). Accuracy of clinical tests in the diagnosis of anterior cruciate ligament injury: a systematic review. *Chiropractic & manual therapies*, *22*, 1-10.

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. https://doi.org/10.1186/s13075-020-02156-5

Yao, S., Cao, M., He, X., Fu, B. S., & Yung, P. S. (2021). Biological modulations to facilitate graft healing in anterior cruciate ligament reconstruction (ACLR), when and where to apply? A systematic review. *Journal of Orthopaedic Translation*, *30*, 51-60.

Yu, B., & Garrett, W. E. (2007). Mechanisms of non-contact ACL injuries. *British Journal of Sports Medicine*, *41*(