



Original Article



Biceps Femoris–Focused Eccentric Exercise Versus Standard Physiotherapy on Dynamic Knee Stability and Pain in Patients with Chronic Knee Pain: A Randomized Controlled Trial

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Abstract

Background: A common musculoskeletal issue that can affect dynamic knee stability, balance functional performance and quality of life is chronic knee pain. Exercise therapy is a first-line treatment, but it's unclear if *Biceps Femoris*-focused eccentric exercise has any additional benefits. **Objective:** To compare the effects of *Biceps Femoris*-focused eccentric exercise and regular physiotherapy on dynamic knee stability and pain in patients with chronic knee pain. **Methods:** This was a parallel group, single-blinded, randomized controlled trial conducted in the outpatient physiotherapy department of JPMC, BAWs Health Facility, Karachi, Pakistan, from 01 March 2026 to 31 August 2026. A total of 160 participants with chronic knee pain were randomly assigned to either the *Biceps Femoris*-focused eccentric exercise group (n = 80) or the standard physiotherapy exercise group (n = 80). For 6 weeks, both groups underwent 3 sessions of supervised exercise therapy three times per week for six weeks (18 sessions total). Progressive eccentric hamstring exercises emphasizing eccentric knee flexion, external tibial rotation and single-leg control were performed by the *Biceps Femoris*-focused eccentric exercise group. These exercises included Romanian deadlifts, lateral step-downs with external rotation cueing, prone knee curls with external tibial rotation, side-lying hip extension with knee flexed 30-45°, standing hip hinges with band resistance, single-leg squats to a box. Straight leg raises, mini-squats (0-45°), step-ups, terminal knee extension with band, static hamstring and calf stretches, and single-leg stance balance training were among the traditional knee rehabilitation exercises performed by the standard physiotherapy group. A total of 149 participants finished the study and were included in the final analysis (74 in the *Biceps Femoris*-focused eccentric exercise group and 75 in the standard physiotherapy group). The primary outcomes were dynamic knee stability which was assessed using the Star Excursion Balance Test, and pain intensity was assessed by using the Numerical Pain Rating Scale. Secondary outcomes were functional performance, knee-related disability, and adverse events. Data were analyzed using SPSS version 26.0, with statistical significance set at $p < 0.05$. **Results:** Dynamic knee stability, pain, functional performance and knee related disability all improved in both groups after six weeks. But compared to the standard physiotherapy group, the *Biceps Femoris*-focused eccentric exercise group significantly improved dynamic knee stability (mean change: 8.4 ± 3.1 vs. 3.6 ± 2.7 ; mean difference: 4.8; 95% CI: 3.9 to 5.7; $p < 0.001$). Additionally, the eccentric exercise group experienced a significantly higher reduction in pain (mean change: 3.3 ± 1.2 vs. 2.1 ± 1.3 ; mean difference: 1.2; 95% CI: 0.8 to 1.6; $p < 0.001$). Functional performance and knee related disability improved more in eccentric exercise group. The most frequent adverse event was mild muscle soreness; no significant adverse events were noted. **Conclusion:** For patients with chronic knee pain, *Biceps Femoris*-focused eccentric exercise was more beneficial than conventional physiotherapy in terms of enhancing dynamic knee stability and lowering pain. It might be suggested as a practical and safe supplement to conventional physiotherapy rehabilitation.

Introduction

One of the most prevalent musculoskeletal issues affecting adults globally is chronic knee pain, which is often linked to osteoarthritis in the knee, prior knee injuries, patellofemoral pain, obesity and age-related degenerative changes. The knee is the one of the most frequently affected joints, and osteoarthritis alone affected about 595 million people or 7.6% of total population [7]. Meniscal tears, patellofemoral pain, and osteoarthritis are common causes of knee pain that are often treated conservatively with self-management techniques, education and exercise [13]. Walking, climbing stairs, getting out of a chair, and maintaining balance during functional activities are all common challenges for people with chronic knee pain, which can result in disability and lower quality of life [1].

The ability of the knee joint to maintain control during weight bearing and functional movements through coordinated activity of quadriceps, hamstrings, hip muscles and sensorimotor system is known as dynamic knee stability. Impaired neuromuscular control, decreased muscle strength, altered proprioception, and abnormal frontal-plane knee movement can increase mechanical stress on the knee joint, leading to chronic knee pain and functional limitation [5]. Although the degree of this correlation varies depending on the type of knee condition, research suggests that improvements in dynamic knee movement control are linked to improvement in pain and function in individuals with knee disorders [5].

The first-line, non-pharmacological treatment for osteoarthritis and chronic knee pain is generally acknowledged to exercise therapy. Aerobic exercise, resistance training, cycling, yoga, and tai chi can improve pain, stiffness, physical function and quality of life in patients with knee osteoarthritis, according to a recent systemic review and network meta-analysis [4]. According to international guidelines, every patient with osteoarthritis of the hip or knee should give a customized exercise program that includes strength, aerobic, flexibility or neuromotor training, with dosage and progression based on patient's function and preferences [11]. Similarly, in patients with chronic knee pain, a 12-month randomized controlled trial found that multimodal active physiotherapy-which included structured exercise for flexibility, stability, neuromuscular control and coordination-produced greater improvements in pain and function than conventional physiotherapy [1].

Even though exercise therapy has been shown to effective, many standard physiotherapy programs focus mostly on general aerobic activities, pain-relieving techniques, quadriceps strengthening, and stretching. In patient with chronic knee pain, the function of the hamstring muscles-specifically, the *Biceps Femoris*-in dynamic knee control has received relatively less attention. The *Biceps Femoris* helps with tibial control during gait, stair descent, and other weight bearing activities. It also serves as an external rotator and knee flexor. Consequently, focused eccentric *Biceps Femoris* strengthening may increase

dynamic knee stability, improve neuromuscular control and lessen pain during functional activities.

Eccentric exercise is linked to beneficial neuromuscular adaptations and involves active lengthening of a muscle while creating tension. Hamstring eccentric training programs may lower the risk of lower-extremity injuries, including knee injuries, and may enhance muscle performance, according to systemic review and meta-analysis [2]. Additionally, a for-week Nordic hamstring exercise program significantly improved static and dynamic postural balance in recreationally active individuals when compared to a control group, according to a randomized controlled trial [6]. These results support the evaluation of eccentric exercise targeting the *Biceps Femoris* in patients with chronic knee pain.

However, in clinical populations, eccentric loading needs to be used with caution. Maximal isokinetic eccentric strengthening was linked to a higher rate of adverse muscle events than concentric strengthening, according to a randomized clinical trial in patients with knee osteoarthritis. This finding highlights the significance of gradual progression, appropriate intensity, and close monitoring when eccentric exercise is prescribed for painful knee conditions [3]. Therefore, compared to high-intensity maximal eccentric training, a supervised and progressive eccentric exercise program focused on the *Biceps Femoris* may offer a safer and more clinically feasible approach

Primary objective

To compare the effects of *Biceps Femoris*-focused eccentric exercise and standard physiotherapy on dynamic knee stability in patients with chronic knee pain.

Secondary Objectives

- To compare the effects of *Biceps Femoris*-focused eccentric exercise and standard physiotherapy on knee pain intensity.
- To compare the effects of both interventions on functional performance and knee-related disability.
- To assess the safety and tolerability of *Biceps Femoris*-focused eccentric exercise in patients with chronic knee pain.

Null Hypothesis (H₀): There were no significant difference between *Biceps Femoris*-focused eccentric exercise and standard physiotherapy in improving dynamic knee stability and pain in patients with chronic knee pain.

Alternative Hypothesis (H₁): *Biceps Femoris*-focused eccentric exercise was producing significantly greater improvement in dynamic knee stability and pain than standard physiotherapy in patients with chronic knee pain.

Review of the Literature

❖ Overview

The literature on dynamic knee stability, standard physiotherapy eccentric exercise, chronic knee pain, and functions of the *Biceps Femoris* in knee control is reviewed in this chapter. The epidemiology and functional effects of chronic pain are covered first in the review, followed by data on exercise-based rehabilitation. After that, it looks at common outcome measures, safety concerns, hamstring eccentric training and the possible role of *Biceps Femoris*-focused exercise. The research gap that supports the current randomized controlled trial is finally identified in the chapter.

❖ Chronic Knee Pain: Burden and Functional Impact

Chronic knee pain is a common musculoskeletal disorder that causes knee osteoarthritis, prior trauma, patellofemoral pain and degenerative joint changes. An estimated 595 million people worldwide, or 7.6% of the world's population had osteoarthritis in 2020 with the knee being one of the most commonly affected joints. Osteoarthritis is a significant contributor to the global burden of the disability [7].

Walking, climbing stairs, squatting and getting out of a chair are examples of weight-bearing activities that patients with chronic knee pain frequently report finding difficult. These restrictions could be brought by pain, weakened muscles, poor balance, changed joint mechanics, and diminished self-assurance when moving. A 12-month randomized controlled trial showed that multimodal active physiotherapy can gradually reduce pain and improve physical function and that chronic knee pain is linked to significant functional limitation [1].

Dynamic postural control was also impacted by chronic knee pain. People must control knee movement in multiple planes while maintaining balance during functional tasks. Patients may exhibit different movement strategies, a shorter reach distance during dynamic balance tasks, and more difficulty carrying out daily task when neuromuscular control is compromised [5].

❖ Dynamic Knee Stability and Neuromuscular Control

The ability to regulate knee position and movement during functional, weight-bearing activities is known as dynamic knee stability. Proprioception, active muscle forces, passive joint structures and neuromuscular coordination between the quadriceps, hamstrings, hip muscles, and trunk stabilizers are all important. Cause the hamstrings help regulate tibial movement and knee rotation, adequate hamstring activity is especially crucial during gait, stair descent and landing tasks.

Nunes et.al (2023) conducted a systemic review and meta-analysis to investigate the relationship between changes in dynamic knee movement control and changes in pain and function in individuals with knee disorders. The review discovered that in people with patellofemoral pain,

improvements in dynamic knee movement control-specifically, decreases in dynamic knee valgus-were linked to improvement in pain and function. However, there is a need for more research in populations with chronic knee pain cause the evidence in knee osteoarthritis was scant and unclear [5].

The Star Excursion Balance Test, single-leg balance test, and functional movement control-tasks are frequently used to evaluate dynamic balance. Dynamic balance might be diminished in patients with knee osteoarthritis due to pain, weakened muscles and compromised sensorimotor control. Combining balance and strengthening exercises improved dynamic balance, quadriceps strength, pain, functional performance and Western Ontario and McMaster Universities Osteoarthritis Index scores in a randomized controlled study of patients with primary knee osteoarthritis [8].

❖ Standard Physiotherapy for Chronic Knee Pain

Patient education, activity modification, pain management techniques, stretching, quadriceps and hip strengthening, aerobic exercise and functional training are all components of standard physiotherapy for chronic knee pain. The goals of these treatments are to lessen pain, strengthen muscles, increase range of motion and improve the patient's capacity to carry out everyday tasks. In order to lessen pain and enhance physical function, the National Institute for Health and Care Excellence also suggests therapeutic exercise, which includes aerobic fitness training and local muscle strengthening [12].

A key component of non-pharmacological treatment for osteoarthritis in the knee is exercise therapy. Aerobic exercise, resistance training, cycling, yoga and tai chi were found to improve pain, stiffness, physical function and quality of life in patients with knee osteoarthritis, according to a systemic review and network meta-analysis that compared various exercise modalities [4]. According to a review, treatment should be tailored to the patient's symptoms functional limitations, and objectives cause no single exercise modality is always better for all outcomes [4].

By combining exercise with education, self-management techniques and functional training, multimodal active physiotherapy may offer further advantages. Patients with chronic knee pain who received multimodal active physiotherapy improved their pain and function more than those who received traditional physiotherapy in a 12-month randomized controlled trial [1]. These results do not prove that targeted *Biceps Femoris* eccentric training is more beneficial than standard physiotherapy, but they do support the use of active, structured rehabilitation.

❖ Eccentric Exercise and Hamstring Function

When a muscle actively lengthens while exerting force, this is known as eccentric exercise. Eccentric training can result in a higher mechanical loading per unit of activation than concentric exercise, and it may enhance neuromuscular control, tendon stiffness and muscle strength. Eccentric exercise is frequently used in rehabilitation to enhance tissue tolerance and muscle performance.

In the context of sports and injury prevention, hamstring eccentric training has been extensively researched. According to a systemic review and meta-analysis of various hamstring eccentric exercise regimens, these regimens may enhance hamstring muscle function and lower the risk of lower-extremity injuries, including knee injuries [2]. The use of exercise-based programs, such as hamstring strengthening, to prevent knee injuries and enhance neuromuscular control is also supported by clinical practice guidelines [16]. The results indicate that hamstring eccentric training can enhance neuromuscular function and was useful for clinical rehabilitation, even though the majority of included studies involved athletes rather than patients with chronic knee pain.

One of the most popular eccentric hamstring exercises is the Nordic hamstring exercise. A four-week Nordic hamstring exercise program considerably improved static and dynamic postural balance in recreationally active individuals when compared to a control group, according to a randomized controlled trial [6]. This result is relevant to the current investigation since it implies that dynamic postural control-a factor directly linked to dynamic knee stability was impacted by eccentric hamstring loading

❖ *Biceps Femoris*-Focused Eccentric Exercise

The *Biceps Femoris* is the lateral hamstring muscle which serves as the tibia's external rotator, hip extensor and knee flexor. It helps with knee control when squatting, walking and descending stairs, among other practical activities. The *Biceps Femoris* eccentric control may affect tibial positioning, knee rotation and frontal-plane knee stability because it crosses both the hip and knee joints.

Modified Nordic hamstring exercises, eccentric hamstring curls, controlled hamstring-lowering exercises and eccentric hamstring strengthening with weights or resistance bands are examples of eccentric exercises that target the *Biceps Femoris*. The focus of these exercises is to gradually lengthen the *Biceps Femoris* while applying tension. Improved eccentric hamstring strength, increased neuromuscular activation, improved tibial control and improved dynamic knee stability are the suggested mechanisms of benefit.

There is little concrete proof that patients with chronic knee pain benefit from eccentric exercise that targets the *Biceps Femoris*. The majority of research that is currently available has focused on either eccentric quadriceps and hamstring strengthening in knee osteoarthritis or general hamstring eccentric training in athletic populations. Somaiya and Samal [9] suggested a randomized controlled trial protocol that compared low-intensity plyometric and eccentric training regimens for patients with osteoarthritis in knee. The planned outcomes included pain, strength and function. Nevertheless, this was a study protocol rather than a finished trial and the *Biceps Femoris* was not explicitly identified as the main target muscle [9].

❖ Safety and Tolerability of Eccentric Exercise

Eccentric exercise can cause more muscle damage and delayed-onset muscle soreness than concentric exercise, especially when done at high intensity, even though it may enhance neuromuscular control and muscle performance. Consequently, in clinical populations with chronic pain, eccentric programs should start out slowly, increase in intensity and closely monitored.

Maximum isokinetic eccentric strengthening was linked to a higher rate of adverse muscle events than concentric strengthening, according to a randomized clinical trial in patients with knee osteoarthritis [3]. This result implies that not all patients with osteoarthritis or chronic knee pain may benefit from maximal eccentric loading. *Biceps Femoris*-focused eccentric exercises were administered gradually and under supervision in the current study to reduce the possibility of excessive soreness, muscle strain or worsening of symptoms.

❖ Outcome Measures

The Star Excursion Balance Test, single-leg stance test, dynamic balance platforms, and movement-control tasks can all used to evaluate dynamic knee stability. The Star Excursion Balance Test is frequently used to assess dynamic postural control by having a single-limb stance and reaching as far as possible in various conditions. Reach distance gains was a sign of improved neuromuscular control, balance and functional stability

The Visual Analog Scale or Numerical Pain Rating Scale are frequently used to measure pain. These instruments offer a straightforward and practically viable way to measure pain levels both prior to and following intervention. Depending on the study population and goals, instruments like Western Ontario and McMaster Universities Osteoarthritis Index, Timed Up and Go Test, six-minute walk test, or Knee Injury and Osteoarthritis Outcome Score maybe used to evaluate functional performance and knee-related disability

Combined strengthening and balance programs had been demonstrated to improve dynamic balance, pain, functional performance and WOMAC scored in patients with osteoarthritis of the knee [8]. Therefore, it is appropriate to assess the efficacy of *Biceps Femoris*-focused eccentric exercise by taking into account both dynamic stability and pain outcomes.

❖ Research Gap

The majority of research has concentrated on general strengthening, aerobic exercise, quadriceps training or multimodal rehabilitation, despite the fact that exercise therapy was beneficial for chronic knee pain. The precise impact of *Biceps Femoris*-focused eccentric exercise on dynamic knee stability in patients with chronic knee pain has not been thoroughly studied by randomized research.

While knee osteoarthritis studies have frequently looked at general eccentric training rather than a targeted *Biceps Femoris* intervention, hamstring eccentric training studies had mostly been done in athletes and healthy individuals [2,9]. Additionally, the evidence that links better dynamic knee movement control to better pain and function is strongest in patellofemoral pain and is still unclear in other knee conditions like osteoarthritis and chronic knee pain [5].

Therefore, in patients with chronic knee pain, a randomized controlled trial comparing *Biceps Femoris*-focused eccentric exercise with conventional physiotherapy is required. A study like this could shed light on whether targeted hamstring eccentric training offers extra advantages for dynamic knee stability and pain alleviation.

Methodology

❖ Study Design

A single-blinded, parallel group, randomized controlled trial were used for this investigation. A *Biceps Femoris*-focused eccentric exercise group or a standard physiotherapy exercise were randomly assigned to participants with chronic knee pain. For a predetermined amount of time, both groups received supervised exercise therapy, and results were evaluated both before and after the intervention was finished.

The Consolidated Standard of Reporting Trials (CONSORT) statement were adhered to in this trial. The main comparison was between standard physiotherapy exercises and eccentric exercises that targeted the *Biceps Femoris*.

❖ Study Setting

The study was carried out in JPMC, BAWs Health Facility, Karachi, Pakistan, from 01 March 2026 to 31 August 2026.

❖ Duration

Three supervised sessions were held each week for the duration of six-week intervention. Each participant received a total of eighteen supervised sessions. At baseline and right after six-weeks intervention period, Outcome assessment was performed at baseline and immediately after the six-week intervention period.

❖ Population

Adults with chronic knee pain who engaged in supervised exercise therapy were included in the study population. There were both male and female participants

❖ Sampling Technique

To find the qualified participants, a non-probability consecutive sampling method was employed. Those who meet the requirements for inclusion were screened and given the opportunity to take part in the research

❖ Sample Size Calculation

GPower software (version 3.1.9.7) was used to determine the sample size for an independent samples t-test that compared

two independent groups. The main result of dynamic knee stability served as the basis for the computation.

A medium effect size of $d=0.50$ was chosen because it is a clinically significant and frequently reported effect size in exercise-based rehabilitation trials for chronic knee pain and knee osteoarthritis. The moderate effects of exercise interventions on pain and functional outcomes in patients with osteoarthritis in the knee are also consistent with this effect size [4].

The computation was performed using the following parameters:

- Statistical test: two-tailed independent samples t-test
- Alpha level (α): 0.05
- Power ($1-\beta$): 0.80
- Expected effect size: $d = 0.50$
- Allocation ratio: 1:1

According to these criteria, a minimum sample size of 64 participants per group was needed, for a total of 128 participants for attrition was taken into consideration.

The sample size was increased in the following ways to account for a 20% expected dropout rate:

$$64 \div (1-0.20) = 80 \quad 64 \div (1-0.20) = 80 \quad 64 \div (1-0.20) = 80$$

As a result, each group were recruit 80 participants

The ultimate sample size was:

Group	Participants
Group A: <i>Biceps Femoris</i> -focused eccentric exercise group	80
Group B: Standard physiotherapy exercise group	80
Total sample size	160

Parent Article / Basis for Effect size

The effect size of $d=0.50$ was chosen based on moderate treatment effects frequently reported in exercise-based randomized controlled trials and meta-analysis involving patients with osteoarthritis and chronic knee pain. According to recent systemic review and network meta-analysis, exercise therapy improves knee osteoarthritis patients' pain, stiffness, physical function and quality of life in a way that is clinically relevant [4].

Parent article reference:

Mo L, Jiang B, Mei T, Zhou D. Exercise therapy for knee osteoarthritis: a systematic review and network meta-analysis. *Orthopaedic journal of sports medicine*. 2023 May 30;11(5):23259671231172773 <https://doi.org/10.1177/23259671231172773>

❖ Eligibility Criteria

Inclusion Criteria

- Adults tween the ages of 30 and 65
- Chronic knee pain that lasts longer than three months, either unilaterally or bilaterally.
- Weight-bearing activities like walking, climbing stairs or squatting which can exacerbate pain.
- The capacity to walk on one's own with or without an assistive device
- Willingness to engage in exercise sessions under supervision
- The capacity to comprehend and adhere to exercise guidelines.

Exclusion Criteria

- Acute knee injury during the previous three months
- Knee injury in the previous six months
- Severe osteoarthritis in the knee that needed to be operated
- Septic arthritis, rheumatoid arthritis, or inflammatory arthritis
- Neurological disorders like peripheral neuropathy, Parkinson's disease and stroke that can impair balance or lower limb control
- Recent lower limb fracture.
- Severe respiratory, cardiovascular or uncontrolled systemic disease.
- pregnancy
- contraindicated to eccentric exercise if having acute hamstring injury or severe muscle soreness
- involvement in a different organized rehabilitation program while the study was conducted.

Operational Definitions

Chronic knee pain: Knee pain that lasts longer than three months during regular or weight bearing activities

Dynamic knee stability: The ability to regulate knee movement during functional weight bearing tasks which could be evaluated using tests like Star Excursion Balance Test, single-leg balance and dynamic movement control tasks.

Biceps Femoris-focused eccentric exercise: Supervised progressive programs that emphasize controlled lengthening contractions, such as modified Nordic hamstring curl, or controlled hamstring-lowering exercise.

Standard physiotherapy: Traditional physical therapy including patient education, hip and quadriceps strengthening, stretching, pain management technique as needed, and aerobic or functional exercise.

Pain: A Visual Analogue Scale or Numerical Pain Rating Scale are frequently used to measure self-reported knee pain intensity.

Randomization and Allocation Concealment

Computer-generated random numbers were used to assign eligible participants at random to one of the two study groups. An impartial individual who is not involved in a participant recruitment or outcome evaluation were prepare the allocation sequence.

Sequentially numbered, opaque, sealed envelopes were used to conceal allocation. The group allocation was contained in each envelope, which were only opened following the participants' official enrollment and baseline evaluation.

Scope and Delimitation of the Study

Adults with chronic knee pain who fit the eligibility requirements were included in this study, and they were randomly assigned to either standard physiotherapy or eccentric exercise focused on the *Biceps Femoris*. Dynamic knee stability and pain were the main results; functional performance, knee-related disability, and adverse events were secondary outcomes.

Only patients receiving treatment for chronic knee pain in outpatient physiotherapy settings were included in the study. Individuals with severe neurological impairment, inflammatory arthritis, major knee deformity, recent knee surgery, acute knee injury or contraindications to eccentric exercise were not allowed to participate. Therefore, adults with chronic knee pain who were able to safely engage in supervised exercise therapy were the main audience for the findings.

Binding

The group assignment was concealed from the outcome assessor. Due to the nature of the exercise interventions, participants and physiotherapist cannot blinded. Participants were told, nevertheless, not to give the outcome assessor any information about their intervention.

An independent statistician who was blind to group assignments analyzed the data.

Study Groups

Both groups received an identical total intervention dose, with each session lasting approximately 30–45 minutes and a total of 18 supervised sessions over six weeks. The two interventions were matched for session frequency, session duration, therapist contact time, and supervised setting; they differed only in the specific content of the exercises. This design minimized the risk that observed between-group differences were attributable to differences in treatment dose or therapist contact time.

Participants were divided into one of the following groups at random:

- **Group A:** *Biceps Femoris*-focused eccentric exercise group
- **Group B:** Standard physiotherapy exercise group

For six weeks, both groups were received exercise therapy under supervision three times a week.

Group A: *Biceps Femoris*-Focused Eccentric Exercise Group

A structured exercise program that emphasizes external tibial rotation, eccentric knee flexion, and single-leg control were given to this group. The program used were functional single-limb exercises and controlled lengthening contractions to target the *Biceps Femoris*.

Intervention Details

Exercise	Dosage	Progression
Single-leg Romanian deadlift with slow eccentric phase	2–3 sets of 8–12 repetitions per leg	Increase from body weight to light dumbbell or resistance band
Lateral step-down with external rotation cue	2–3 sets of 8–12 repetitions per leg	Increase step height or repetitions
Prone knee curl with external tibial rotation	2–3 sets of 8–12 repetitions per leg	Increase band resistance or manual resistance
Side-lying hip extension with knee flexed 30–45 degrees	2–3 sets of 10–15 repetitions per leg	Increase repetitions or add light ankle weight
Standing hip hinge with band or manual resistance and knee flexion control	2–3 sets of 8–12 repetitions	Increase band resistance or range of motion
Single-leg squat to box with external rotation cue	2–3 sets of 6–10 repetitions per leg	Reduce box height or increase repetitions

Exercise Descriptions

❖ Single-Leg Romanian Deadlift

The participants kept their spine neutral while standing on one leg and bending forward from the hip. For 3–4 seconds, the eccentric lowering phase were carried out slowly. The exercise used were single-leg stability and hip extension control to target the *Biceps Femoris*.

❖ Lateral Step-down with External Rotation Cue

The participant lowered the opposing foot gradually toward the floor while standing on a step. To prevent excessive knee valgus during the step-down, the participants were instructed to gently push the knee outward while the stance foot is positioned slightly outward. The descents were regulated to highlight hip control, hamstring, and eccentric quadriceps.

❖ Prone Knee Curl with External Tibial Rotation

The participant flexed their knee while lying prone against resistance from an elastic band or by hand. To highlight the activation of the *Biceps Femoris*, the foot was slightly rotated outward at the conclusion of knee flexion. To highlight eccentric knee flexion, the lowering phase were executed slowly.

❖ Side-lying Hip Extension with Knee Flexed 30–45 Degrees

The participant flexed their upper knee to about 30 to 45 degrees while lying on one side, there was a controlled extension of the upper hip. This position was encouraged for co-activation of the gluteus maximus and the long and short heads of the *Biceps Femoris*.

❖ Standing Hip Hinge with Band or Manual Resistance and Knee Flexion Control

The participant kept their knees slightly bent while maintaining a hip-hinge position. The participant gradually flexed and extend the knee through a partial range while holding a resistance band or experiencing manual resistance. Focus was on eccentric knee-flexion phase.

❖ Single-leg Squat to Box with External Rotation Cue

A controlled single-leg squat was performed until the participant barely touches a chair or a box. The participants were instructed to prevent knee collapse inward while the stance knee is positioned slightly outward. To highlight eccentric control, the lowering phase was carried out slowly.

Progression and Safety

Depending on the participant's tolerance, the intensity of the exercise was gradually increased. Repetitions, sets, resistance, range of motion or step height were increased to make progress. If participants feel sharp pain, lightheadedness, numbness or unusual discomfort, they were told to stop the exercise.

Eccentric exercise may result in delayed-onset muscle soreness. As a result, low resistance and fewer repetitions, were used in the first session fore gradually increasing

For individuals with osteoarthritis, therapeutic exercise regimens should offer a sufficient amount of exercise, with advancement determined by the person's goals, function and tolerance [15].

Group B: Standard Physiotherapy Exercise Group

The group were undergoing a standard knee rehabilitation program without an eccentric component specifically focused on the *Biceps Femoris*. Stretching, general balance training, functional weight-bearing exercises and the quadriceps strengthening was the part of the program.

Intervention Details

Exercise	Dosage	Progression
Straight leg raises	2–3 sets of 10–15 repetitions per leg	Increase repetitions or add light ankle weight
Mini-squat, 0–45 degrees knee flexion	2–3 sets of 10–15 repetitions	Increase repetitions or sets
Step-up on front step	2–3 sets of 8–12 repetitions per leg	Increase step height or repetitions
Terminal knee extension with band	2–3 sets of 10–15 repetitions per leg	Increase band resistance
Static hamstring stretches	2–3 repetitions of 20–30 seconds per leg	Increase holding time gradually
Calf stretch, gastrocnemius and soleus	2–3 repetitions of 20–30 seconds per leg	Increase holding time gradually
Single-leg stance on firm surface, eyes open	2–3 repetitions of 20–30 seconds per leg	Increase holding time or repetitions

Exercise Descriptions

❖ Straight Leg Raise

Lying on their back with one knee straight, the participant raises the leg to 30–45 degrees, then lowers it slowly. This strengthens the quadriceps and hip flexors.

❖ Mini-squat

Performing a partial squat from 0 to 45 degrees strengthens the quadriceps glutes, and calves, enhancing knee control.

❖ Step-up

Stepping onto a low step with one leg and returning to the start position improves functional strength and stair-climbing ability.

❖ Terminal Knee Extension with Band

Using a resistance band around the knee, the participant extends the knee against the resistance to target the quadriceps, especially the vastus medialis.

❖ Static Hamstring Stretch

A supine or sitting hamstring stretch held for 20–30 seconds enhances flexibility.

❖ Calf Stretch

A standing calf stretch with the back knee straight for the gastrocnemius and slightly bent for the soleus, each held for 20–30 seconds.

❖ General Balance Exercise

Standing on one leg with eyes open for 20–30 seconds improves static balance and postural control.

Progression and Safety

Clinical judgement and participant tolerance were determined the course of treatment. Repetitions, sets, resistance, step height and balance-holding time can all be increased to boost intensity. Participants were instructed to stop the exercise if they experience extreme pain, lightheadedness or discomfort.

Outcome Measures

❖ Primary Outcome Measures

Dynamic Knee Stability

Dynamic knee stability was assessed using the Star Excursion Balance Test (SEBT). The participant stood on one leg and reached as far as possible in the anterior, posteromedial, and posterolateral directions. Reach distance was normalized to leg length. Higher reach distances indicated better dynamic stability.

Pain Intensity

Pain was assessed using the Numerical Pain Rating Scale (NPRS). The participant rated knee pain during activity over the previous 24 hours. Higher scores indicated greater pain intensity [14].

❖ Secondary Outcome Measures

Functional Performance

Functional performance was assessed using the Timed Up and Go Test (TUG). This measure evaluated mobility, balance, and walking speed.

Knee-Related Disability

Knee-related disability was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

Adverse Events

Any adverse event, including increased pain, muscle soreness, cramps, dizziness, or injury, was recorded throughout the study period.

Data Collection Procedure

Age, sex, body mass index, length of knee pain, affected size, and comorbidities are among the baseline demographic information that were documented. Prior to randomization, baseline outcome measure was acquired.

As soon as the six-week intervention is over, outcome measures were re-evaluated. To minimize measurement bias, baseline and post-intervention assessments were conducted by the same assessor.

Data Analysis

SPSS Version 26.0 was used to analyze the data. The clinical and demographic features were summed up using descriptive statistics. For continuous variables, the mean and deviation were reported, whereas for categorical variables, the frequency and percentage were reported.

The Shapiro-Wilk test was used to determine whether the data was normal. An independent-sample t-test for normally distributed continuous data or the Mann-Whitney U-test for non-normally distributed data was used to compare baseline differences between groups. Fisher's exact test or the chi-square was used to compare categorical variables.

Dynamic knee stability (SEBT) was the main outcome, and an analysis of covariance (ANCOVA) was the main method of analysis. The dependent variable was the post-intervention score, the fixed factor was the treatment group, and the covariate was the corresponding baseline score. This method produced an adjusted mean between-group difference with a 95% confidence interval after accounting for baseline differences. An important secondary outcome that was examined using the same ANCOVA method was pain intensity (NPRS). Exploratory secondary outcomes included knee-related disability (WOMAC) and functional performance (TUG).

A Holm-Bonferroni correction was used to manage the family-wise Type I error rate for two primary/key secondary outcomes. Formal multiplicity adjustment was not used in the descriptive interpretation of exploratory results.

A paired-samples t-test for normally distributed data or the Wilcoxon signed-rank test for non-normally distributed data were used to analyze within-group changes; p-values were accompanied by mean changes and 95% confidence intervals.

For between-group variations in the primary and key secondary outcomes, standardized effect sizes (Cohen's d) with 95% confidence intervals were computed.

All participants who finished the six-intervention and had post-intervention outcome data (n=149; 74 in Group A and 75 in Group B) were included in the main analysis, which was a per-protocol (completer) analysis. The primary analysis did not include participants who left the intervention before it was finished. The robustness of the results under an intention-to-treat framework was evaluated through a sensitivity analysis that used multiple imputation for missing post-intervention data.

A significance level of $p < 0.05$ was set.

Ethical Considerations

The institutional ethical review committee was granted ethical approval prior to the study's start. After outlining the goals,

methods, possible risks, and advantages of the study, each participant was provided with written informed consent.

Participants were free to discontinue participation at any moment without it affecting their regular medical care. Participants were given identification codes, and data were stored safely to ensure confidentiality. To guarantee participant safety, a licensed physiotherapist oversaw the intervention.

Results

❖ Overview

The results of a randomized controlled-trial comparing standard physiotherapy exercise with eccentric exercise targeted at the *Biceps Femoris* in patients with chronic knee pain are presented in this chapter. Two equal groups of 80 participants each were randomly selected from a total of 160 participants.

Participant flow, baseline characteristics, primary and secondary outcome measures, within-group and between-group comparisons, and adverse events are the sequence in which the results are presented. The threshold for statistical significance was set at < 0.05 . SPSS version 26.0 was used to analyze the data.

❖ Participant Flow

A total of 212 individuals underwent eligibility screening. Of these, 56 were excluded for other reasons, 14 declined to participate, and 32 did not meet the inclusion criteria.

A total of 160 individuals were recruited and assigned at random:

Group A: *Biceps Femoris*-focused eccentric exercise group: 80 participants

Group B: Standard physiotherapy exercise group: 80 participants

Six individuals from Group A and 5 from Group B withdrew during the six-week intervention period. As a result, 74 participants in Group A and 75 participants in Group B finished the study and were taken into account for the final analysis.

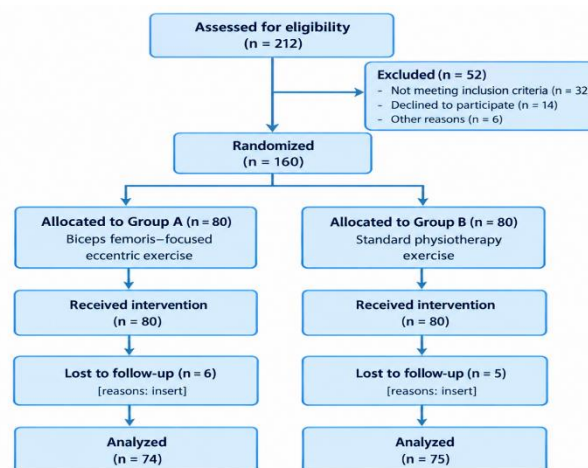


Table 4.1: Participant Flow Through the Trial

Stage	Group A: <i>Biceps Femoris</i> -focused eccentric exercise	Group B: Standard Physiotherapy	Total
Screened for eligibility	—	—	212
Excluded	—	—	52
Randomized	80	80	160
Completed Intervention	74	75	149
Dropouts	6	5	11
Analyzed	74	75	149

❖ Baseline Characteristics

Table 4.2 shows the clinical and demographic features of both groups. Age, sex, body mass index, duration of knee pain, affected side and baseline outcome scores did not differ statistically significantly between the two groups at baseline,

suggesting that the groups were similar at the beginning of the study.

Table 4.2: Baseline Demographic and Clinical Characteristics of Participants

Variable	Group A: <i>Biceps Femoris</i> -focused eccentric exercise (n=80)	Group B: Standard Physiotherapy (n=80)	p-value
Age in years, mean $\pm$ SD	48.6 $\pm$ 9.4	49.2 $\pm$ 9.1	0.642
Sex, male, n (%)	34 (42.5%)	36 (45.0%)	0.741
Sex, female, n (%)	46 (57.5%)	44 (55.0%)	0.741
Body mass index, kg/m ² , mean $\pm$ SD	27.8 $\pm$ 3.6	28.1 $\pm$ 3.8	0.589
Duration of knee pain in months, mean $\pm$ SD	14.7 $\pm$ 6.8	15.2 $\pm$ 7.1	0.617
Unilateral knee pain, n (%)	52 (65.0%)	54 (67.5%)	0.733
Bilateral knee pain, n (%)	28 (35.0%)	26 (32.5%)	0.733
Baseline dynamic knee stability score, mean $\pm$ SD	74.2 $\pm$ 6.9	74.5 $\pm$ 7.2	0.778
Baseline pain score, mean $\pm$ SD	6.4 $\pm$ 1.2	6.5 $\pm$ 1.3	0.596

❖ Primary Outcome Measures

Dynamic Knee Stability

The Star Excursion Balance Test composite score was used to evaluate dynamic knee stability. The *Biceps Femoris*-focused

eccentric exercise group showed noticeably more improvement than the standard physiotherapy group, but both groups showed improvement from baseline to post-intervention.

Table 4.3: Comparison of Dynamic Knee Stability Between Groups (Analyzed Sample: n = 74 and n = 75)

Outcome	Group A: <i>Biceps Femoris</i> -focused eccentric exercise (n = 74), Mean $\pm$ SD	Group B: Standard physiotherapy (n = 75), Mean $\pm$ SD	Mean Difference (95% CI)	Between-group p-value
Baseline score	74.2 $\pm$ 6.9	74.5 $\pm$ 7.2	0.3 (-1.8 to 2.4)	0.778
Post-intervention score	82.6 $\pm$ 6.4	78.1 $\pm$ 6.8	4.5 (2.5 to 6.5)	<0.001
Mean change from baseline	8.4 $\pm$ 3.1	3.6 $\pm$ 2.7	4.8 (3.9 to 5.7)	<0.001
p-value	<0.001		<0.001	<0.001

According to the tween-group comparison, the *Biceps Femoris*-focused eccentric exercise group improved dynamic knee stability significantly more than the standard physiotherapy group. ($p < 0.001$).

Pain Intensity

The Numerical Pain Rating Scale was used to measure the degree of pain. Following the intervention, both groups showed

a decrease in pain, but the *Biceps Femoris*-focused eccentric group showed a noticeably larger decrease.

Table 4.4: Comparison of Pain Intensity Between Groups (Analyzed Sample: $n = 74$ and $n = 75$)

Outcome	Group A: <i>Biceps Femoris</i> -focused eccentric exercise ($n = 74$), Mean $\pm$ SD	Group B: Standard physiotherapy ($n = 75$), Mean $\pm$ SD	Mean Difference (95% CI)	Between-group p-value
Baseline NPRS score	6.4 $\pm$ 1.2	6.5 $\pm$ 1.3	0.1 (-0.3 to 0.5)	0.596
Post-intervention NPRS score	3.1 $\pm$ 1.4	4.4 $\pm$ 1.5	1.3 (0.8 to 1.8)	<0.001
Mean change from baseline	3.3 $\pm$ 1.2	2.1 $\pm$ 1.3	1.2 (0.8 to 1.6)	<0.001

NPRS = Numerical Pain Rating Scale. Lower post-intervention scores indicate less pain. The between-group p-value refers to the comparison of mean change scores between groups.

❖ Secondary Outcome Measures

Functional Performance

The Timed Up and Go Test was used to evaluate functional performance. Better functional performance is indicated by

lower scores. Following the intervention, both groups showed improvement, but the *Biceps Femoris*-focused eccentric exercise group's improvement was noticeably higher.

Table 4.5: Comparison of Functional Performance Between Groups (Analyzed Sample: $n = 74$ and $n = 75$)

Outcome	Group A: <i>Biceps Femoris</i> -focused eccentric exercise ($n = 74$), Mean $\pm$ SD	Group B: Standard physiotherapy ($n = 75$), Mean $\pm$ SD	Mean Difference (95% CI)	Between-group p-value
Baseline TUG time (seconds)	12.8 $\pm$ 2.6	12.9 $\pm$ 2.7	0.1 (-0.7 to 0.9)	0.812
Post-intervention TUG time (seconds)	10.2 $\pm$ 2.3	11.4 $\pm$ 2.5	1.2 (0.5 to 1.9)	0.002
Mean change from baseline (seconds)	2.6 $\pm$ 1.4	1.5 $\pm$ 1.3	1.1 (0.4 to 1.8)	0.002

TUG = Timed Up and Go Test. Lower scores indicate better functional performance. The between-group p-value refers to the comparison of mean change scores between groups.

Knee-Related Disability

The Western Ontario and McMaster Universities Osteoarthritis Index was used to measure knee-related disability. better-knee

related function and less disability are indicated by lower scores.

Table 4.6: Comparison of Knee-Related Disability Between Groups (Analyzed Sample: $n = 74$ and $n = 75$)

Outcome	Group A: <i>Biceps Femoris</i> -focused eccentric exercise ($n = 74$), Mean $\pm$ SD	Group B: Standard physiotherapy ($n = 75$), Mean $\pm$ SD	Mean Difference (95% CI)	Between-group p-value
Baseline WOMAC score	48.6 $\pm$ 8.7	48.9 $\pm$ 8.9	0.3 (-2.3 to 2.9)	0.804
Post-intervention WOMAC score	31.2 $\pm$ 7.8	38.7 $\pm$ 8.4	7.5 (5.1 to 9.9)	<0.001
Mean change from baseline	17.4 $\pm$ 5.6	10.2 $\pm$ 5.1	7.2 (4.9 to 9.5)	<0.001

WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index. Lower scores indicate better knee-related function and less disability. The between-group p-value refers to the comparison of mean change scores between groups.

❖ Within-Group Comparison

According to within-group analysis, both groups significantly improved in dynamic knee stability, pain, functional

performance and knee-related disability from baseline to post-intervention.

Table 4.7: Within-Group Comparison from Baseline to Post-Intervention (Mean Change With 95% CI)

Outcome	Group A: Mean change (95% CI)	Group A: p-value	Group B: Mean change (95% CI)	Group B: p-value
Dynamic knee stability	8.4 (7.7 to 9.1)	<0.001	3.6 (3.0 to 4.2)	<0.001
Pain intensity	3.3 (3.0 to 3.6)	<0.001	2.1 (1.8 to 2.4)	<0.001
Functional performance (TUG)	2.6 (2.3 to 2.9)	<0.001	1.5 (1.2 to 1.8)	<0.001
Knee-related disability (WOMAC)	17.4 (16.1 to 18.7)	<0.001	10.2 (9.0 to 11.4)	<0.001

❖ Between-Group Comparison

The *Biceps Femoris*-focused eccentric exercise group significantly outperformed the standard physiotherapy group in terms of dynamic knee stability and pain intensity after controlling for baseline values. Additionally, functional performance and knee-related disability showed significant between-group differences.

Table 4.8: Between-Group Comparison After Six Weeks of Intervention

Outcome	Mean difference favoring Group A	95% confidence interval	p-value
Dynamic knee stability	4.8	3.9 to 5.7	<0.001
Pain intensity	1.2	0.8 to 1.6	<0.001
Functional performance	1.1	0.4 to 1.8	0.002
Knee-related disability	7.2	4.9 to 9.5	<0.001

❖ Adverse Events

Throughout the course of the study, adverse events were documented. The most frequently reported adverse event in the *Biceps Femoris*-focused eccentric exercise group was mild muscle soreness. During the study, no significant adverse events were reported.

Table 4.9: Adverse Events During the Intervention

Adverse event	Group A: <i>Biceps Femoris</i> -focused eccentric exercise, n(%)	Group B: Standard physiotherapy, n(%)
Mild muscle soreness	18 (24.3%)	4 (5.3%)
Increased knee pain	5 (6.8%)	3 (4.0%)
Muscle cramps	3 (4.1%)	1 (1.3%)
Dizziness	1 (1.4%)	1 (1.3%)
Serious adverse events	0 (0.0%)	0 (0.0%)

❖ Summary of Results

A total of 160 participants were randomized equally into two groups. After six weeks of treatment, both groups demonstrated improvements in knee-related disability, pain, dynamic knee stability and functional performance. However, compared to the standard physiotherapy group, the *Biceps Femoris*-focused eccentric exercise group showed a significantly greater improvement in dynamic knee stability and a greater reduction in pain.

Additionally, there was a significant improvement in functional performance and a greater reduction in knee-related disability in the eccentric exercise group that focused on the *Biceps Femoris*. The most frequent adverse event in this group was mild muscle soreness; neither group experienced any significant adverse events.

These results imply that eccentric exercise targeting the *Biceps Femoris* was a safe and useful supplement to conventional physical therapy for enhancing dynamic knee stability and lowering pain in individuals with chronic knee pain.

Discussion, Conclusion, Limitations, And Recommendations

❖ Overview

The primary results of a randomized controlled trial comparing standard physiotherapy exercise with *Biceps Femoris*-focused eccentric exercise in patients with chronic knee pain are presented in this chapter. The discussion highlights the clinical implications, explains potential mechanism hind the observed effects, evaluates the study's strengths and limitations and interprets the results in light of earlier research. Recommendations for future research and clinical practice are included at the end of the chapter.

❖ Discussion on the Main Findings

In the study, 160 patients with chronic knee pain were randomized to either standard physiotherapy exercise or eccentric exercise focused on the *Biceps Femoris*. For six weeks, both groups underwent three sessions of supervised exercise therapy. Dynamic knee stability and pain intensity were the main outcomes; functional performance, knee-related disability and adverse events were the secondary outcomes.

The study's primary conclusion was that eccentric exercise targeting the *Biceps Femoris* significantly improved dynamic knee stability more than conventional physical therapy. The dynamic knee stability score improved by an average of 8.4 points for the eccentric exercise group and 3.6 points for the standard physiotherapy group. The 4.8-point difference between the group was statistically significant ($p < 0.001$). This result lends credence to the theory that patients with chronic knee pain were benefited from targeted eccentric strengthening of the *Biceps Femoris* in terms of neuromuscular control and dynamic knee stability.

The intervention's particular focus on eccentric knee flexion, external tibial rotation, and single-leg control may account for the larger improvement in dynamic knee stability. Exercises that improve *Biceps Femoris* activation, hamstring strength and control of tibial movement during weight-bearing task include the single-leg Romanian deadlift, lateral stepdown with external rotation cue, prone knee curl with external tibial rotation and single-leg squat to box. Enhanced dynamic postural stability and less excessive knee movement may have resulted from improved hamstring control.

This result is in line with earlier research demonstrating that hamstring eccentric training can enhance postural control and neuromuscular function. A four-week Nordic hamstring exercise program considerably improved static and dynamic postural balance when compared to a control group, according to a randomized controlled trial by Podczarska-Głowacka et al. [6]. Similarly, hamstring eccentric training regimens may lower the risk of lower-extremity injuries and enhance muscle function, according to a systemic review and meta-analysis by Hu et al. [2]. The biological plausibility of the current findings is supported by these studies, despite the fact that they were primarily carried out in athletic or healthy populations.

Additionally, compared to standard physiotherapy, *Biceps Femoris*-focused eccentric exercise significantly reduced pain, according to the current study. In the eccentric exercise group, pain dropped from 6.4 to 3.1, while in the standard physiotherapy group, it dropped from 6.5 to 4.4. The Numeric Pain Rating Scale showed a statistically significant ($p < 0.001$) between-group difference of 1.2 points. This reduction may have clinical significance cause even minor pain reductions can boost self-esteem, mobility and engagement in everyday activities.

Improved dynamic knee control and decreased abnormal joint loading during functional activities were linked to the pain reduction. The knee was more stable when walking, descending stairs, and performing single-leg weight-bearing activities when hamstring neuromuscular control improves. Better movement control may lessen protective muscle guarding, lessen mechanical irritation, and ultimately lessen pain. Nunes et al. [5] found that improvements in dynamic knee movement control were linked to improvements in pain and function in individuals with knee disorders, leading credence to this interpretation.

Pain, dynamic knee stability, functional performance, and knee related disability all significantly improved within both groups. Given that exercise therapy is a proven first-line treatment for osteoarthritis and chronic knee pain, this result is not surprising. Aerobic exercise, resistance training, cycling, yoga and tai chi had been shown to improve pain, stiffness, physical function and quality of life in patients with knee osteoarthritis, according to a systemic review and network meta-analysis by Mo et al. [4]. Similarly, over the course of a 12-month follow-up, Cui et al. [1] discovered that multimodal active physiotherapy improved pain and function in patients with chronic knee pain.

However, the current study indicates that incorporating an eccentric component that focuses on the *Biceps Femoris* may offer advantages beyond those of conventional physical therapy. Compared to the standard physiotherapy group, the eccentric exercise group demonstrated a greater improvement in functional performance and a greater reduction in knee-related disability. The Timed Up and Go Test improved by 2.6 seconds in the eccentric exercise group, while the standard physiotherapy group's improved was 1.5 seconds. Comparably, the eccentric exercise group's WOMAC score increased by 17.4 points while the standard physiotherapy group's improved by 10.2 points.

The secondary findings are significant cause they imply that advantages of eccentric exercise targeting the *Biceps Femoris* may go beyond pain relief and balance. The patient's capacity to carry out functional tasks like walking, climbing stairs, standing up from a chair and maintaining single-limb balance may improve with improved hamstring control. As a result, the intervention was useful for helping patients with chronic knee pain perform better during everyday activities.

❖ Comparison with Previous Literature

The results of this study are in line with the larger body of research that supports exercise therapy as a treatment for chronic knee pain. Exercise interventions increase functional performance, neuromuscular control, muscle strength and balance, all of which may lessen pain and disability [4,1].

Evidence that hamstrings eccentric training can enhance postural balance supports the larger improvement in dynamic knee stability seen in the eccentric exercise group. Static and dynamic balance significantly improved following a four-week Nordic hamstring exercise program, according to Podczarska-Głowacka et al. [6]. The current study expands this evidence to patients with chronic knee pain by using a targeted *Biceps Femoris*-focused program that included functional single-leg tasks.

The systemic review by Nunes et al. [5] should be interpreted in conjunction with the current findings, but not directly. This review looked at the relationship between changes in pain and function and changes in dynamic knee movement control, particularly frontal-plane valgus/varus. In contrast, the Star Excursion Balance Test, which measures multidirectional single-leg reach rather than frontal-plane knee alignment, was used in this study to evaluate dynamic knee stability. The results of Nunes et al. [5] only offer indirect, contextual support

for the plausibility of a relationship between knee control and clinical outcomes, and the observed improvements in SEBT performance cannot be directly linked to improved frontal-plane knee control because valgus or varus movement control was not evaluated in the current trial. To determine whether *Biceps Femoris*-focused eccentric exercise enhances valgus control and whether such modifications mediate improvements in pain and function, future research should directly assess frontal-plane knee movements (e.g. two-dimensional or three-dimensional video analysis.)

The current study's safety conclusions are relevant. The *Biceps Femoris*-focused eccentric exercise group experienced more mild muscle soreness, but no significant side effects were noted. This aligns with the need for cautious eccentric loading in clinical populations. Coudeyre et al., [3] indicated that maximal eccentric strengthening might increase adverse muscle events in knee osteoarthritis patients. Thus, the supervised, progressive, submaximal eccentric program in this study appears to a safer clinical strategy.

❖ Hypothesized Mechanisms of Improvement

Since this study did not use electromyography, three-dimensional motion analysis, or direct measurement of muscle activation timing, the mechanisms listed below were not directly measured. As a result, rather than being proven mechanisms, the following explanations should be seen as tenable theories.

The greater improvements seen in the *Biceps Femoris*-focused eccentric exercise group could be explained by a number of mechanisms.

First, eccentric hamstring strength may be enhanced by eccentric exercise. The *Biceps Femoris* capacity to regulate tibial movement during functional task may be improved by increased eccentric strength. This could lessen excessive movement during weight-bearing activities and enhance knee joint control.

Second, neuromuscular activation may be enhanced by eccentric training. The timing of muscle activation during movement, hamstring and quadriceps coordination, and motor unit recruitment may all be improved by repeated exposure to controlled eccentric loading. Nevertheless, there was no direct evaluation of these neuromuscular adaptations.

Third, postural control and balance may be enhanced by single-leg exercises. Exercises that require control of the knee and hip while maintaining balance on one limb include the single leg Romanian deadlift, lateral step-down and single-leg squat to box. Dynamic stability, reactive control and proprioception may all be enhanced by these exercises, despite the lack of formal measurements for proprioception and reactive control.

Forth, better knee control could lessen abnormal joint loading. Improved function and less pain might result from reduced mechanical stress on the knee joint caused by better alignment

and control during functional tasks. Without biomechanical outcome data, this suggested pathway is still theoretical.

To directly test these suggested mechanisms, more research utilizing electromyography, three-dimensional motion analysis, and force-platform-based balance assessment is required.

❖ Critical Interpretation of Effect Sizes and Safety Findings

Compared to exercise-based trials for knee osteoarthritis and chronic knee pain, where standardized effect sizes typically range from 0.3 to 0.5, the between-group effect sizes seen in this study were larger.⁴ Therefore, care should be taken when interpreting the significant effect for dynamic knee stability (Cohen's $d=$). This result could have been caused by a number of factors. First, there may be a task-specific training effect rather than a general improvement in knee stability because the primary outcome measure (SEBT) shares movement characteristics with the intervention's single-leg exercises. Second, compared to lower-contact rehabilitation programs, the supervised, high-contact nature of the intervention might have increased adherence and dose effects. Third, by eliminating participants who withdrew, possibly those with worse tolerance or results, the per-protocol (completer) analysis may have overestimated treatment effects. These possibilities need to be confirmed in larger, independent, preferably multicenter samples with longer follow-up because they cannot be separated out in the current study.

The known muscle-damage response to unfamiliar eccentric loading is consistent with the higher rate of mild muscle soreness in the *Biceps Femoris*-focused eccentric exercise group (24.3% vs 5.3%). This difference should be taken into consideration when using eccentric exercise in clinical populations with chronic knee pain, even though there were no significant adverse events and the soreness was temporary. Although the lack of serious adverse events is encouraging, the rate of soreness indicates that a significant minority of patients may experience noticeable short-term muscle symptoms even with a progressive, submaximal eccentric protocol. Therefore, especially in older adults or those with lower baseline activity levels, clinicians should advise patients about expected soreness, employ gradual progression and closely monitor symptoms. In order to determine the lowest effective dose with least amount of symptom burden, future research should compare various eccentric dosing strategies and systemically grade the intensity and duration of soreness.

❖ Conceptual framework

The relationship between hamstring neuromuscular control, dynamic knee stability, pain and functional performance forms the basis of this study's conceptual framework. Impaired muscle activation, decreased hamstring strength, altered knee movement control and poor balance may all be linked to chronic knee pain. During functional activities, these

impairments may exacerbate abnormal joint loading and prolong pain [5].

It is expected that eccentric exercise targeting the *Biceps Femoris* will enhance dynamic knee stability, neuromuscular control and eccentric hamstring strength. When walking, descending stairs, and performing other weight-bearing activities, abnormal joint loading and pain might be lessened with better knee control. On the other hand, through patient education, general strengthening, stretching and traditional rehabilitation techniques, standard physiotherapy is supposed to improve pain and function [4,1].

Independent variable: *Biceps Femoris*-focused eccentric exercise versus standard physiotherapy

Dependent Variables: dynamic knee stability and pain

Possible secondary outcomes: functional performance, knee-related disability and adverse events.

❖ Clinical Implications

The results of this study indicate that patients with chronic knee pain may benefit from *Biceps Femoris*-focused eccentric exercise in addition to standard physiotherapy. In rehabilitation programs for patients with impaired dynamic knee stability, physiotherapist might think about incorporating progressive eccentric hamstring exercise, especially those that emphasize *Biceps Femoris* activation and single-leg control.

The intervention doesn't require expensive equipment and is inexpensive. Body weight, a step, a chair, resistance bands, or manual resistance could be used for the majority of exercise. As a result, the program might work in supervised home-based programs, rehabilitation facilities and outpatient physiotherapy settings.

Eccentric exercise should be added gradually. Clinicians should start with controlled range of motion and minimal resistance, then advance according to patient tolerance. Patients should be informed that mild muscle soreness is normal and encouraged to report any unusual symptoms, such as sharp pain or swelling.

The purpose of this randomized controlled trial is to ascertain whether patients with chronic knee pain benefit more from an eccentric exercise program focused on the *Biceps Femoris* than from standard physiotherapy in terms of dynamic knee stability and pain. If successful, the intervention could be an inexpensive easily implemented and supervised addition to standard physiotherapy practice.

For patients whose symptoms are associated with impaired posterior-thigh neuromuscular control, the results may assist physiotherapist in choosing more focused exercise regimens. Additionally, if hamstrings-focused eccentric loading is applied gradually and under proper supervision, it might be safe for patients with chronic knee pain. This is especially important cause prior studies have shown that patients with knee osteoarthritis might be more susceptible to muscle-related adverse events if they receive poorly dosed or maximal eccentric training [3].

❖ Strengths of the Study

This study has number of advantages. It employed a randomized controlled design with blinded outcome evaluation and allocation concealment. The 160 participants in the sample had sufficient power to identify a medium effect size for the main outcome. For six weeks, both groups underwent supervised exercise therapy, which increased treatment fidelity.

Through eccentric knee flexion, external tibial rotation, and single-leg control, the intervention was specifically created to target the *Biceps Femoris*. cause the study assessed a focused rehabilitation approach rather than a general exercise regimen, it is clinically relevant. Furthermore, a more thorough assessment of treatment effects was made possible by the evaluation of both primary and secondary outcomes.

❖ Limitations of the Study

This study has a number of limitations despite its advantages. First, due to the nature of the exercise interventions, it was not possible to blind participants and treating physiotherapists. Performance bias cannot totally rule out, even though the outcome assessor was blinded.

Secondly, the duration of the intervention was restricted to six weeks. It is unknown how eccentric exercise targeting the *Biceps Femoris* will affect pain, stability and functions in the long run. Follow-up evaluations at three, six and twelve months should be included in future research.

Third, patients from outpatient physiotherapy settings who had chronic knee pain were included in the study. As a result, patients with severe osteoarthritis in their knees, knee pain following surgery or substantial comorbidities may not able to apply the results.

Fourth, clinical balance measures were used to evaluate dynamic knee stability. These measurements may not fully capture all facets of knee joint control, such as muscle activation timing, joint mechanics, or movement quality during gait, even though they are practical and clinically significant.

The single-leg reaching used in the primary outcome measure (SEBT) is similar to the single-leg exercises used in the intervention in terms of movement. The intervention also included multi-planar and functional weight-bearing activities that did not directly replicate the SEBT reaching pattern, though this might have contributed to a task-specific training effect. To differentiate general improvements in knee stability from task-specific learning effects, future research should incorporate additional objective outcome measures, such as hop tests or three-dimensional motion analysis.

Fifth, there was no objective way to gauge adherence to at-home workouts. To more precisely measure compliance, future research should make use of digital adherence tools, wearable activity monitors or exercise logs.

The results' applicability to particular diagnostic subgroups may be limited by the inclusion of a diverse population with chronic knee pain. The sample size within each diagnostic

subgroup may have been too small to identify significant differences, despite the fact that a subgroup analysis by primary diagnosis was carried out. Future research should either use larger samples with sufficient power for subgroup analyses or concentrate on diagnostically homogenous populations.

❖ Recommendations for Future Research

Future research should use follow-up evaluations at three, six and twelve months to assess the long-term effects of eccentric exercise focused on the *Biceps Femoris*. Additionally, studies should contrast this intervention with other focused rehabilitation techniques like neuromuscular electrical stimulation, proprioceptive training or quadriceps-focus strengthening.

Objective biomechanical results, such as electromyography, three-dimensional motion analysis, and force-platform-based balance evaluation should be included in future trials. The methods by which *Biceps Femoris* eccentric exercise enhances knee control may be better understood of biomechanics.

The effectiveness of the intervention in particular subgroups, such as patients with osteoarthritis in the knee, patellofemoral pain, obesity or a history of knee injuries, should also be investigated. Lastly, future studies should assess the viability and efficacy of home-based eccentric exercise regimens that target the *Biceps Femoris* or tele-rehabilitation.

Conclusion

According to the results of this randomized controlled trial, patients with chronic knee pain may benefit more from biceps-femoris-focused eccentric exercise than from standard physiotherapy exercises for enhancing dynamic knee stability and lowering pain. Additionally, there was a greater decrease in knee-related disability and a greater improvement in functional performance in the eccentric exercise group.

The *Biceps Femoris*-focused eccentric exercise group showed better results for the main outcomes, but both interventions produced notable within-group improvements. The most frequent adverse event was mild muscle soreness; no significant adverse events were noted.

For patients with chronic knee pain, especially those with impaired dynamic knee stability, *Biceps Femoris*-focused eccentric exercise may be suggested as a safe, affordable and effective addition to standard physiotherapy. To validate and expand on these results, longer follow-up studies with objective biomechanical outcomes are required.

Conflict of Interest: NIL

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Authors' Contribution:

- All Authors Conceptualization, data collection, interpretation, drafting of the manuscript and intellectual revisions
- The authors agree to take responsibility for every facet of the work, making sure that any concerns about its integrity or veracity are thoroughly examined and addressed

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