RESEARCH PAPER

Efficacy of Ankle Proprioceptive Neuromuscular Facilitation with Mulligan Mobilization Versus Conventional Therapy in Restoring Ankle Biomechanics Following Plantar Fasciitis - A Comparative Study

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ABSTRACT

Background: Plantar fasciitis, a common musculoskeletal condition, affects 1-2 million people annually and 10% of the general population. It is more common in active working adults aged 25-65. Pain is often triggered by loading and inactivity. Mulligan's concept approach to orthopaedic manual physical therapy posits that the plantar fascia and the subtalar joint is responsible for plantar heel pain, aiming to improve joint mobility, reduce pain, and restore biomechanical integrity whereas, PNF enhances neuromuscular stimulation, promoting muscle contraction and stretching, improving movement patterns, joint mobility, strength, flexibility, balance, and reducing pain in tight tissues.

Objective: There would be very little research related to the effectiveness of ankle PNF with Mulligan mobilization. So, the purpose is to compare the impact of ankle PNF with Mulligan mobilization and conventional therapy on pain, foot biomechanical function, and functional quality of foot in individuals with plantar fasciitis.

Methodology: The study was conducted at NIMS University, Jaipur, and Rajasthan. Total 60 patients with plantar fasciitis were randomly assigned into two groups, that is 30 in each group and named as Group A (Ankle PNF with Mulligan Mobilization) and Group B (Conventional therapy), the treatment was administered over six weeks, 4 days per week. The outcomes were evaluated through using the numerical pain rating scale (NPRS), dorsiflexion range, the Weight-bearing Lunge Test (WBLT), and the Foot Function Index (FFI) before the intervention and after six weeks, again as post-intervention assessments.

Result: Post intervention, both groups showed clinical significant improvements ($p<0.0001$) in pain, ankle dorsiflexion range, weight-bearing function, and foot functionality. However, group A showed significantly greater improvements ($p<0.05$) across the dorsiflexion range, WBLT and functional scale, suggesting the combined PNF and Mulligan mobilization approach is superior. Conclusion- The study found that the combination of ankle PNF and Mulligan mobilization offers a holistic approach to plantar fasciitis, with significant clinical relevance. It is particularly beneficial for those with physically demanding work or hobbies, such as long-time standing work or sports.

Keywords: Plantar Fasciitis, Ankle PNF, Mulligan mobilization, FFI, WBLT.

How to cite this article: Riya, Kumari J, Stanley SR, Kumar V, Khan HP, Mittal K, Kanwar O.., Efficacy of Ankle Proprioceptive Neuromuscular Facilitation with Mulligan Mobilization Versus Conventional Therapy in Restoring Ankle Biomechanics Following Plantar Fasciitis - A Comparative Study. Int J Drug Deliv Technol. 2026;16(3s): 502-513; DOI: 10.25258/ijddt.16.3s.64

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Plantar fasciitis or plantar heel pain is a common musculoskeletal complaint that affects an estimated 1–2 million people annually and approximately 10% of the population at some point during their lives. The exact incidence and prevalence of plantar fasciitis by age are unknown [1]. Some literature shows high prevalence rates among runners as 22%. Thought to occur in about 10% of the general population, 83% of these patients are active working adults between the ages of 25 to 65 years old. 11% to 15% of all foot symptoms require professional medical care [2]. Plantar fasciitis pain can cause significant disability and a low health-related quality of life (QoL). There is a significant correlation between BMI and changes in the foot arch height in young adults. Recent research on young adults found that obese people are more likely to develop plantar fasciitis because their plantar fascia is thicker and their foot arch is lower than that of people of normal weight.[5]

In plantar heel pain, pain is often provoked with loading and the initial few steps following periods of inactivity, such as rising from sleep in the morning and increasing toward the end of the day. Patients may have decreased ankle dorsiflexion secondary to a tight Achilles tendon, which

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may lead to compensatory pronation of the foot. Up to one-third of patients with plantar fasciitis will present with bilateral symptoms. Some evidence suggests that intrinsic and extrinsic risk factors, both modifiable and non-modifiable, influence the development of plantar fasciitis. These elements consist of factors such as prolonged standing, inappropriate footwear, previous injury, limited dorsiflexion of the ankle, hyper-pronation of the foot, weak calf musculature, aging, increased body mass index, and alteration of ankle-foot biomechanics resulting from soft tissue or joint limitation [3, 4, 5].

The Mulligan concept approach to orthopedic manual physical therapy (OMPT) was conceived by a New Zealand physiotherapist, Brian R. Mulligan. Mulligan has postulated that the subtalar joint, plantar fascia, is responsible for plantar heel pain. He proposed that there was a positional fault at the subtalar joint, and clinically, the tapping technique applied in a particular manner following a series of joint mobilization proved beneficial. Recent research shows that the Mulligan mobilization and stretching exercises group received subtalar traction, talocrural posterior glide, subtalar lateral glide, first tarsometatarsal joint dorsal glide, gastrocnemius stretching and plantar fascia specific stretching to the affected foot to improve joint mobility and decrease pain and to restore biomechanical integrity. Particularly to the ankle complex, in participants status post lateral ankle sprains, the Mulligan concept was shown to have a positive effect on ankle dorsiflexion mobility and pain levels [6,7,8,9] . PNF is a technique to improve the neuromuscular stimulation of the proprioceptive sense response system. These methods include ways to stimulate the proprioceptive sense, which improves the response of neurological and muscular systems. PNF is a type of neuromuscular facilitation that causes muscles to contract or stretch, leading to patterns of movement that incorporate both. To coordinate and develop the movement patterns of the foot's intrinsic and exterior muscles to increase joint mobility; and to enhance muscle strength, flexibility, and balance [10, 11]. Recent studies have demonstrated that PNF stretching, such as hold-relax or contract-relax, improves the flexibility and decreases pain in tight tissues like the calf muscles, Achilles tendon, and plantar fascia.

Additionally, PNF encourages better joint mobility and coordination, which reduces the risk of injury and aids in the restoration of functional movement patterns [12, 13, 14]. Strengthening exercises for the intrinsic foot muscles and stretching exercises for the calf and plantar fascia are key components of traditional physiotherapy therapies. Stretching, especially of the plantar fascia, improves tissue extensibility, lessens discomfort, and lowers mechanical stress. Frequent plantar fascia and gastrocnemius- soleus complex stretching reduces pain and enhances foot biomechanics [16, 17] . Because they assist dynamic arch support and stability of the foot, strengthening the intrinsic foot muscles, such as the flexor hallucis brevis, flexor digitorum brevis, and abductor hallucis, is an essential component of rehabilitation [15]

MATERIALS & METHODOLOGY

STUDY DESIGN: Comparative Study

STUDY AREA: NIMS University, Jaipur, Rajasthan

STUDY PERIOD: From January 2025 to March 2025

STUDY POPULATION: Students and staff from NIMS University

SAMPLE SIZE: A total of 60 patients were included in the study from NIMS University

SAMPLING TECHNIQUE: A single blind randomized controlled trial was conducted at NIMS University

Inclusion Criteria:

People in the age group 25- 35 years.

Having Pain for More than 4 weeks with no radiating pain.

Having morning pain and stiffness.

Windlass test positive.

No history of other musculoskeletal conditions around the foot region (Fracture, foot deformity, trauma, degenerative changes).

Exclusion Criteria:

Undiagnosed pain in the foot, those undergoing steroid treatment for plantar fasciitis

Radiating pain.

History of other musculoskeletal conditions around the foot region (Fracture, foot deformity, trauma, degenerative changes).

Presence of neurological deficits.

Pregnant women

OUTCOME MEASURES

Numeric pain rating scale (NPRS): An 11-point NPRS (0, no pain; 10, worst imaginable pain) was used to measure pain intensity. Research indicates that NPRS demonstrates strong construct validity, consistent test-retest reliability, and high sensitivity in musculoskeletal conditions, making it a reliable instrument for evaluating pain and monitoring treatment efficacy [45].

Dorsiflexion range of motion: A goniometer measured the dorsiflexion range in a non-weight-bearing position. It's a common clinical instrument for determining joint range of motion.

Weight-bearing lunge test (WBLT): When evaluating ankle dorsiflexion range of motion (ROM) in a functional, weight-bearing position, the weight-bearing lunge test (WBLT) is a commonly used clinical measure that, in contrast to non-weight-bearing tests, takes into account the demands placed on the ankle during daily activities such as walking, squatting, and running [46].

Foot function index: The Foot Function Index (FFI) is a self-reported questionnaire used to measure the impact of foot pathology on function, pain, and disability. It has shown strong validity and reliability in populations with plantar fasciitis and is often used to evaluate patient outcomes [34\]

METHOD OF COLLECTION OF DATA

Total samples (N = 60)

On the basis of inclusion and exclusion criteria

Pre-treatment Assessment

- ➢ Numeric pain rating scale
- ➢ Dorsiflexion range of motion by goniometer
- ➢ Weight bearing lunge test by inch tape
- ➢ Foot function index through detailed assessment

Randomly divided into two group: Group A and Group B

GROUP A: ankle PNF with mulligan mobilization (n1 = 30) Stretching – calf and plantar fascia

Ankle PNF

- ➢ D1 flexion (DF + INV)
- ➢ D2 Extension (PF + EV)
- ➢ D2 Flexion (DF + EV)
- ➢ D2 Extension (PF +INV)

Mulligan Mobilization

- ➢ Talocrural joint
- ➢ Subtalar joint

GROUP B Conventional therapy (n2 = 30) Stretching – calf and plantar fascia

Active ankle exercise

- ➢ Dorsiflexion
- ➢ Plantarflexion
- ➢ Inversion
- ➢ Eversion

Strengthening exercise

- ➢ Intrinsic towel curl
- ➢ Intrinsic Thera band
- ➢ Lifting pebbles

After completion of six weeks

Post-treatment Assessment

- ➢ Numeric pain rating scale
- ➢ Dorsflexion range of motion by goniometer
- ➢ Weight bearing lunge test by inch tape
- ➢ Foot function index through detailed assessment

Data Analysis and Result

INTERVENTION PROTOCOL

The selected patients were randomly divided into two groups. Group A underwent a combined intervention of ankle proprioceptive neuromuscular facilitation (PNF) with Mulligan mobilization and stretching. Group B received conventional physiotherapy, consisting of stretching and strengthening exercises and active ankle movements. After taking the baseline assessment. The treatment was administered over six weeks, with sessions held four times per week, each lasting for 20 to 30 minutes.

Table 3.10 Treatment Protocol

From 1-3 weeks	
Group A: ANKLE PNF with MULLIGAN MOBILIZATION	**Group B**: CONVENTIONAL THERAPY
Stretching 3 reps, 10 sec hold Plantar Fascia Stretch Calf Stretch	Stretching 3 reps, 10 sec hold Plantar Fascia Stretch Calf Stretch
Ankle PNF 8 reps, 2 sets D1 Flexion (DF + INV) D1 Extension (PF + EV)	Active ankle exercise 10 reps, 2sets Dorsiflexion Plantarflexion
D2 Flexion (DF + EV) D2 Extension (PF + INV)	Inversion Eversion
Mulligan Mobilization 10 reps, 2 sets Talocrural joint Subtalar joint	Strengthening exercise 10 reps, 2 sets Intrinsic towel curl Intrinsic Thera band Lifting pebbles
From 3-6 weeks	
Stretching 3 reps, 15 sec hold Plantar Fascia Stretch Calf Stretch	Stretching 3 rep, 15 sec hold Plantar Fascia Stretch Calf Stretch
Ankle PNF 8 reps, 3 sets D1 Flexion (DF + INV) D2 Extension (PF + EV) D2 Flexion (DF + EV) D2 Extension (PF+INV)	Active ankle exercise: 10 reps, 3 sets Dorsiflexion Plantarflexion Inversion Eversion
Mulligan Mobilization 10 reps, 3 sets Talocrural joint Subtalar joint	Strengthening exercise: 10 reps, 3 sets Intrinsic towel curl Intrinsic Thera band Lifting pebbles

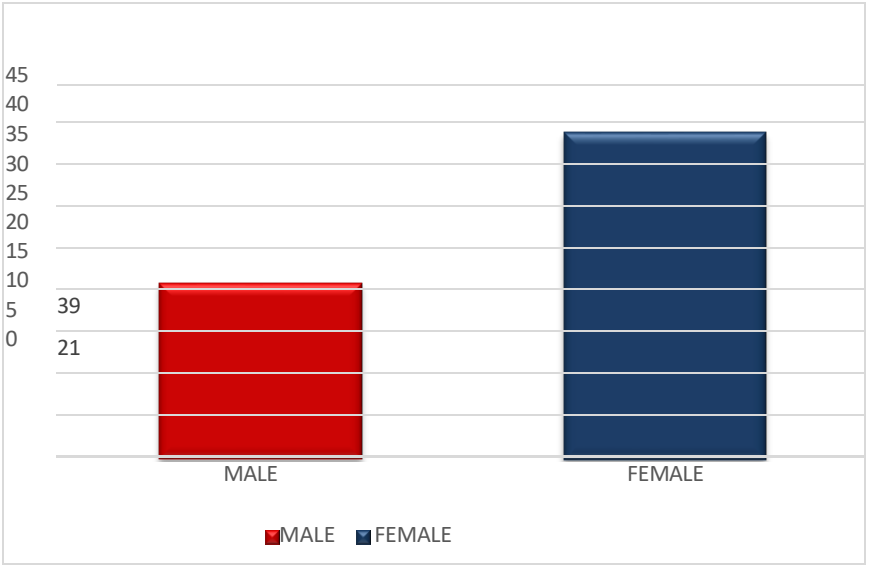
STATISCAL ANALYSIS

Data was analyzed using IBM SPSS, version 30.0. Descriptive statistics were used for demographic variables, and inferential statistics were applied to compare outcomes within and between the two groups. A paired t-test was used to evaluate changes within each group, while an unpaired t-test was applied to compare outcomes between the groups. A p-value of <0.05 was considered statistically significant.

A total of 60 patients were gathered and randomly divided into two groups: Group A: Mulligan Mobilization and Ankle Proprioceptive Neuromuscular Facilitation (PNF) and Group B: Conventional Therapy. Each group included thirty people. The average age was 26.5 years old overall. In total, there were 39 Females and 21 Male.

Table 1. Demographic profile: Gender distribution and Mean age

GENDER	TOTAL NUMBER	PERCENTAGE	MEAN AGE
MALE	21	35%	26.36
FEMALE	39	65%	



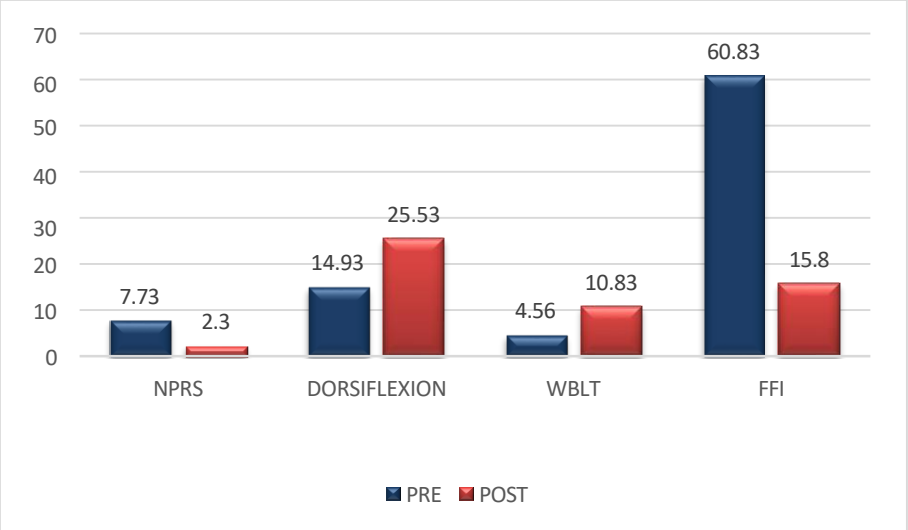
Graph 1 Demographic Chart: Gender distribution

WITHIN-GROUP ANALYSIS

Group A (Ankle PNF + Mulligan Mobilization): Statistically significant improvements were observed in NPRS, Dorsiflexion ROM, Weight Bearing Lunge Test, and Foot Function Index ($p < 0.0001$).

Table 2. Paired t- test of Group A

SCALES	PRE TEST (MEAN±SD)	POST TEST (MEAN±SD)	P VALUE	T VALUE	INFERENCE
NPRS	7.73 ± 0.89	2.3 ± 1.77	0.0001	18.22	SIGNIFICANT
DORSIFLEXION ROM	14.93 ± 2.17	23.53 ± 3.11	0.0001	14.66	SIGNIFICANT
WBLT	4.56 ± 1.49	10.83 ± 1.93	0.0001	21.80	SIGNIFICANT
FFI	60.83 ± 7.91	15.8 ± 11.17	0.0001	23.85	SIGNIFICANT

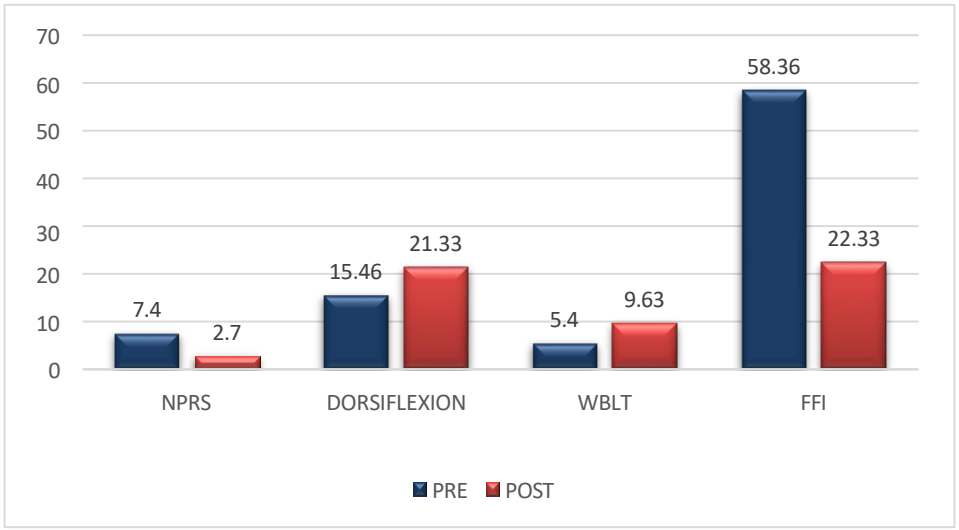


Graph 2 Intragroup analysis of Group A (pre vs post-test)

Group B (Conventional Therapy): Statistically significant improvements were observed in NPRS, Dorsiflexion ROM, Weight Bearing Lunge Test, and Foot Function Index ($p < 0.0001$).

Table 3 Paired t-test of Group B

SCALES	PRE TEST (MEAN± SD)	POST TEST (MEAN± SD)	PVALUE	T-VALUE	INFEREN CE
NPRS	7.4±0.91	2.7±1.89	0.0001	16.70	SIGNIFICA NT
DORSIFLEXI ON ROM	15.46±2.26	21.33±3.13	0.0001	16.10	SIGNIFICA NT
WBLT	5.4±1.70	9.63±1.53	0.0001	17.42	SIGNIFICA NT
FFI	58.36±8.56	22.33±12.70	0.0001	19.54	SIGNIFICA NT



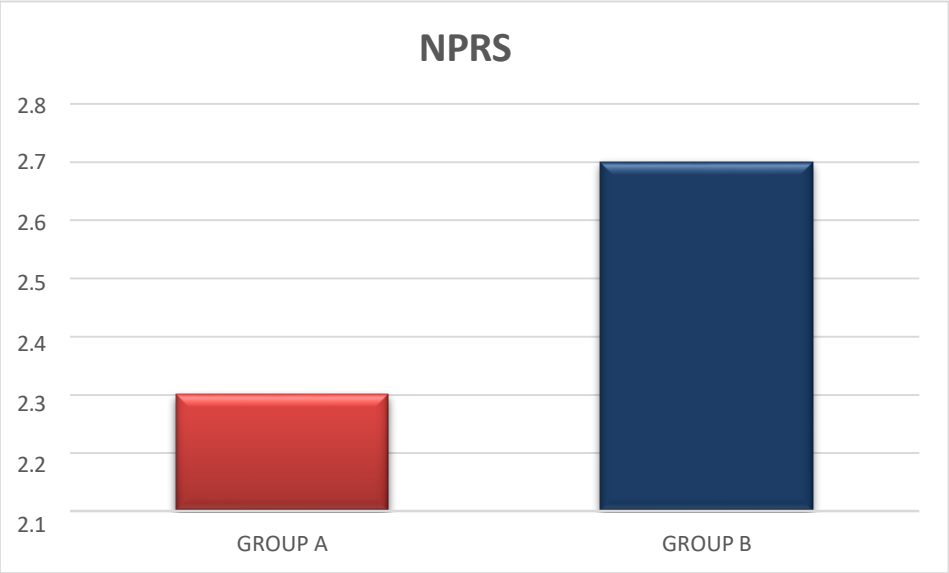
Graph 3: Intragroup analysis of Group B (pre vs post-test)

BETWEEN GROUP COMPARISON

NPRS: Although no statistically significant difference was found between the two groups ($p > 0.05$), but Group A demonstrated slightly greater improvement compared to Group B.

Table 4 Unpaired t-test of NPRS between groups A & B

SCALES	GROUP A (MEAN±SD)	GROUP B (MEAN±SD)	P VALUE	T VALUE	INFERENCE
NPRS	2.3 ± 1.89	2.7 ± 1.89	0.33	0.969	NOT SIGNIFICANT

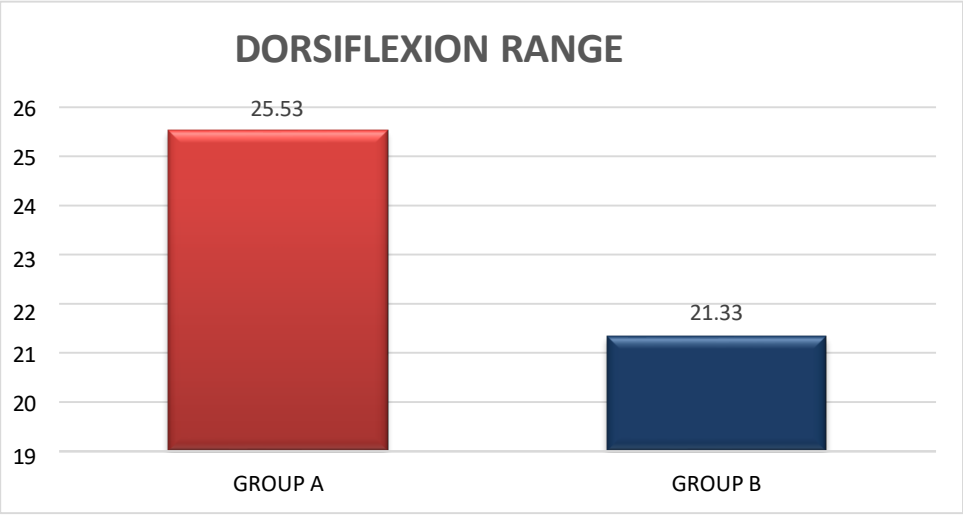


Graph 4 Intergroup analysis of NPRS: Group A vs. Group B

DORSIFLEXION RANGE OF MOTION: Statistically significant increase in ankle mobility in Group A ($p < 0.05$)

Table 5. Unpaired t-test of Dorsiflexion range between groups A & B

SCALES	GROUP A (MEAN± SD)	GROUP B (MEAN± SD)	P VALUE	T VALUE	INFERENCE
DORSIFLEXION ROM	23.53±3.11	21.33±3.13	0.009	2.68	SIGNIFICANT

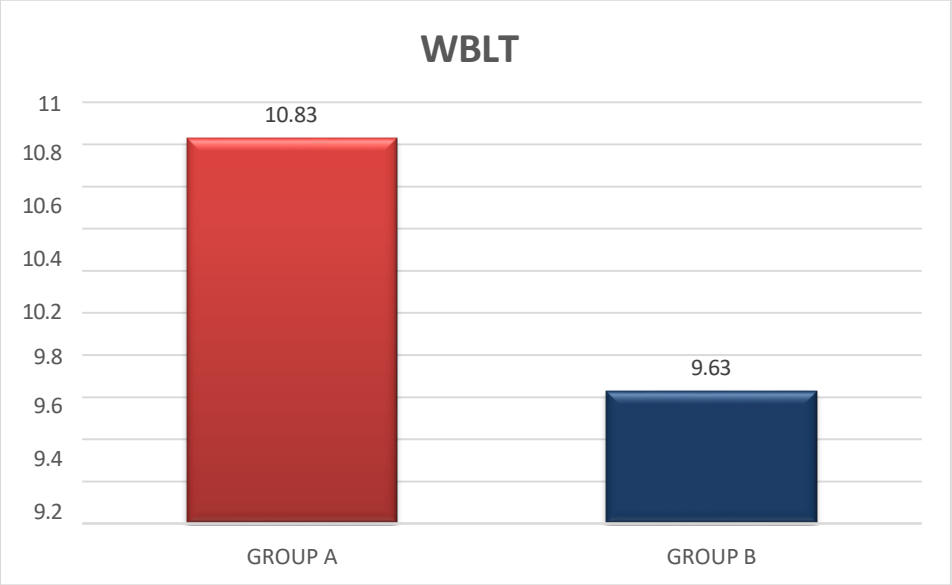


Graph 5 Intergroup analysis of dorsiflexion range of motion: Group A vs. Group B

WEIGHT-BEARING LUNGE TEST (WBLT): There was statistically significant improvement in weight-bearing lunge test in group A ($p < 0.05$)

Table 6. Unpaired t-test of WBLT between groups A & B

SCALES	GROUP A (MEAN±SD)	GROUP B (MEAN±SD)	P VALUE	T VALUE	INFERENCE
WBLT	10.83 ± 1.93	9.63 ± 1.53	0.011	2.61	SIGNIFICANT

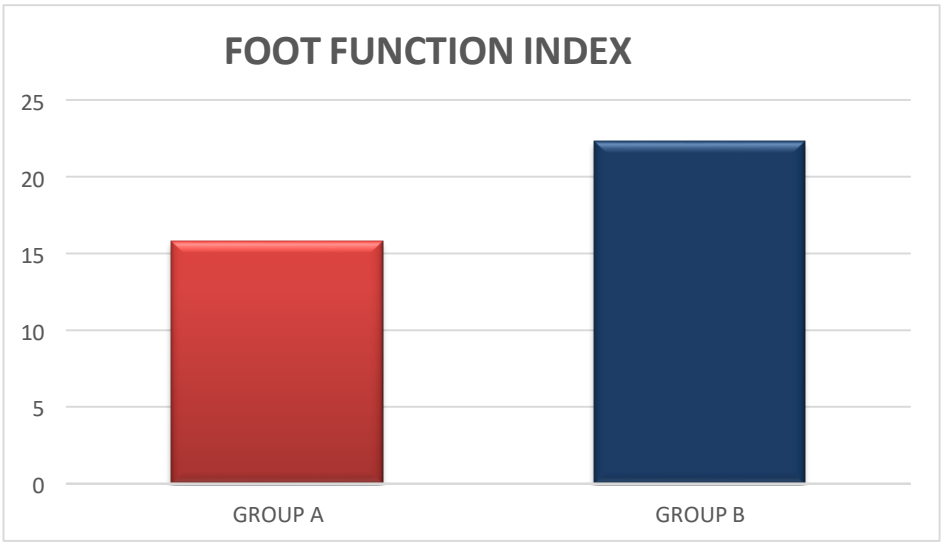


Graph 6 Intergroup analysis of WBLT: Group A vs. Group B

Foot Function Index (FFI): Statistically significant enhancement in the foot function and decreased disability in Group A ($p < 0.05$)

Table 7 Unpaired t-test of FFI between groups A & B

SCALES	GROUP A (MEAN±SD)	GROUP B (MEAN±SD)	P VALUE	T VALUE	INFERENCE
FFI	15.8 ± 11.17	22.33± 12.70	0.042	2.07	SIGNIFICANT



Graph 7. Intergroup analysis of FFI: Group A vs. Group B

DISCUSSION:

The current study aimed to assess and compare how well ankle proprioceptive neuromuscular facilitation (PNF) combined with Mulligan mobilization works against traditional physiotherapy for people with plantar fasciitis. Post-intervention results revealed that both groups experienced clinical improvements in pain, ankle dorsiflexion range of motion, weight-bearing function, and foot functionality through the foot function index. However, both groups showed no significant difference in pain; both showed somewhat equal results with a slight variation in their result. Meanwhile, Group A demonstrated significantly greater improvements across the dorsiflexion range and on the functional scale, with p-values less than 0.05, indicating the superiority of the combined PNF and Mulligan mobilization approach over conventional therapy. Through Mulligan mobilizations, especially the weight-bearing mobilization with movement (MWM) technique, we were directly targeting functional joint movements. Mulligan techniques are known to correct positional faults of joints and promote pain- free movement, thus reducing the stress on surrounding structures such as the plantar fascia. Additionally, these mobilizations likely stimulated joint mechanoreceptors, activating the pain gate mechanism and inhibiting nociceptive input [39].

According to a study, people with plantar heel discomfort respond better to manual therapy. The reason why persons with PF have less discomfort and better foot function is that subtalar mobilization helps to increase the talus and calcaneus' mobility, which reduces traction stress across the plantar fascia [40, 48].

PNF contributes by improving neuromuscular control, which plays a crucial role in balance and coordinated weight shifts [50]. It is efficacious in enhancing proprioception, increasing muscle activation, and reducing compensatory pain patterns. So in our present study, the implication of a combination of both techniques, manual therapy and neuromuscular re-education, addresses multiple contributing factors to plantar fasciitis, from faulty foot mechanics to compensatory movement patterns, ultimately resulting in reduced disability and better quality of life.

When Akre and Kumaresan examined the effects of proprioceptive training and a four-week strengthening program on dynamic balance in athletes with persistent ankle instability, they discovered that both approaches were equally successful in enhancing dynamic balance. Ankle proprioception is crucial for balance control because postural and balance control integration is made possible by the brain processing ankle proprioceptive data in conjunction with other sensory data [43].

In the present study, the ankle PNF concentrates more on timing the internal and external muscle activation patterns of the foot, which lead to improved dorsiflexion range and reduced functional disability. In a previous study, proprioceptive neuromuscular facilitation, or PNF, was frequently used to improve functions in the zone of sports and exercise.

As in previous study according to Karakaya et al. (2015), they have explained nicely that to maintain both static and dynamic balance under more complex circumstances, as well as to prevent and treat a variety of illnesses and impairments like functionally unstable feet, hypermobility syndromes, falls, or neurological issues with balance disorders. As we have observed in the present studies, ankle PNF is very beneficial for functional control, and there is significant improvement in the functional quality of the foot [42]. The traditional group in our study was given exercises to strengthen the intrinsic foot muscles, which help to stabilize the arches of the feet. According to earlier studies, it strongly supports that strengthening is essential for treating plantar fasciitis and functional risk factors, such as weakness in the intrinsic foot muscles. Plantar fasciitis is often caused by intrinsic muscle weakness and poor force attenuation.

And this study, we found that strengthening the intrinsic foot muscles was one of the most effective strategies to treat heel pain. In the current study, we have seen there is improvement in the conventional group too in relation to pain and dorsiflexion range and functional scale in individuals with plantar heel pain (PF), as in the previous study, Thong-On S et al. (2019) also strongly discovered that both stretching and strengthening activities enhanced pain and gait characteristics [30].

At a 2-month follow-up, the strengthening exercises that targeted the Achilles tendon, calf muscles, and ankle dorsiflexors had long-term improvements. Ankle dorsiflexion range of motion increased by the heel raise exercise, which would strengthen the plantar flexor. The enhanced ankle dorsiflexion range of motion brought about by the calf and Achilles tendon stretching exercises may have contributed to the improvements in both groups. So in our study, the strengthening exercise by Thera- Band provided resistance, which strengthened the plantar flexors and ankle dorsiflexors by requiring the use of forward-back muscle work to control up and down. It stretched their Achilles and calf tendons and increased their ankle dorsiflexion range of motion [30].

The main goal of the present study is to replicate the windlass mechanism and reduce recurrent micro-trauma and related chronic inflammation of the plantar fascia-stretching program. In previous studies related to this by Benedict F et al. (2003), they have done a comparison between Achilles tendon and plantar fascia stretching and found that, compared to the group treated with normal Achilles tendon stretching activities, the group treated with plantar fascia stretching exercises showed improved results in terms of discomfort, function, and overall satisfaction. As in our study in the latter stages of the stance phase, it enables the medial arch to rise correctly, the calcaneus to rotate inward (into varus), and the toes to dorsiflex [16].

Through this, the windlass mechanism is not precisely replicated by the standard Achilles tendon-stretching exercise and does not isolate the plantar fascia. However, in terms of improvement, both stretching protocols are beneficial because there will be tightness of the Achilles tendon, which is also a reason for limiting the factor for less dorsiflexion range and leads to the foot being in a plantarflexion position [16]. In another article, they supported that calf stretching is also useful in enhancing function in people with plantar fasciitis, and there will be no significant difference [17]. As we also observed in our present study, plantar fascia stretching with calf stretching shows a

positive effect on functional outcome, and this needs to be included in the therapy regimen for such individuals as an important component.

Stretching increases connective tissue tension, which helps to develop gross motor skills and prevent contractures. Alpha motor neurons are stimulated by primary afferent fibers, and parallel elastic components can extend because slow stretch force reduces tension [51]. In our present study, the length suddenly changes as a result of mechanically disrupting cross-bridges caused by passive stretch. Stretch force must be sustained over time to sustain the long-term length growth.

According to the study, stretching and mobilizing the ankle, subtalar, and midfoot help individuals with persistent plantar fasciitis experience less pain, more range of motion, and improved functional activities. So, in our study, the combination of passive accessory mobilization with active movement and stretching may be the mechanism for this improvement. This repositions the joint and stimulates proprioceptive tissues, leading to proper joint tracking [51].

The current study's results are in line with other research that backs the application of PNF and Mulligan mobilization to treat plantar fasciitis and associated lower limb conditions. The benefits of both traditional physiotherapy and ankle mobilization and PNF, according to Boob M. A. et al. (2024), suggest a holistic approach that treats the underlying causes of heel spurs and plantar fasciitis in addition to their symptoms.

The efficacy of this combination strategy is described by its multifaceted nature, which supports both functional enhancements and pain reduction, which are critical for the patient's general health. In this case study, a yoga trainer's plantar fasciitis and heel spurs were effectively treated with an advanced physical therapy intervention, more specifically, the Mulligan joint mobilization. The findings demonstrate the efficacy of this comprehensive rehabilitation approach since it enhances dynamic balance, foot function, and range of motion while reducing discomfort [38]

CONCLUSION:

According to the results of both groups, the intervention group (people receiving ankle PNF with Mulligan mobilization) and the conventional group (people receiving strengthening exercise of intrinsic foot muscles along with stretching and active movements of the ankle joint) have shown improvement in pain, dorsiflexion range in both WBLT and non-weight-bearing positions, and in the functional scale of the foot (the foot function index). But on comparison, people who are receiving ankle PNF with Mulligan mobilization are having more significant improvement in dorsiflexion range in both WBLT and non-weight-bearing positions and in the functional quality of the foot (the foot function index).

So from this study we concluded that the combination of ankle PNF and Mulligan mobilization offers a more holistic approach for plantar fasciitis and has significant clinical relevance, and it is highly beneficial for those who have physically demanding work, like long-time standing work, hobbies like sports, etc.

CONFLICT OF INTEREST: The authors declare that there are no conflicts of interest related to this research work. No financial, personal, or professional relationships have influenced the findings, analysis, or conclusions presented in this study

FUNDING: This research paper was fully funded by the authors. No external financial support was received...

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