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Case Report

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Effects of Treatment Using PNF Pattern Irradiation in the Weight-Bearing Position on Pain and Foot Alignment in a Patient with Patellofemoral Pain Syndrome:

A Single-Subject Experimental Study

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| Abstract |

Purpose: This study aimed to investigate the use of insoles in patients with temporomandibular joint disorders to assess the function and changes in pain when walking in daily life.
Methods: Sixty-five patients with temporomandibular joint disorder, were selected, with 34 assigned to the control group and 31 to the experimental group. The control group walked more than 7,000 steps per day in their daily life, while the experimental group wore insoles and was instructed to take at least 7,000 steps every day. To evaluate the effect on temporomandibular joint pain, steady-state pain, maximum mouth opening, average pain, and the most severe pain were measured before and after the experiment. In addition, to determine function, mouth opening in a comfortable state, mouth opening pain, and the point of sound and the maximum degree of mouth opening were evaluated before and after the experiment.
Results: After the experiment, pain, mouth opening, and sound points showed significant differences compared to the control group. However, there was no significant difference in the maximum mouth opening range.
Conclusion: The application of air insoles to patients with temporomandibular joint disorder confirmed the function of the temporomandibular joint and its positive effects on pain.

Key Words: Temporomandibular Joint, Air Insole, Walking, TMJ Disorder

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Ⅰ. Introduction

Patellofemoral pain syndrome (PFPS) is a common condition, accounting for 25-40% of all knee disorders, and is caused by various factors affecting the knee (Crossley et al., 2016). PFPS, also known as anterior knee pain, is defined as pain occurring around or behind the kneecap that worsens with activities that load or compress the patellofemoral joint, such as squats, stair climbing, jumping, and running (Crossley et al., 2016). It has been reported that PFPS occurs 2.2 times more frequently in females than in males (Boling et al., 2010). Up to 78% of PFPS patients reportedly experience chronic pain 5-20 years after rehabilitation (Stathopulu & Baildam, 2003). According to a study targeting individuals with patellofemoral osteoarthritis before undergoing joint replacement surgery, 22% of the total subjects experienced PFPS during adolescence or early adulthood (Utting et al., 2005). Early diagnosis and appropriate management of PFPS are essential to prevent persistent issues (Crossley et al., 2016).

Proprioceptive neuromuscular facilitation (PNF) is a technique for treating patients based on neuro-physiological principles. It enhances balance, flexibility, muscle strength, and other functions by stimulating the proprioceptive senses of muscles and tendons (Klein et al., 2002). The PNF approach provides optimal muscle strength by eliciting appropriate resistance and assistance to complete the patient's movements (Oh, 2011). Among the basic procedures of PNF, irradiation refers to the phenomenon where the response to a given stimulus spreads to other areas beyond the stimulated site, promoting muscle contraction in muscles other than the area directly stimulated. By inducing indirect contractions, patients can perform exercises more easily and without pain within the range of motion (Adler et al., 2007). Various exercise methods using irradiation, a basic procedure of PNF, have been frequently attempted in clinical practice. Recent studies have investigated improving patients' ability to accept weight loads during daily activities using the effects of irradiation (Lee & Yun, 2012; Yang et al., 2019) and facilitating the activity of contralateral muscles (Choi et al., 2019; Lee & Lee, 2018).

To our best knowledge, while confirming functional levels and morphological changes in muscles is crucial, previous studies have not addressed the effects of irradiation on contralateral weight-bearing and changes in muscle activity obtained from its application. This study applied irradiation effects caused by PNF patterns toward a patient who have had a difficulty in weight bearing due to knee pain. Irradiation can be applied when there is pain in the area intended for exercise. This study aims to investigate the effects of pain and foot alignment on patients when performing pain-free weight-bearing exercises using irradiation.

Ⅱ. Methods

1. Subject

The subject of this study is a 28-year-old female (weight: 52 kg and height: 158 cm) diagnosed with PFPS. For the past 10 months, she has complained of significant pain in her right knee when climbing stairs, sitting and standing up, and during daily routine activities such as walking. This woman's profession is a physical therapist. There were no other specific issues that could cause knee pain. She did not engage in regular exercise. Suspecting PFPS (Patellofemoral Pain Syndrome) based on a history of recurrent knee pain, she was selected as a subject after the positive results of the Clark's test and patellar tilt test. The pain has been persistent in the right knee, with no pain reported in the left knee. She was aware that if the symptoms persisted, they could worsen into patellofemoral osteoarthritis and was highly motivated for treatment due to the ongoing pain. The subject was provided with sufficient explanation regarding the purpose and procedures of the study, and she consented to participate in the research.

2. Study design and procedures

This study employed a single-subject experimental design with reversal design (A-B-A'). During the initial assessment, the patient's general information, medical history, and functional activity level were collected through interviews, and then therapeutic goals were established to address major symptoms including pain relief and correction of malalignment. Measurements of quadriceps strength, hamstring strength, and pain during squatting were conducted eight sessions each during the baseline phase, intervention phase, and follow-up observation phase. Foot pressure, perceived pain level, navicular drop test, and Clark's test were performed before and after the intervention phase.

3. Outcome measures

1) Strength test

Muscle strength tests were conducted using a digital dynamometer (digimax, Mechatronic GmbH, Germany) (Fenter et al., 2003; Lu et al., 2007). This device provides an objective and numerical presentation of muscle strength and are convenient tools with high clinical utility (Lu et al., 2007). Using the dynamometer, the maximum strength (unit: N) of the quadriceps and hamstring muscles was measured three times each, and the maximum value of the three trials was used for visual analysis. Rest-interval between trials was 3 minutes. During quadriceps strength measurement, the subject sat with knees bent at a 90-degree angle, with a strap connected to the dynamometer placed 2 cm above the ankle joint. The subject then maximally extended the knee for 3 seconds. Hamstring muscle strength measurement was conducted with the subject standing upright, with a strap connected to the dynamometer placed 2 cm above the ankle joint. The subject was instructed to maximally extend the leg being tested for 3 seconds (Fredericson & Yoon, 2006).

2) Distribution of foot pressure

Foot pressure distribution was measured using the balance assessment system (Biorescue, RM Ingenierie, France). Scanning images on foot pressure distribution was offered to compare its change before and after the intervention phase.

3) Navicular drop test (NDT)

The measurement of NDT was conducted with the subject seated. The examiner contacted the subtalar joint to neutral position by palpating the talus neck with the thumb and index finger while moving the ankle joint left and right to relax it. Subsequently, the examiner aligned the thumb and index finger parallel to the front of the ankle joint to establish the neutral position of the subtalar joint and marked the most protruding part of the navicular tuberosity on the rough surface of the navicular bone. Then, while maintaining the neutral position of the subtalar joint, the subject gradually stood up, bearing weight and rising slowly. Afterward, the examiner contacted the navicular tuberosity again to mark it in the relaxed state. By comparing the points marked in the seated and standing positions, foot posture was classified as pronated foot if the difference was less than 4mm, supinated foot if it was more than 10mm, and normal foot if it ranged between 5-9mm. The NDT is a reliable method with high reliability ranging from 0.88 to 0.91 (Plisky et al., 2007).

4) Clark's test

The examiner positioned the subject in supine position and placed their hands above the subject's kneecaps. While simultaneously pushing the patella downwards and instructing the subject to contract the quadriceps muscle, the examiner assessed for pain around the knee. If pain was elicited in the peripatellar area after contraction, the test was considered positive (Solomon et al., 2001). Clark's test has been known to by reliable for clinical use (r=0.69) (Nijs et al., 2006). Additionally, pain experienced during the examination was measured using the Numeric Pain Rating Scale (NPRS).

4. Intervention procedures

In this study, the intervention involved applying PNF patterns to the unaffected lower limb to induce an irradiation effects on the affected side. The treatment consisted of three stages: Supine, sitting, and standing positions. In each position, two lower limb patterns—flexion, abduction, internal rotation, and flexion, adduction, external rotation—were applied to facilitate muscle strengthening. Additionally, weight-bearing status on the affected side and the combination of isotonic were concurrently utilized within pain-free ranges.

Firstly, PNF patterns were performed in the supine position with knees flexed at 90° and feet against the wall. Verbal command such as "Push against the wall" was given to the patient to encourage the formation of

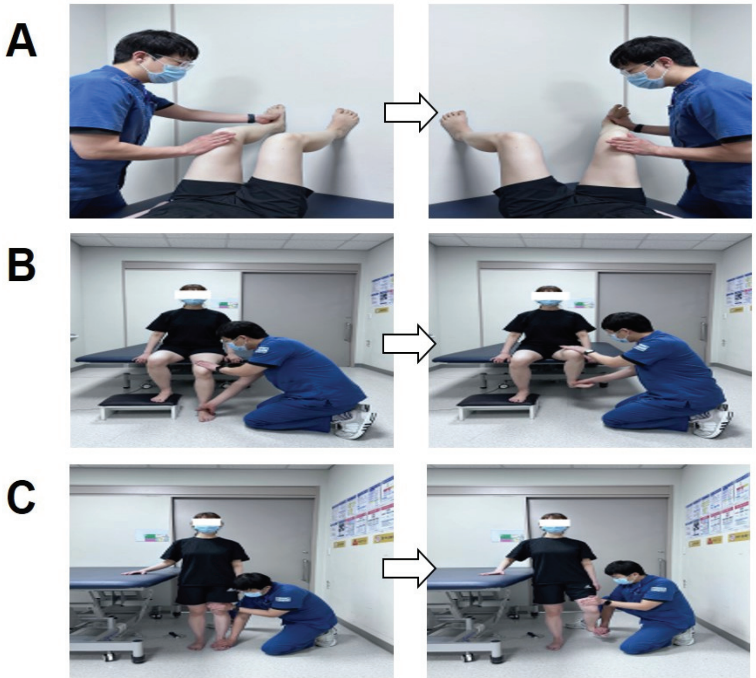

Fig. 1. PNF pattern: Flexion-abduction-internal rotation with knee flexion. (A) supine (B) sitting, and (C) standing.

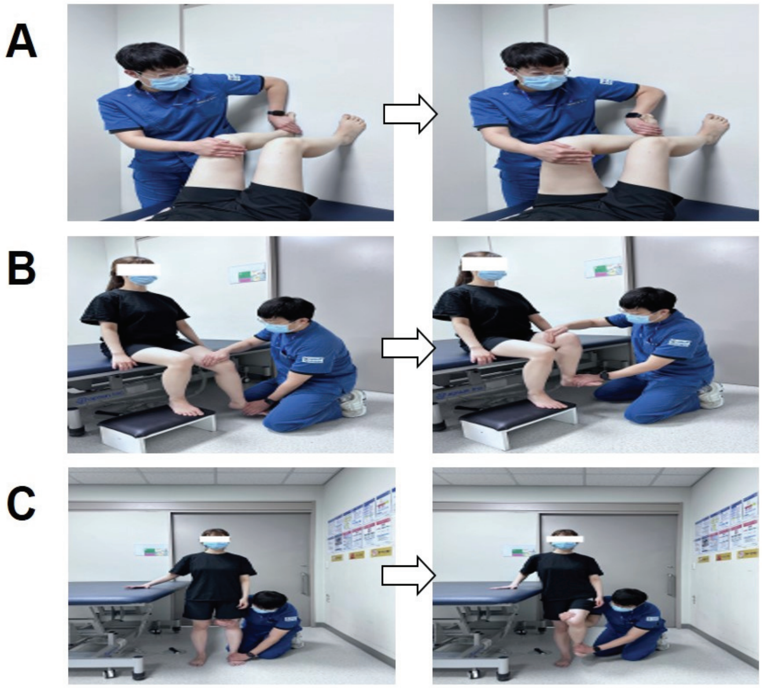

Fig. 2. PNF pattern: Flexion-adduction-external rotation with knee flexion. (A) supine (B) sitting, and (C) standing.

the foot arch by applying sufficient force on the affected lower limb while PNF patterns were performed on the unaffected side (Fig. 1-A and Fig. 2-A). Secondly, PNF patterns were performed in the sitting position with hips and knees flexed at 90°, with only the affected side placed on the foot plate. Verbal command such as “Press against the floor” was given to the patient to facilitate the formation of the foot arch of affected side while applying PNF patterns on the affected side (Fig. 1-B and Fig. 2-B). Thirdly, PNF patterns were executed in the standing position with an erect posture. The patient was instructed with a verbal command such as “Press against this spot” while offering stimulation at the first metatarsal bone to provide accurate sensory input on the affected lower limb while PNF patterns were carried out on the unaffected side (Fig. 1-C and Fig. 2-C). The treatment consisted of 5 sets of 3 repetitions with a 1-minute interval between sets. The total treatment time was approximately 30 minutes.

5. Data analysis

During the baseline, intervention, and follow-up phases, muscle strength data were collected for visual analysis. The 2-standard deviation-band method (2SD) was employed to support visual analysis by demonstrating clinical significance of data collected in each session. Foot pressure distribution before and after intervention was introduced visually through photographs, and results of NDT were presented graphically. Results from Clark’s test were presented as a table.

Ⅲ. Results

Fig. 3 shows the pre- and post-intervention values of foot pressure distribution. Before intervention, the arch of the foot appears collapsed, while after intervention, the arch shows a restored shape. Table 1 displays the changes in Clark's sign and pain experienced during the examination. The sign turned negative after intervention, and the pain experienced during the examination decreased from NPRS 2 to 0. Fig. 4 showed a difference of 13 mm (28 mm to 15 mm), and a difference of 8 mm (27 mm to 19 mm). Fig. 5 illustrates the changes in muscle strength during the baseline, intervention, and follow-up phases. Both the intervention and follow-up phases showed clinically significant improvements compared to the baseline, as indicated by 2SD band method.

Table 1. Results of Clark's test

	Before the intervention	After the intervention
Sign	Positive	Negative
Pain (points)	2	0

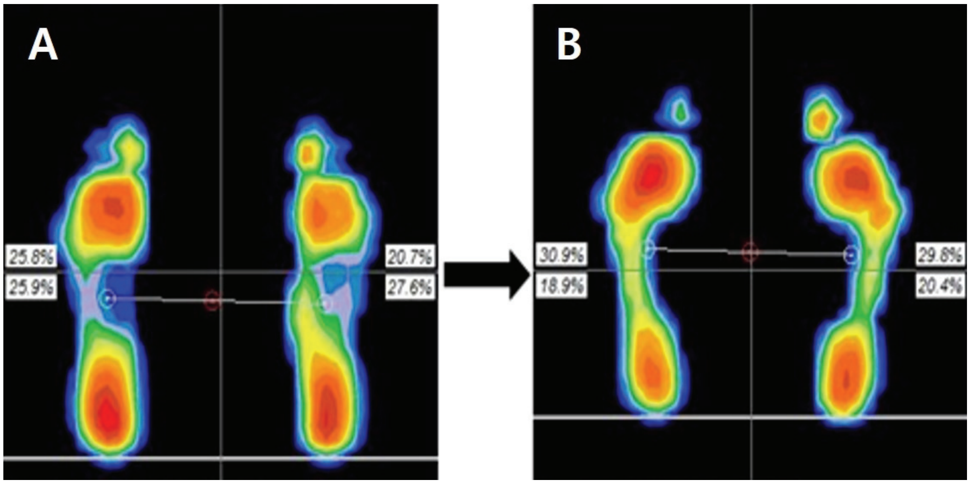

Fig. 3. Scanning images on foot pressure distribution in standing. (A) Before and (B) after the intervention phase.

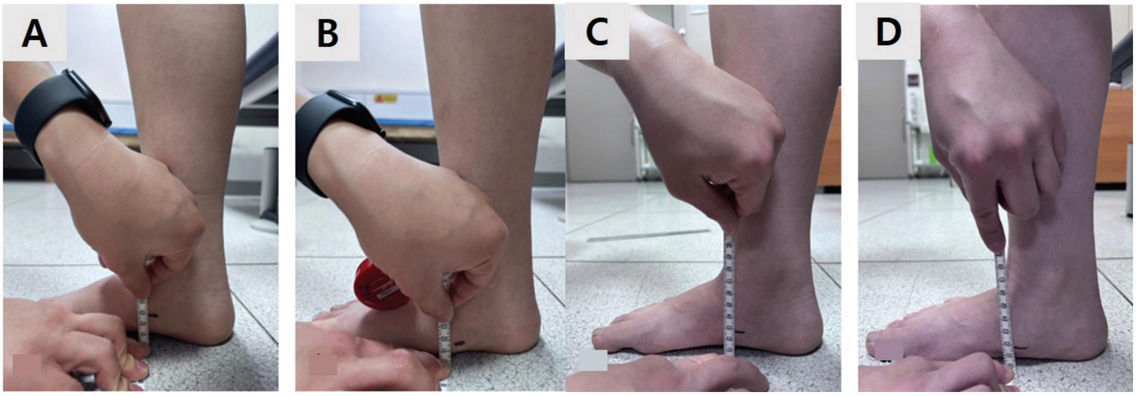

Fig. 4. Navicular drop test. (A) before weight-bearing (pre-intervention), (B) after weight-bearing (pre-intervention), (C) before weight-bearing (post-intervention), and (D) after weight-bearing (post-intervention).

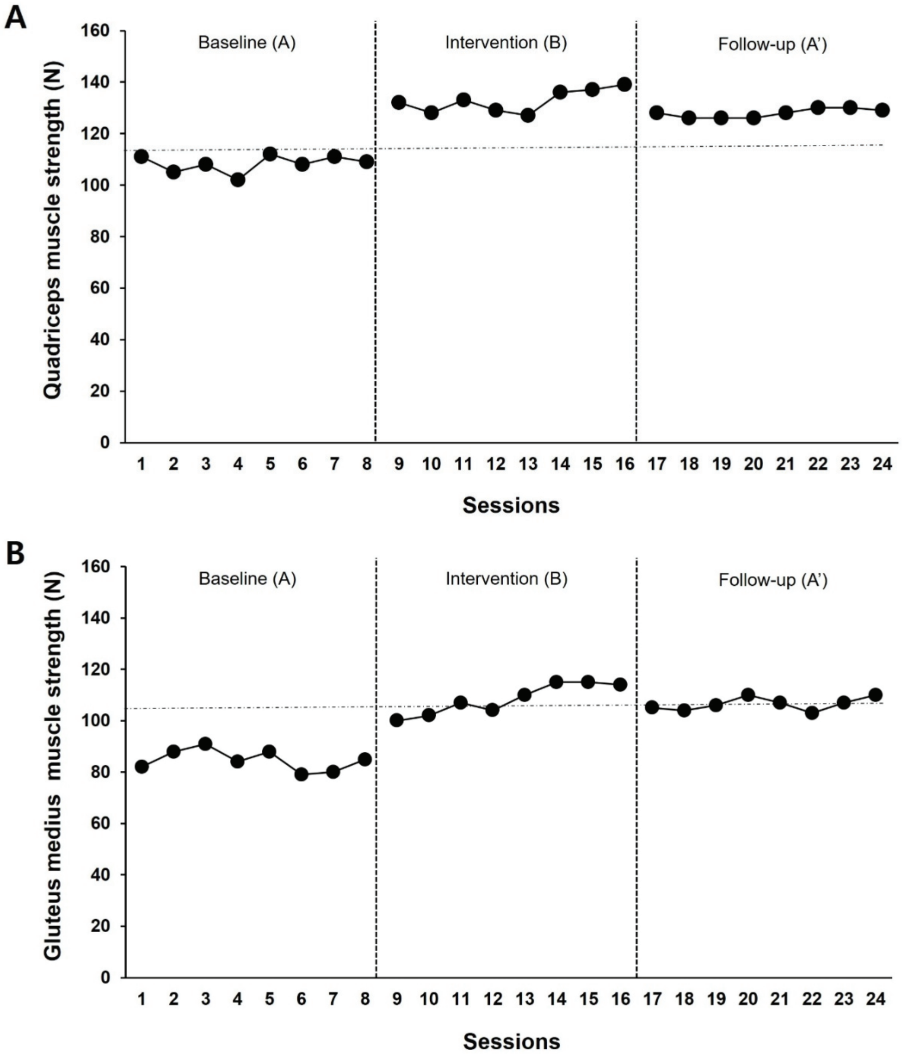

Fig. 5. Comparison of the muscle strength test during the baseline, intervention, and follow-up phases. (A) Quadriceps femoris muscle strength and (B) gluteus medius muscle strength.

Ⅳ. Discussion

This study aimed to investigate the effects of using irradiation from PNF patterns as the training method of the affected side in a patient with PFPS. Study results suggest that irradiation effect by applying PNF patterns might be beneficial to the symptoms of a patient with PFPS.

PFPS arises due to abnormal patellar tracking, where the patella is pushed outward due to structural disparity or muscle weakness. This leads to reduced contact area between the patella and femur, concentrating force on specific areas, resulting in pain during activities (Gaitonde et al., 2019). Previous studies focused on activating the vastus medialis oblique (VMO) muscle, a subset of the vastus medialis, to address PFPS (Waryasz & McDermott, 2008). However, recent research suggests that trainings targeting the VMO may not show significantly greater improvement of PFPS symptoms when compared to general quadriceps exercises (Bennell et al., 2010; Son et al., 2023). Other studies have identified risk factors for PFPS such as foot misalignment, female gender, knee instability, and weakness of the vastus medialis (Gaitonde et al., 2019), which was similar with the symptoms observed in the subject of this study.

As seen in this study, the intervention focused on improving risk factors through strength training and alignment, resulting in both pain relief and improved alignment. Irradiation is defined as the spread of response to a given neural stimulus (Adler et al., 2007). It allows indirect treatment of areas where direct intervention is challenging due to neurological or orthopedic issues (Rhee et al., 2021). Previous research has supported that irradiation can improve muscle activation of contralateral side (Choi et al., 2019; Lee & Lee, 2018). In this study, the intervention using irradiation led to pain relief and muscle strengthening in the subject complaining of persistent pain in the right knee. This suggests that irradiation can enhance muscle strength and effectively alleviate pain even without direct stimulation.

Individuals with flat feet have reduced ability to maintain the medial longitudinal arch while maintaining normal toe-spread. Flat feet also induce internal rotation of the tibia, fibula, and calcaneus, making them a risk factor for PFPS (Petersen et al., 2014; An & An, 2023; Yu et al., 2023). Interventions using PNF lower limb patterns can help activate intrinsic foot muscles and improve foot alignment (Kim & Park, 2018). In this study, the intervention resulted in improved foot alignment, which may have contributed to pain relief by addressing one of the risk factors. Additionally, strengthening of the intrinsic foot muscles and the vastus medialis through PNF patterns may have facilitated normal patellar tracking. Ultimately, this could have influenced the absence of pain in Clark’s test.

Despite favorable effects of our intervention, we acknowledge that there are several limitations in interpreting study results. Firstly, the study involved only one subject, limiting the generalizability of the findings to all PFPS patients. Secondly, the results of this study should not be interpreted as long-term effects of the intervention used. Thirdly, our results it might be challenging to address dynamic valgus, one of the risk factors for PFPS, from our intervention. The preceding study delineates several factors associated with PFPS, including hip abductor strength and Q-angle. Subsequent research endeavors should concentrate on intervening in and addressing the diverse factors contributing to PFPS, along with their associated constraints.

Ⅴ. Conclusion

PFPS patients often experience difficulty performing everyday activities due to serious pain, which makes it challenging to sufficiently accept weight loads on the knees. This study gradually increased the load on the lower extremities and utilized the proprioceptive effect to ensure safe weight bearing. Intervention applying irradiation effects from a gradual PNF pattern in PFPS patients resulted in improvements in pain and alignment of the feet. To enhance the functional abilities of PFPS patients in future clinical settings, further researches with more robust design are needed to evidence greater values obtained from systematic PNF interventions.

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