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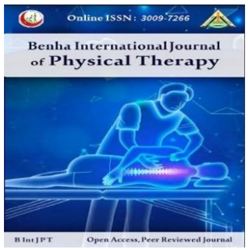

Original research

The Impact of Proprioceptive Neuromuscular Facilitation Techniques versus Core Strengthening Exercises on Balance in Adolescents with Patellofemoral Pain Syndrome.

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Abstract

Background: It's common for adolescents to experience a condition called patellofemoral pain syndrome (PFPS). Basically, this causes pain at the front of the knee, and it can make it hard for them to do things like play sports or just go about their daily lives. **Purpose:** This study aims to explore how effective PNF stretching and core exercises are in improving balance and reducing discomfort for adolescents dealing with Patellofemoral Pain Syndrome (PFPS). **Methods:** We carried out a quasi-experimental trial involving 24 adolescents aged 16 to 18, all diagnosed with PFPS. We randomly split the participants into two groups of 12. Over a two-month period, one group focused on Proprioceptive Neuromuscular Facilitation (PNF) stretching three times a week, while the other worked on core exercises with the same frequency. To see how they were doing, we measured their pain levels using the Visual Analog Scale (VAS), checked how their knees were functioning with the Anterior Knee Pain Scale (AKPS), and tested their balance with the Biodex Balance System. **Results:** Both groups made impressive progress, showing reduced pain, better knee function, and improved balance. That said, the PNF stretching group really stood out—they experienced a more dramatic drop in pain and even greater improvements in knee function compared to the core exercise group. As for dynamic balance, there didn’t seem to be much of a difference between the two groups. **Conclusion:** The results show that PNF techniques might be a better way to relieve pain and improve knee function for teenagers dealing with PFPS than core strengthening exercises. However, there's still more to learn. Future research can dive deeper into the long-term effects and help figure out the best strategies to ensure patients get the most benefits from their treatment.

Keywords: Patellofemoral Pain Syndrome, Proprioceptive Neuromuscular Facilitation, Core Training, Balance, Adolescents.

INTRODUCTION:

Patellofemoral pain syndrome (PFPS) significantly affects adolescents, causing pain around the kneecap, particularly during activities like running, squatting, and stair climbing. This condition is estimated to impact 6–7% of this population, with a higher prevalence in females. The condition is complicated, with causes ranging from muscle imbalances and abnormal kneecap movement to inefficiencies in biomechanics. These difficulties create a real struggle for doctors and therapists trying to help

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people with PFPS, and they put a lot of extra pressure on our already busy healthcare systems.[1,2]

Studies support PNF stretching and core exercises as effective treatments for PFPS, improving function through increased flexibility and stability.[1,3] Even though we see good results with stretching and core work, we haven't really looked closely at how they help young people with PFPS, especially when it comes to their balance and getting back to their usual activities. That's why we decided to compare these two approaches, to see which one helps teenagers with PFPS feel less pain and stand more confidently. The patellofemoral joint (PFJ) is where the kneecap (patella) and thighbone (femur) meet at the trochlear groove. The patella, a distinctive sesamoid bone, plays a crucial role by boosting the efficiency of the quadriceps muscle, making knee extension both stronger and more effective.[4]

The proper functioning of the patellofemoral joint (PFJ) during exercise relies on a combination of bony structures, static support, and dynamic stabilizing forces. The vastus medialis obliquus (VMO), part of the quadriceps muscle group, plays a key role in keeping the kneecap stable. If the VMO becomes weak or responds too slowly, the kneecap can shift out of alignment, raising the chances of developing PFPS. [5,6] Basically, our kneecaps are essential for strong, smooth knee movement. They give our thigh muscles a real advantage. But, when we bend our knees, the way the kneecap interacts with the thighbone changes, and that can put extra stress on the joint.[7] If this happens repeatedly and the kneecap isn't tracking right, it can lead to a lot of pain and make it difficult to do everyday things. That's why we really need to focus on finding good rehab solutions to help people get their lives back.[8]

Our bodies are designed for balance, for smooth, controlled movement. But when our core muscles are weak, that balance is off. It's like trying to walk on a wobbly surface, and that wobble affects our knees. This can lead to increased knee strain and, unfortunately, that frustrating knee pain, PFPS. We want to help people move without that frustration.[9,10]

Proprioceptive neuromuscular facilitation exercises have been demonstrated to dramatically increase strength and flexibility, improving functional results across a range of groups.[11] Knee pain, specifically PFPS, is a common problem for teenagers, often making it hard for them to do everyday activities and putting a strain on healthcare systems. We know that both PNF stretching and core exercises can help with PFPS, but we haven't really looked closely at how they affect something really important: balance. This study wants to find out which of these two treatments, stretching or core work, helps teenagers with PFPS improve their balance the most. We're starting with the assumption that there might not be a difference between the two. Ultimately, we hope this research will give physical therapists who work with kids and teens better tools to help them get back to moving comfortably and confidently.

METHODS

Study design:

Approved by the Faculty of Physical Therapy Ethical Committee at Delta University for Science and Technology (F.P.T2407027), this quasi-experimental study ran from April 2024 to July 2024 and followed the ethical guidelines of the 1975 Helsinki Declaration. It was registered on ClincaTrails.gov (NCT06696872). A total of 24 teenagers, aged 16 to 18, who were diagnosed with PFPS, were recruited from Delta University for Science and Technology's Faculty of Physical Therapy. Each participant willingly provided written informed consent. To ensure reliable results, the sample size was carefully calculated using G*Power 3.1.9, providing the study with sufficient statistical strength.

Participants:

Adolescents aged 16 to 18 years with PFPS were included if they had anterior knee pain for at least 4 weeks, pain intensity exceeding 3 on a visual analog scale (VAS), pain worsened by at least two of the following activities: jumping, running, prolonged sitting, climbing stair, kneeling, and squatting, and a positive patellar grind test, and were within the normal body mass

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index (BMI) percentile categories. Exclusion criteria consisted of previous lower limb surgery or musculoskeletal deformities, cruciate ligament injuries, meniscal injuries, collateral ligament injuries, tenderness associated with these structures, intra-articular injury, iliotibial band tenderness, patellar tendon tenderness, pes anserine tendons tenderness, joint effusion, referred pain from the hip or lumbar region, or known articular cartilage damage.

Adolescents were randomly assigned to two equal groups: the PNF group and the core strengthening group, **Figure (1)**. All participants received conventional treatment alongside their respective intervention protocols (30 minutes daily, three times per week for two months).

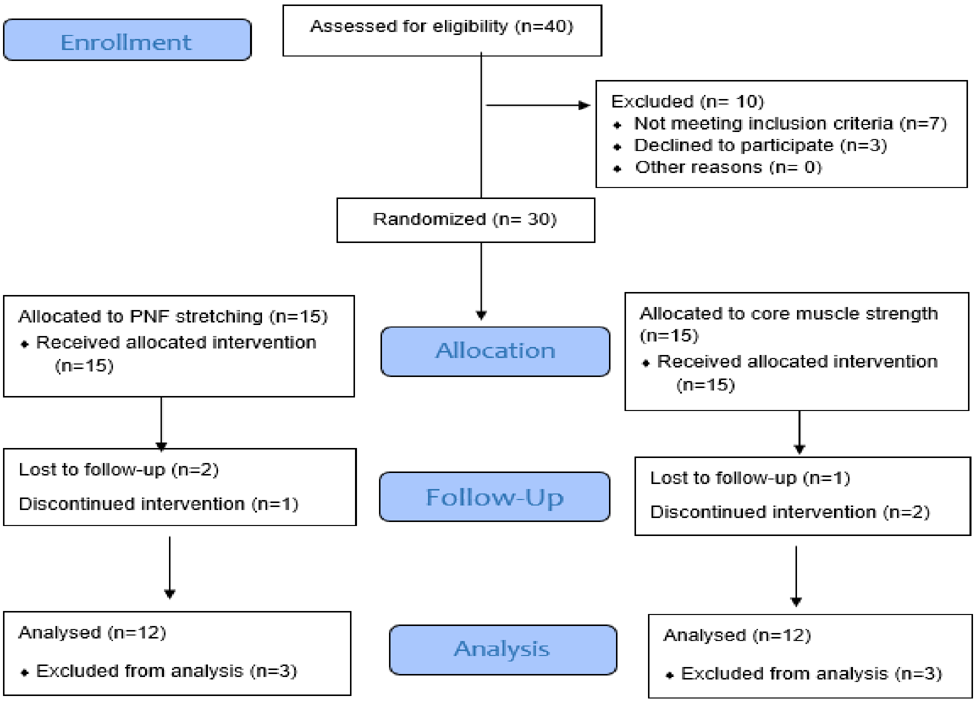

Figure (1): Study flow chart.

Assessment tools

Pain and Functional Assessment:

This study employed several validated tools to quantify the effects of the interventions. Pain intensity was measured using the 10-point Numeric Pain Rating Scale called Visual Analog Scale (VAS)), a widely used and effective method for assessing subjective pain experience.[12, 13] Functional limitations associated with PFPS were evaluated using the self-administered Anterior Knee Pain Scale (AKPS), a questionnaire commonly used in research to assess pain and functional limitations in individuals with PFPS.[14, 15]

Balance Assessment:

Balance, both static and dynamic, was assessed using the Biodex Balance System SD (BBS), a reliable and valid instrument for measuring postural stability.[16] The BBS was used to conduct postural stability test, measuring deviations from the canter of balance (anteroposterior, mediolateral and overall), where lower scores indicate better stability.

Procedures:

Assessment Procedures

A number of evaluations were carried out both before and after the 8-week intervention. The 10-point Numeric Pain Rating Scale (NPRS) was used to gauge the severity of the pain.[13]

The self-administered Anterior Knee Pain Scale (AKPS) was used to evaluate functional limits.[13, 14] We evaluated balance using the Biodex Balance System SD (BBS)[16], with an emphasis on both static and dynamic components, including postural stability test. To ensure that the measurements were both accurate and consistent, we took meticulous care in positioning participants correctly, configuring

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the system to meet standard protocols, and adhering strictly to the precise procedures detailed in the BALANCE SYSTEM SD OPERATION/SERVICE MANUAL for collecting and recording data.

Intervention Procedures

Both groups participated in a conventional physical therapy program for eight weeks, three times per week. This program included eccentric exercises, quadriceps and hip muscle strengthening, isometric exercises, and stretching, with a focus on improving knee stability and function.[10]

The PNF group received PNF stretching in addition to their regular routine. During these sessions, the therapist carefully guided each child through certain stretches, especially for their hamstrings and quadriceps. To assist them relax and get the most out of the stretch, the kids were told to take long, steady breaths while the therapist performed the exercises. Each stretch was held for two or three repetitions, each lasting a significant period of time. Each stretch was held for 30 seconds by the therapist. Passive stretching, isometric contraction (10 seconds), muscular relaxation (30 seconds), and deepening stretch were all part of the Hold-Relax PNF regimen.

For eight weeks, the CORE group followed a structured core strengthening program alongside the conventional training routine, exercising three times a week. To enhance core activation, adolescents were guided to gently engage their deep abdominal muscles while maintaining slow, steady breathing.[1] The "big 3" exercises—curl-up, side bridge, and quadruped position—as defined by McGill comprised the core training regimen. Training intensity was progressively increased throughout the program by adjusting lever lengths and repetitions.

Data Analysis

The data were screened before the final analysis to test the normality assumption by using the Shapiro-Wilk test, which reflects no normal distribution ($p > 0.05$). Additionally, Levene's test was used to test the homogeneity of variance, which revealed no significant difference ($p > 0.05$). The SPSS package program version 25 for Windows (SPSS, Inc., Chicago, IL– IBM) was used. All data were expressed as group's median and interquartile range (IQR) for demographic data, pain, AKPS, static postural stability and dynamic postural stability. The Whitney U test was used to compare the tested variables in both groups and measuring periods. The first independent variable (between-subject factors) was the tested group with 2 levels (core group and PNF group). The second independent variable (within-subject factor) was the testing time before and after treatment. The four dependent variables were pain, AKPS, static postural stability and dynamic postural stability.

RESULTS:

In this study, 24 adolescents were randomly divided into two groups, with 12 participants in each the PNF group and the core training group. Both groups were closely matched in terms of age, weight, height, and BMI, with no significant differences ($p > 0.05$), table (1). The gender distribution was fairly balanced between the two groups, with the core group made up of 58% females and 42% males, while the PNF group had 42% males and 58% females ($p = 0.414$). Likewise, the proportion of participants with right or left leg involvement was nearly the same in both groups ($p = 0.423$). This even distribution ensured that any differences in outcomes were a direct result of the treatments rather than pre-existing individual differences among participants.

Table (1): Demographic Comparison Between PNF and Core Groups

Variable	PNF Group (n=12)	Core Group (n=12)	P-Value
Age (years)	17.79 ± 0.26	17.79 ± 0.26	1.000
Weight (kg)	66.50 ± 6.16	66.49 ± 9.07	0.998
Height (m)	1.69 ± 0.07	1.69 ± 0.09	0.892
BMI (kg/m²)	23.20 ± 1.47	23.19 ± 0.93	0.984
Gender (M/F)	5(42%) / 7(58 %)	7(58 %) / 5(42%)	0.414
Affected Leg (RT/LT)	7(58 %) / 5(42%)	5(42%) / 7(58 %)	0.423

Numerical Data are expressed as mean ± SD or number (%)
P-value > 0.05: non-significant.

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Both the PNF and Core training programs brought significant relief, improving anterior knee function and reducing pain levels. That said, the PNF approach really shone adolescents reported a dramatic 74% drop in pain intensity, compared to the 58.3% reduction seen with Core activities, table (2).

Table (2): The design Mann-Whitney U for pain within and between groups.

Items		Groups (Median ±IQR)		U-value	Z-value	P-value
		PNF Group (n=12)	Core Group (n=12)			
Pain	Pre-treatment	6.50 (5.25-7.00)	6.00 (5.00-7.00)	62.50	0.563	0.573
	Post –treatment	2.00 (1.00-4.00)	1.50 (1.00-2.00)	41.00	2.031	0.042*
	Z-value	3.089	3.071			
	P-value	0.002*	0.002*			
	Mean difference (change)	4.50	3.50			
	Improvement %	74%	58.30%			
	Effect Size	5.46	4.09			

Anterior Knee Pain Scale scores also saw greater improvements with PNF, table (3). Interestingly, across the board, PNF was the clear favorite. Adolescents significantly preferred it, with pain relief (p=0.042) and AKPS gains (p=0.047) reinforcing the edge it had over Core training. Large effect sizes in both groups suggested that knee function and pain perception had changed in a way that was clinically significant.

Table (3): The design Mann-Whitney U for AKP within and between groups.

Item		Groups (Median ±IQR)		U-value	Z-value	*P*-value
		PNF Group (n=12)	Core Group (n=12)			
AKPS	Pre-treatment	79.00 (71.00-89.50)	79.00 (71.00-89.50)	69.50	0.137	0.891
	Post -treatment	94.00 (89.75-95.75)	90.00 (87.00-95.00)	42.50	1.987	0.047*
	Z-value	3.071	3.061			
	P-value	0.002*	0.002*			
	Mean difference (change)	15.8	13.90			
	Improvement %	16.14%	14.48%			
	Effect Size	2.50	2.30			

*Significant P-value: < 0.05 Effect Size (r): 0.1 = small, 0.3 = medium, 0.5 = large

In assessing static postural stability, table (4), both the PNF and Core training groups exhibited varying levels of improvement. The PNF group showed a significant decrease in the Antro-Posterior Stability Index (APSI), with median values dropping from 0.4 to 0.3, resulting in a 60% improvement and a medium effect size of 0.46 (p=0.023). The Core group didn't really make much progress with APSI. Their median scores barely budged, starting at 0.5 and only dropping slightly to 0.3 a tiny 25% improvement that didn't amount to much (effect size: 0.07, p=0.721). It was a different story for the Medio-Lateral Stability Index (MLSI).

The analysis revealed that both groups demonstrated improvement; however, the PNF group exhibited a significantly greater improvement (66.7%) compared to the Core group (50%). This sharp difference highlights how effective PNF stretching methods are in improving physical skills and general fitness levels. Moreover, this advantage extended beyond mere performance metrics, manifesting more profoundly in terms of general stability and muscular robustness. The PNF team witnessed a notable 57.1% increase in stability, whereas the Core group saw no observable change, further emphasizing the superiority of PNF strategies in fortifying bodily balance. This comparison leaves no doubt: PNF stretching is the more effective and reliable approach. It has shown remarkable improvements in both performance and stability, outperforming the Core group by a significant margin. For anyone looking to boost their physical ability and balance, incorporating PNF stretching into their regular training routine is a game-changer.

Dynamic postural stability improved in both groups, table (5), although the PNF group's benefits were more pronounced. In particular, the Dynamic Antro-Posterior Stability Index (APSI) increased by 50% in the Core group, with median values shifting from 1.0 to 0.8 (p=0.015), and by 57.1% in the PNF group, with median values shifting from 0.7 to 0.6 (p=0.005). To put it simply, the PNF group showed better results than the Core group when we measured their balance. Specifically, the PNF group improved their Dynamic Medio-Lateral Stability Index (MLSI) by a notable 71.4%, compared to the Core group's 40%. This improvement wasn't just a small change, either. The PNF group's median score for Overall Stability Index (OASI) went from 0.4 to 1.1 (p=0.003), which is a pretty substantial shift. The Core group, on the other hand, only showed minor changes. What this tells us is that PNF stretching seems to give people a bigger boost in dynamic balance compared to core training.

Table (4): The design Mann-Whitney U for Static Postural Stability APSI within and between groups.

Item		Groups (Median ±IQR)		U-value	Z-value	P-value
		PNF Group (n=12)	Core Group (n=12)			
Static Postural Stability APSI	Pre-treatment	0.4 (0.2-0.4)	0.5 (0.4-0.6)	52.5	1.270	0.204
	Post –treatment	0.3 (0.2-0.5)	0.3 (0.2-0.4)	71.0	0.058	0.954
	Z-value	2.275	0.357			
	P-value	0.023*	0.721			
	Mean difference (change)	0.3	0.1			
	Improvement %	60%	25%			
	Effect Size	0.46	0.07			
Static Postural Stability MLSI	Pre-treatment	0.2 (0.2-0.3)	0.3 (0.1-0.4)	65.00	0.433	0.665
	Post –treatment	0.2 (0.2-0.4)	0.2 (0.1-0.2)	60.50	0.693	0.488
	Z-value	2.118	1.134			
	P-value	0.034*	0.257			
	Mean difference (change)	0.2	0.1			
	Improvement %	66.70%	50%			
	Effect Size	0.43	0.23			
Static Postural Stability OASI	Pre-treatment	0.7 (0.5-0.8)	0.5 (0.4-0.6)	54.5	1.155	0.248
	Post –treatment	0.4 (0.3-0.5)	0.5 (0.4-0.8)	63.5	0.520	0.603
	Z-value	2.589	0.980			
	P-value	0.010*	0.327			
	Mean difference (change)	0.4	0.1			
	Improvement %	57.10%	20%			
	Effect Size	0.53	0.20			

*Significant P-value: < 0.05 Effect Size (r): 0.1 = small, 0.3 = medium, 0.5 = large

DISCUSSION

This study looked at how PNF stretching and core strength exercises affect balance in teenagers who have PFPS. The study included twenty-four teenagers, who were between sixteen and eighteen years old, and they were recruited from the Physical Therapy department at Delta University for Science and Technology. Participants were randomly assigned into two groups of equal number, twelve adolescents in each group, representing the PNF group and the CORE group. All adolescents in both groups were assessed before and after two successive months of conducting the treatment program. The PNF group received proprioceptive neuromuscular facilitation stretching in addition to a conventional program for eight weeks (3 sessions/week). The CORE group received core muscle strength exercises in addition to the same conventional program given to the PNF group for eight weeks (3 sessions/week). All adolescents in both groups were evaluated preand post-treatment for pain, AKPS, and posture stability. Comparing the mean values of the demographic data (age, weight, height, BMI, frequency of gender, and affected leg), pain, AKPS, and posture stability tests indicators (APSI, MLSI, and OASI) showed no significant differences between the two groups, clarifying the pre-treatment matching between the groups. In the current study, comparing the pre- and post-treatment mean values of pain and AKPS for each group represented significant differences within each group. Comparing the post-test mean values of pain and AKPS between the two groups showed significant differences in favor of the PNF group. Patellofemoral pain syndrome (PFPS) is a really common cause of knee pain in teenagers, and it's not due to an injury. It affects about 6-7% of kids in school, and it's even more common in girls and athletes. This condition can seriously mess with a teen's ability to move around, their overall quality of life, and how much they participate in social activities. Patellofemoral pain syndrome (PFPS) is a really common issue. It's actually the most frequent type of non-traumatic knee pain we see in adolescents. It affects about 6-7% of school-aged kids, and it tends to show up even more often in girls and young athletes.[17] It's worth noting that the age range of the young people we included in our review (16-18 years old) is similar to what other researchers have used. For instance, **Sanchis et al. (2024)** studied individuals aged 15 to 19, [18] and **Rathleff et al. (2012)** looked at those between 10 and 18 years old.[19] Now, here's something important: some studies that have followed these patients over time have shown us that PFPS in teens isn't usually something they just outgrow. In fact, a pretty large number of people who get diagnosed with PFPS continue to deal with the symptoms for quite a few years. To maintain proper posture, our bodies rely on information from what we see, our inner ear (the vestibular system), and our sense of touch and position (the somatosensory system). Things like pain, our awareness of where our body is in space (proprioception), how strong our muscles are, and how stable our core is all play a role in our balance. When someone has knee pain and their kneecap isn't tracking properly, which is common in patellofemoral pain syndrome (PFPS), it can mess up the signals going to the nervous system. This can lead to problems with neuromuscular control, both when they're standing still and when they're moving.[20] Pain severity was measured pre- and post-intervention using the VAS. Consistent with **Gunay (2017)**, the VAS was employed, which is a 10-centimeter scale ranging from 0 (no pain) to 10 (maximum pain), to quantify pain intensity.[4] In this study, the AKPS was used pre- and post-treatment to assess knee function. This is consistent with **Moyano et al. (2013)**, who mentioned that the AKPS is a 13-item questionnaire designed to characterize individuals with patellofemoral pain syndrome. Also, in this study, all adolescents received pre- and post-treatment evaluations using the BBS. This evaluation process aimed to assess static and dynamic balance through postural stability and single-leg stability tests.[13] This aligns with findings from **Akhbari et al. (2015)**, who suggested that measurements of static and dynamic balance using the BBS are reliable in people with PFPS. (For clarity, the BBS is a tool used to objectively measure postural balance. It's important to remember that the BBS is designed to give an objective assessment of postural balance.[16] This may support our selection for the measurable variables in the current study (pain, AKPS, postural stability and single leg stability tests indicators in both static and dynamic conditions) to investigate the comparative effects of PNF stretching and core strength exercises on balance in adolescents with PFPS. Improvement or pain reduction in PFPS may be due to various mechanisms, including improved neuromuscular control and biomechanics, which support the funding of **Balci et al. (2009)**, who reported that exercise therapy, particularly focusing on closed-chain exercises, has been shown to alleviate pain and improve function. These exercises likely help people improve their control over the quadriceps muscles.[21] This, in turn, can lead to better alignment of the kneecap and less stress on the patellofemoral joint.[22] Also, when you strengthen the core muscles, it can result in greater stability. This translates to less of that uncontrolled movement in the trunk, which, in turn, helps to reduce stress on the knee joint. The importance of trunk control lies in the fact that when someone exhibits poor trunk control, it can lead to excessive inward rotation and movement of the hip towards the body's midline. This then forces the knee outwards, and that increases the pressure on the patellofemoral joint.[23] Reducing pain is also key because it can allow the quadriceps muscles to work more effectively. Pain and quadriceps inhibition are closely linked in PFPS. Stronger quadriceps can counteract the shinbone rotating outward and improve how stable the whole knee is. On top of that, when pain goes down, it might be easier for people to have better posture, and that can also reduce stress on the patellofemoral joint. Addressing tightness in the muscles and tissues on the outside of the thigh, like the iliotibial band, can help lessen sideways pressure on the kneecap. And finally, having good postural control and balance is really important for being able to move and function well.[1] In this study, comparing the pre- and post-treatment mean value of static posture stability for each group represented significant differences within the PNF group for APSI, MLSI, and OASI, while the Core group represented a significant difference in the APSI. Comparing the post-test mean values of static posture stability between the two groups showed non-significant differences. In this study, comparing the pre- and post-treatment mean value of dynamic posture stability for each group represented significant differences within each group for APSI, MLSI, and OASI. When we compared the two groups after the treatment, we didn't find any significant differences in their static or dynamic posture stability. However, the group that received PNF (proprioceptive neuromuscular facilitation) techniques, along with a standard exercise program for eight weeks (three times a week), did show improvements. We think this is because PNF helps in several ways: it can improve how flexible and strong the muscles are, increase how far the knee joint can move, and enhance the communication between the nervous system and the muscles. All of these things together can lead to better balance and improved ability to perform everyday tasks, which is what we saw in the PNF group participants. These effects could be supported by the following concepts: Proprioceptive neuromuscular facilitation stretching targets Golgi Tendon Organs (GTOs) and muscle spindles. By inhibiting muscle spindles and stimulating GTO activity, PNF techniques allow for greater muscle elongation. Several theories, including autogenic inhibition and reciprocal inhibition, attempt to explain the mechanisms underlying PNF's effectiveness in increasing range of motion and improving performance.[24] Specialized sensors known as Golgi tendon organs detect the rise in tension that occurs during muscular contraction. This triggers a reflex reaction, in which a signal is sent through the spinal cord to instruct the contracting muscle to relax and ease off. This is known as autogenic inhibition. Additionally, there is reciprocal inhibition, which causes the muscle on the other side of the joint to reflexively relax when one muscle contracts. Smooth and effective movement depends on this coordinated activity, and methods for promoting muscle relaxation frequently make advantage of this idea.[24] The observed improvements in the PNF group align with **Gao et al. (2023)**, who mentioned that PNF techniques have the potential to alleviate pain, improve load distribution at the knee, and enhance gait patterns.[11] Different stretching techniques can have varying effects on range of motion (ROM) and muscle activity. Proprioceptive Neuromuscular Facilitation techniques work by stimulating proprioceptors to either increase or decrease the activity of muscle groups. A key idea in PNF is combining voluntary muscle contractions with stretching. This helps to reduce reflexive muscle contraction, encourage relaxation, and ultimately increase how far a joint can move (ROM). [25]

Proprioceptive Neuromuscular Facilitation (PNF) stretching techniques have been shown to be more effective than regular stretching for increasing how far a joint can move. These techniques are commonly used in sports and clinics to improve both active and passive range of motion, which helps people move better and recover from injuries. One type of PNF technique is called hold-relax, and it involves contracting muscles in specific ways. PNF techniques, especially hold-relax stretching, are thought to be better than traditional stretching for increasing muscle length. The idea is that PNF reduces the activity of the nerves that make muscles contract, allowing the muscle to stretch more. A number of studies support the fact that PNF techniques are superior when it comes to improving range of motion and flexibility.

Study Limitations

While this study gives us some valuable information about how PNF stretching and core strength exercises affect balance in teenagers with patellofemoral pain syndrome (PFPS), it's important to point out some of its limitations. First off, the study didn't include a control group. To clarify, a control group is essentially a group of participants who don't receive the treatment being studied; this allows researchers to compare their results to those who do. Also, the sample size needs to be increased. It's harder to be certain that the exercises were the sole cause of the improvements we observed without that comparison. Furthermore, in some cases, the researchers didn't use more detailed methods to assess muscle activity during movement, such as electromyography (EMG) or isokinetic dynamometers. Using these technologies could give us a more precise understanding of how the muscles are working, which could help explain why the exercises were beneficial. Third, the study doesn't say how long they followed up with the participants, and it doesn't mention any long-term check-ins to see if the benefits of PNF and core training lasted. But knowing how well these treatments work in the long run is super important for deciding how to manage PFPS over time.

CONCLUSION

Both PNF stretching and core strengthening exercises led to noticeable improvements in pain levels and how well the knees functioned, as we saw from changes in pain scores and the AKPS. While both types of exercise did improve postural stability – whether we measured it during movement or while standing still – neither type was clearly better than the other at improving stability. Overall, these results suggest that both PNF stretching and core strengthening are useful for reducing knee pain and improving function in teenagers with PFPS. However, it looks like PNF stretching might have a slight edge when it comes to reducing pain and improving how well patients can function

Recommendations

Given the limitations of this review and the body of evidence we assessed, there are several avenues to suggest for future research and clinical practice. First, to enable more robust comparisons and strengthen the evidence base for PNF stretching and core training in the treatment of PFPS, future studies really should include a control group. Basically, a group that doesn't get either treatment, so we can see how much of a difference the treatments actually make. Second, to get a more precise idea of what's happening with the muscles during movement, future research should use electromyography (EMG) and isokinetic evaluation. To get more detailed information, we'd really benefit from studies that give us very specific data on how muscles are working and exactly how different treatments change that activity. Also, to fully understand how PNF and core training affect pain, function, and balance in people with PFPS over time, it's important to do longitudinal studies that include follow-up assessments. This kind of research would allow us to develop longer-term treatment strategies and see how well the benefits of these therapies hold up.

Abbreviations

AKPS: Anterior Knee Pain Scale: APSI: Antro-Posterior Stability Index; BBS: Biodex Balance System; BMI: body mass index; MLSI: Medio-Lateral Stability Index; OASI: Overall Stability Index; PFJ: Patellofemoral joint; PFPS: patellofemoral pain syndrome; PNF: Proprioceptive Neuromuscular Facilitation; VAS: Visual Analog Scale.

Declarations:

Ethics approval and consent to participate

This study adhered to the ethical principles outlined in the Declaration of Helsinki (1975). Prior to participation, all subjects provided written informed consent after a comprehensive

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explanation of the study procedures. Ethical approval was granted by the Ethics Review Committee for Human Research at Delta University for Science and Technology's Faculty of Physical Therapy, Egypt. Participants were assured of their right to withdraw from the study at any point without incurring negative consequences.

Consent for publication

NA

Availability of data and materials

The data underpinning this study are accessible upon reasonable request from the corresponding author.

Competing interests

The authors declare no competing financial interests.

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