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Effectiveness of Pilates based Exercises Versus Blood Flow Restriction Training for Improving Pain and Function in Patellofemoral Pain Syndrome

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ABSTRACT
Background: Pain that originates in the adjacent soft tissues or the patellofemoral joint itself is collectively referred to as patellofemoral pain syndrome (PFPS). In orderto improve muscle strength and encourage tissue adaptation without putting the body through strenuous exercise, blood flow restriction (BFR) training hasbecome a popular and promising method. Pilates uses a combination of simple, repetitive exercises to create muscular exertion. The primary goal of the study isto compare the effectiveness of blood flow restriction training and Pilates-based exercises in reducing pain and improving function in patients suffering from patellofemoral pain syndrome.
Method: Thirty patients diagnosed with patellofemoral pain were selected as observation subjects and randomly divided into two groups. The treatment periodwas 3 months (3 sessions/week). In this study, we conducted a comparison and analysis of the Numerical pain rating scale (NRS), Anterior knee pain scale. In this study compared and analyzed the NRS score of the knee, Anterior knee painscale at two different time points—before treatment and after treatment.
Result: After treatment, Group A experienced a significant reduction in pain intensity compared to Group B. Functional status and health-related quality of life improved dramatically in Group A following treatment compared to Group B.
Conclusion: The study's findings demonstrate that teens with PFPS can benefit from Pilates-based core strengthening exercises in a number of ways, including pain reduction, improved functional status, and improved quality of life.

KEY WORDS: Blood flow restriction training, Patello-femoral pain syndrome, Pilates exercises.

INTRODUCTION

Patellofemoral syndrome (PFS), a prevalent cause of anterior knee pain (AKP), is often referred to as runner's knee or patellofemoral pain syndrome (PFPS). This condition affects individuals across various activity levels and age groups, though it is commonly observed in active individuals and adolescents. Characterized by pain at the front of the knee, PFS symptoms are typically exacerbated by activities such as squatting, stair climbing, prolonged sitting, and similar movements. While often self-limiting, the duration of symptoms can be lengthy, sometimes persisting for up to two years.

The reported incidence and prevalence of PFS vary, highlighting the need for accurate epidemiological data to inform healthcare resource allocation and research efforts. As a frequent complaint encountered by physiotherapists, PFS represents a significant portion of anterior knee pain cases.

The global rise in musculoskeletal disorders, including PFS, underscores the growing burden of these conditions. AKP affects a substantial portion of the active population, particularly those aged 20-40, and can negatively impact work-related physical activities, leading to decreased productivity. Beyond the direct costs of treatment, PFS also carries indirect costs associated with reduced productivity and work disability, significantly affecting patients' quality of life.

Patients with PFS typically experience generalized anterior knee pain that worsens with knee flexion, such as during running, stair climbing, or squatting. Diagnosis often involves excluding other intra-articular or peripatellar pathologies. While the exact etiology of PFS remains unclear, it is likely multifactorial, with contributing factors including training regimens and biomechanical imbalances. Several anatomical structures, including the subchondral bone, synovium, retinaculum, skin, nerves, and muscles, may be involved. Anterior knee pain, in general, has a high prevalence, affecting a significant number of individuals annually, with a higher incidence in women.

Studies have indicated a relatively high prevalence of PFP and knee pain, particularly in younger individuals under 40. Although conservative management often resolves PFS symptoms, some individuals experience persistent pain. Patient education regarding the condition, its potential causes, and available treatment options is crucial. Physical therapy or a home exercise program can guide patients in performing appropriate exercises. While the overall prognosis for PFS is generally favorable, a substantial percentage of patients may experience ongoing symptoms even after standard treatment. Factors such as dual symptoms, advanced age, and patellar hypermobility may influence long-term outcomes.

The differential diagnosis for PFS is broad, encompassing conditions such as patellofemoral osteoarthritis, Osgood-Schlatter disease, plica syndrome, bursitis, neuritis, tendinopathies, and referred pain. Clinicians should exercise caution when prescribing quadriceps strengthening exercises, as these may exacerbate PFS symptoms by increasing patellofemoral joint load. Patellar maltracking is often implicated in PFS, though its precise role is debated. The patellofemoral joint's complex function involves a dynamic interplay of static and dynamic structures within the lower extremity. Static factors include leg length discrepancies, foot morphology, hamstring and hip muscle tightness, rotational or angular deformities, and trochlear morphology. Dynamic factors encompass foot pronation, ground reaction forces, and muscle weakness. Hip abductor weakness and hip biomechanics, particularly increased hip adduction angles, have been identified as potential contributing factors.

Numerical pain rating scale – A valid tool of Numerical Rating Scale (NRS), patients are asked to circle the number between 0 and 10 that fits best to their pain intensity. Zero usually represents 'no pain at all' whereas the upper limit represents 'the worst pain ever possible. Anterior knee pain scale – The 11 items that make up the AKPS suggested in this study are divided into distinct categories corresponding to varying degrees of knee function. Each item's categories are scored, and the responses are added up to create a global index. A score of 85 indicates "no deficit," while a score of 0 indicates the maximum possible deficit.

Overload, often related to increased activity levels, is also associated with PFS development. Risk factors for overload include elevated BMI, prior exercise regimens, and pre-existing fitness levels. Structural damage in the patellar region, whether direct or indirect, can contribute to PFS. While various risk factors have been linked to PFS, it is generally accepted that the condition rarely arises from a single cause. Initial management often involves rest, NSAIDs, and ice application. While NSAIDs may provide some pain relief, long-term use is generally discouraged. Other modalities, such as electrical stimulation and therapeutic ultrasound, have not demonstrated consistent symptom reduction. Blood flow restriction (BFR) training combined with low-load exercise has emerged as a potential tool in musculoskeletal rehabilitation, showing promise in improving muscle strength and potentially aiding in PFS management. Pilates, with its emphasis on core stability and controlled movements, may also offer benefits, though research on its application in adolescents with PFPS is limited.

A thorough understanding of patellofemoral joint biomechanics is essential for comprehending PFS. The patellofemoral joint, where the patella articulates with the femur, plays a crucial role in knee extension. Patellar tracking within the femoral groove is influenced by various static and dynamic factors, and imbalances in these forces can lead to abnormal tracking, increased stress, and potentially PFS. Factors such as the Q angle, influenced by bone alignment and other biomechanical factors, can also contribute to patellar maltracking. The pathophysiology of PFS is complex, involving biomechanical factors, muscle imbalances, and potentially inflammation and microdamage within the joint. Patellar instability and other conditions should also be considered in the differential diagnosis of anterior knee pain.

METHODOLOGY

This single-blinded, two-arm randomized controlled trial investigated the effects of Pilates exercises and Blood Flow Restriction (BFR) therapy on pain and functional status in 30 individuals with patellofemoral pain syndrome (PFPS). Recruited via convenience sampling from the outpatient department of Thanthai Roever College of Physiotherapy, Perambalur, participants were randomly assigned to either the Pilates exercise group (n=15) or the BFR therapy group (n=15). The three-month intervention involved three sessions per week. Inclusion criteria encompassed male and female individuals aged 18-35 with anterior knee pain at rest, exacerbated by activities like prolonged sitting, squatting, running, and stair climbing, and experiencing insidious onset for over six weeks without traumatic injury, and no physical therapy within the past three months. Exclusion criteria included meniscal tears, ligament involvement, knee osteoarthritis, rheumatoid arthritis, prior patellar dislocation/subluxation, knee/hip surgery, and active knee inflammation. The independent variables were Pilates exercises and BFR training, while the dependent variables, or primary outcome measures, were the Numerical Pain Rating Scale (NPRS) and the Anterior Knee Pain Scale (AKPS).

The materials used in this study included exercise mats for participant comfort and support during exercises, resistance bands (both Pilates bands and standard elastic bands) to provide varying levels of resistance for strengthening exercises, Pilates balls for core engagement and balance challenges, a pulse oximeter to monitor participant safety during BFR training, and a specialized blood flow restriction cuff for application of controlled pressure during the BFR intervention.

Group A: Pilates – based exercise protocol
Participants ion the Pilates group engaged in 30 – minutes sessions incorporating Pilates exercises. These exercises were designed to address core stability, lower extremity strength, and flexibility, with a focus on proper from and controlled movements. A variety of equipment, including mats, resistance bands (Pilates bands and elastic bands) and Pilates balls, were utilized to enhance the exercises and provide varied levels of challenge. The specific exercises were tailored to the individual's needs and pain tolerance, progressing in difficulty as tolerated throughout the intervention period.

The Pilates exercise protocol consisted of a 30-minute session incorporating various exercises targeting core stability, lower extremity strength, and flexibility. These included the Hundred exercise, Single Leg Stretch, Plank, Hip Twist with a Pilates band, Side Kick Internal/External Rotation with a Pilates band, Squats using a mat, Swimming with a stabilization ball, and Wall Squat Rolls using a Pilates ball. Each exercise was performed for a specified number of sets and repetitions, with the intensity and progression adjusted based on individual participant tolerance and progress throughout the three-month intervention.

Group B : Blood flow restriction training protocol
The Blood Flow Restriction (BFR) training protocol adhered to current literature recommendations for exercise variables. Participants in the BFR group performed a series of exercises three times per week for six weeks, with 15-30 repetitions per set. The resistance load was set at 20-50% of 1 repetition maximum (1RM), although this may have been estimated due to practical limitations in a clinical setting. A pneumatic cuff was placed on the upper third of the thigh, and the inflation pressure was maintained between 20-50 mmHg, also subject to clinical judgment and participant tolerance. The exercises included seated leg extensions, seated leg presses, lateral glider lunges, and side-lying hip abductions. For the seated leg extension, participants performed knee flexion and extension while seated.

The seated leg press involved a supine position with slight hip flexion, and participants performed the press movement. Lateral glider lunges were performed in a standing position, with participants performing side lunges. Finally, side-lying hip abductions were performed with the participant in a side-lying position, lifting the top leg away from the midline. The specific pressure and resistance were adjusted as needed based on individual participant response and tolerance, with careful monitoring to ensure safety and comfort

DATA ANALYSIS AND INTERPRETATION

TABLE: 1 (DEMOGRAPHIC DATA GROUP-A & B)

Variables	**Group A (Mean ± SD)**	**Group B (Mean ± SD)**
Age	24.67 ± 6.172	24.80 ± 6.097
Height	166.40± 10.480	169.67 ± 8.381
Weight	62.60 ± 17.614	61.33 ± 10.445
BMI	24.460 ± 2.4550	21.640 ± 4.7089
Total number of subjects	N=15	N=15

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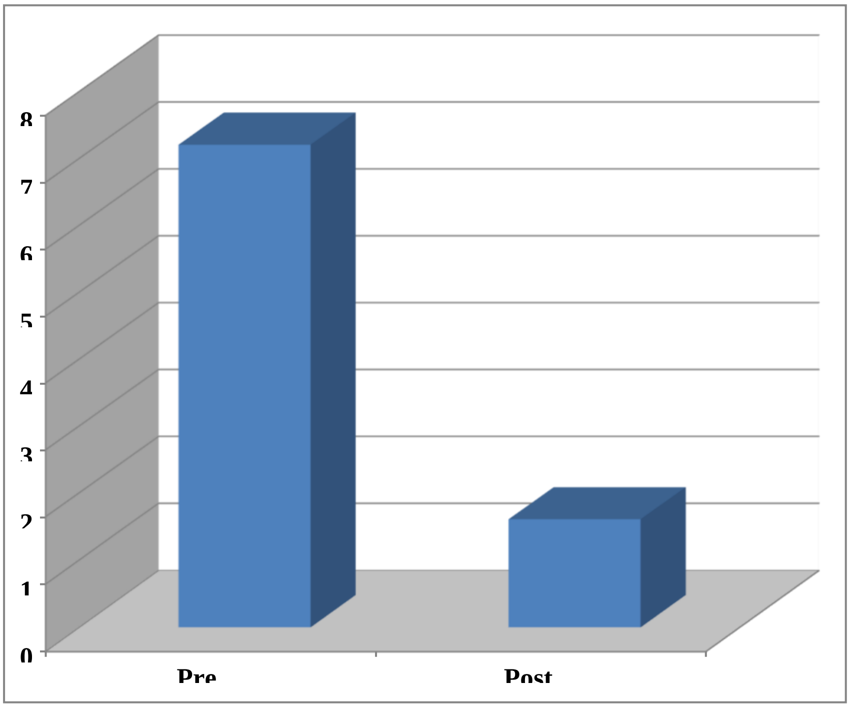
TABLE – II - NUMERICAL PAIN RATING SCALEPAIRED ‘t’ TEST – GROUP A PILATES BASED EXERCISE

S. N	GROUP – A	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	‘t’ VALUE
1.	Pre – test	7.20	0.94	5.60	20.54
2.	Post – test	1.60	0.51		

The table II shows the comparison of pre – test and post – test values of Numerical pain rating scale of Pilates based exercise for Group A showed the calculated‘t’ value 20.5464 is significantly greater than the tabulated ‘t’ value 2.145 at 5% level of significance. This shows that there is significant improvement in Numerical pain rating scale of Pilates based exercise.

GRAPH – NUMERICAL PAIN RATING SCALE PAIRED ‘T’ TEST – GROUP A SCALE



The Graph II shows the mean value of pre – test and post – test analysis ofNumerical pain rating scale of Pilates based exercise in Group – A.

TABLE – 3 NUMERICAL PAIN RATING SCALE – PAIRED ‘t’ TEST – GROUP B BLOOD FLOW RESTRICTION TRAINING

S. N	GROUP – A	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	‘t’ VALUE
1.	Pre – test	7.73	0.70	4.70	31.06
2.	Post – test	2.60	0.63		

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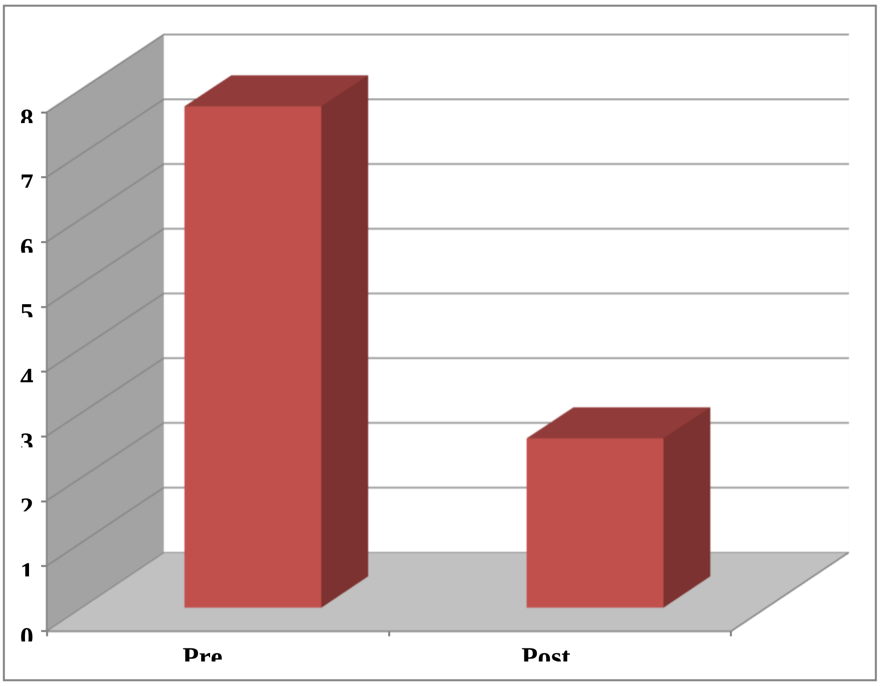
The table III shows the comparison of pre – test and post – test values of Numerical pain rating scale of Blood flow restriction training for Group B showed the calculated‘t’ value 31.0674 is significantly greater than the tabulated‘t’ value 2.145 at 5% level of significance. This shows that there is significant improvement in Numerical pain rating scale of Blood flow restriction training.

GRAPH - 2 NUMERICAL PAIN RATING SCALE PAIRED ‘t’ TEST – GROUP B BLOOD FLOW RESTRICTION TRAINING



The Graph III shows the mean value of pre – test and post – test analysisof Numerical pain rating scale of Blood flow restriction training in Group – B.

TABLE – 4 NUMERICAL PAIN RATING SCALE, UNPAIRED ‘t’ TEST – GROUP Vs GROUP B (POST TEST VALUES)

S. N	SBP	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	‘t’ VALUE
1.	Group – A	1.60	0.51	1.00	4.77
2.	Group – B	2.60	0.63		

The table VI shows the comparison of post – test values of Numerical painrating scale between Group A and Group B showed that the calculated‘t’ value 4.7777 is significantly greater than the tabulated ‘t’ value 2.048 at 5% level of significance. This shows that there is a significant improvement of Numerical pain rating scale in Group – A than Group – B.

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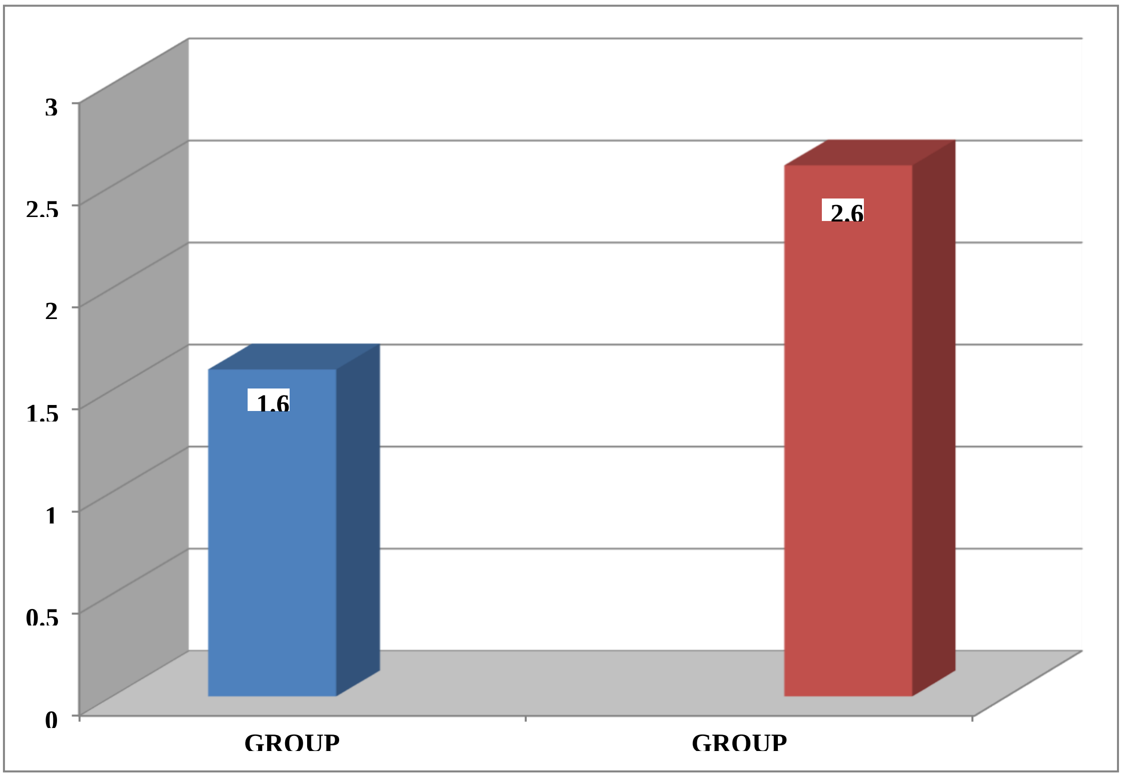
GRAPH – 5 NUMERICAL PAIN RATING SCALE UNPAIRED 't' TEST – GROUP A Vs GROUP B (POST TEST VALUES)



The Graph – VI shows the comparison of post – test values of Numerical painrating scale between Group A and Group B.

TABLE – 5 ANTERIOR KNEE PAIN SCALE
PAIRED 't' TEST – GROUP APILATES BASED EXERCISE

S. N	GROUP – A	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	't' VALUE
1.	Pre – test	58.40	10.14	32.13	20.62
2.	Post – test	90.53	6.51		

The table V shows the comparison of pre – test and post – test values of Anterior knee pain scale of Pilates based exercise for Group A showed the calculated't' value 20.625 is significantly greater than the tabulated 't' value 2.145 at 5% level of significance. This shows that there is significant improvement in Anterior knee pain scale of Pilates based exercise.

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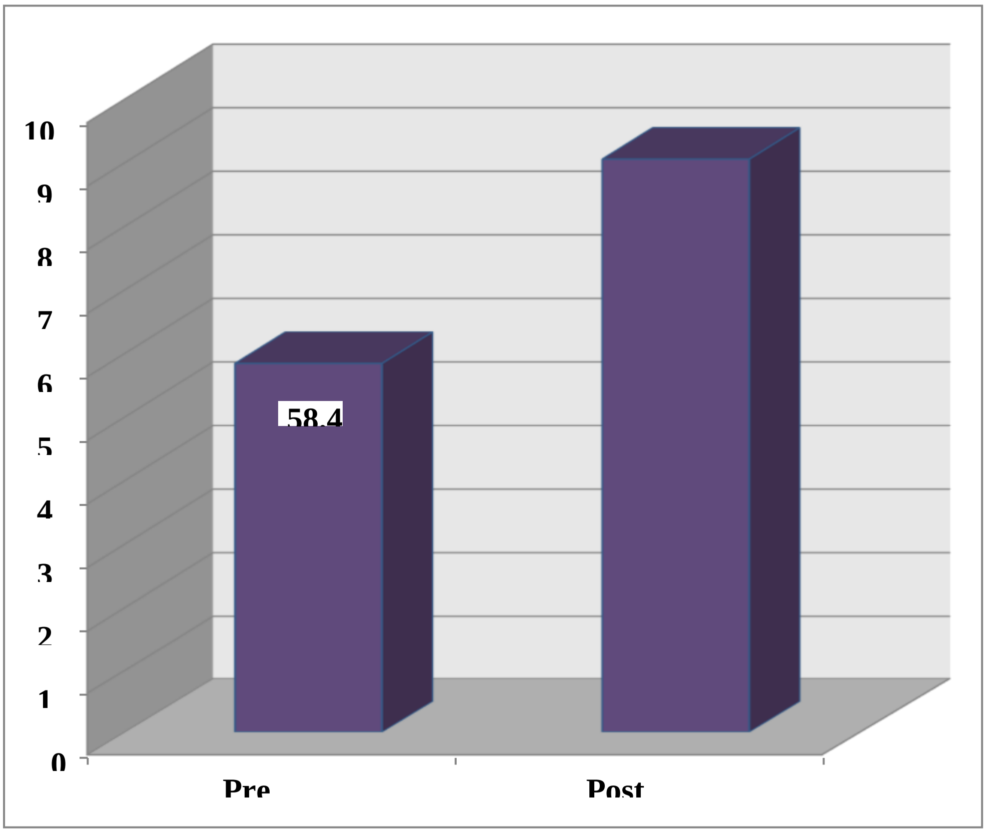
GRAPH – V ANTERIOR KNEE PAIN SCALE
PAIRED 't' TEST – GROUP APILATES BASED EXERCISE



The Graph – V shows the comparison of pre – test and post – test values ofAnterior knee pain scale of Pilates based exercise for Group A.

TABLE – VI ANTERIOR KNEE PAIN SCALE PAIRED 't' TEST – GROUP BBLOOD FLOW RESTRICTION TRAINING

S. N	GROUP – A	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	't' VALUE
1.	Pre – test	56.00	6.39	21.33	17.69
2.	Post – test	77.33	5.63		

The table VI shows the comparison of pre – test and post – test values of Anterior knee pain scale of Blood flow restriction training for Group B showed the calculated't' value 17.692 is significantly greater than the tabulated 't' value 2.145 at 5% level of significance. This shows that there is significant improvement in Anterior knee pain scale of Blood flow restriction training.

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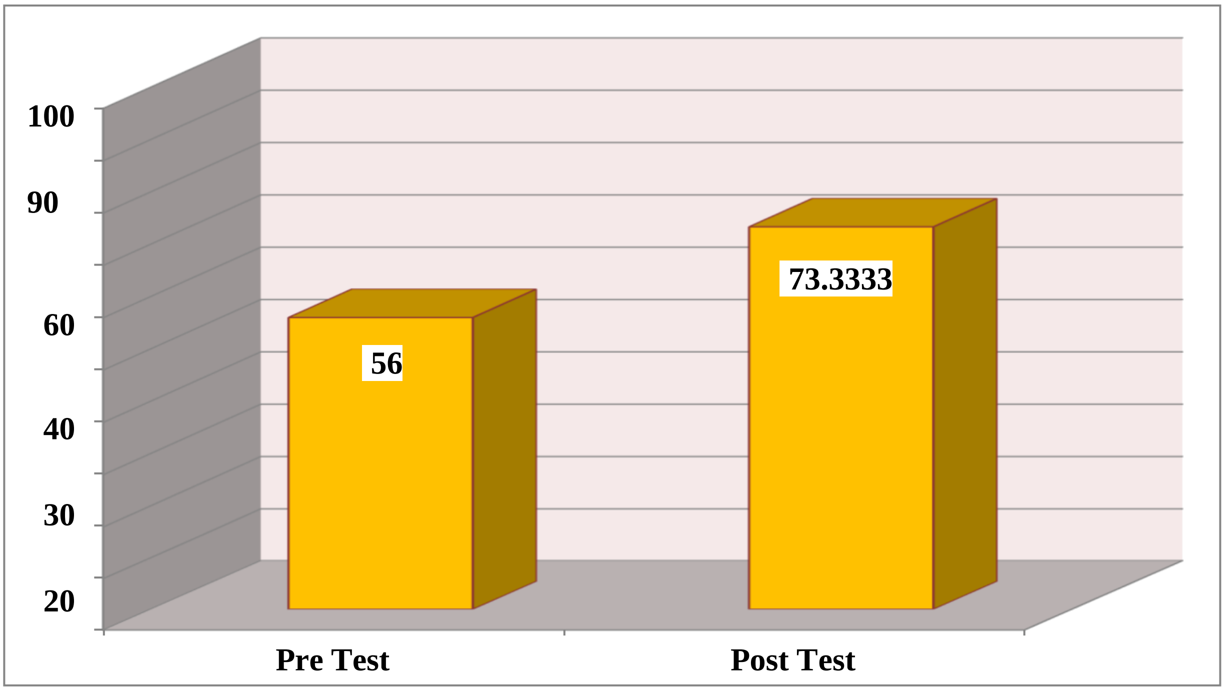
GRAPH – VI ANTERIOR KNEE PAIN SCALE PAIRED 't' TEST – GROUP B BLOOD FLOW RESTRICTION TRAINING



The Graph – VI shows the comparison of pre – test and post – test values ofAnterior knee pain scale of Blood flow restriction training for Group B.

TABLE – VII ANTERIOR KNEE PAIN SCALE
UNPAIRED 't' TEST – GROUP A Vs GROUP B(POST – TEST VALUES)

S. N	SBP	MEAN	STANDARD DEVIATION	MEAN DIFFERENCE	't' VALUE
1.	Group – A	90.53	6.51	13.20	5.93
2.	Group – B	77.33	5.63		

The table VII shows the comparison of post – test values of Anterior kneepain scale between Group A and Group B showed that the calculated't' value 5.934 is significantly greater than the tabulated 't' value 2.048 at 5% level of significance. This shows that there is a significant improvement of Anterior kneepain scale in Group – A than Group – B.

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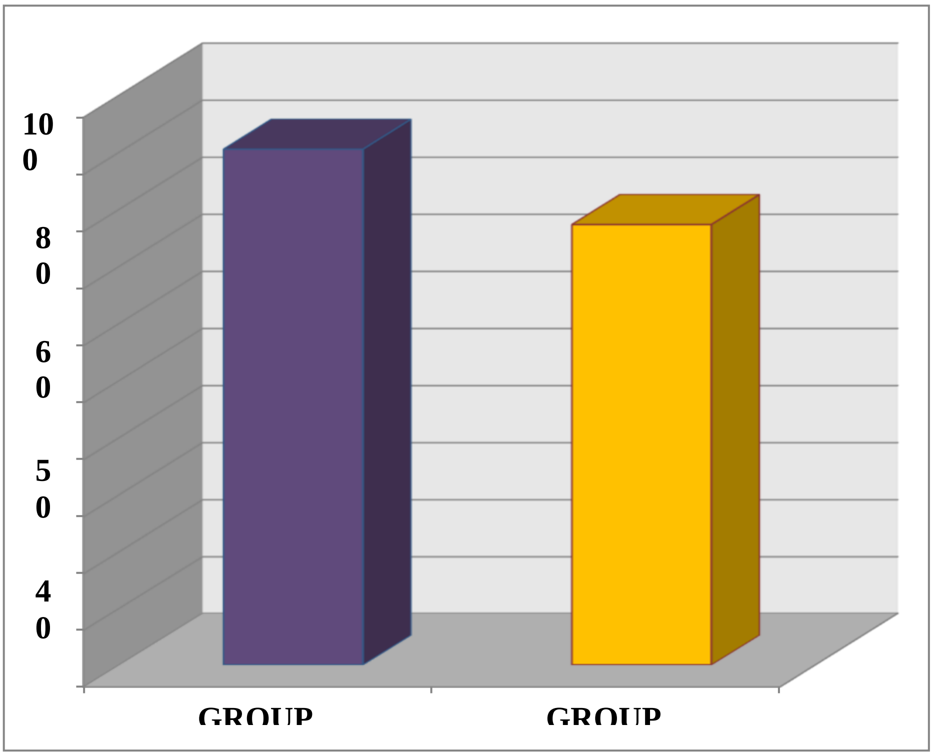
GRAPH – VII UNPAIRED ‘t’ TEST – GROUP A Vs GROUP B(POST – TEST VALUES)



The Graph – VII shows the comparison of post – test values of Anterior knee painscale between Group A and Group B.

RESULT

Both Pilates (Group A) and BFR (Group B) interventions led to significant improvements in pain and function. However, comparisons between groups suggest that Pilates may have resulted in greater reductions in pain (NPRS) and more substantial improvements in function (AKPS). Group A demonstrated significant improvements in KOOS and CAHAI scores, while Group B showed significant improvements in grip strength and CAHAI scores. Unpaired t-tests confirmed statistically significant differences between groups for both NPRS and AKPS changes ($p < 0.001$), favoring Group A.

DISCUSSION

This study investigated the effects of a 12-week Pilates exercise program and blood flow restriction (BFR) training regimen on pain and functional status in adolescents with patellofemoral pain syndrome (PFPS). The knee joint, as the body's most complex joint, is crucial for lower limb movement and stability, making it susceptible to pain and injury, thereby increasing the risk of knee-related disorders. Evidence suggests a link between knee pain and abnormal joint pressure, as well as weakness in stabilizing muscles, particularly the quadriceps, hip abductors, and external rotators. PFPS, a condition with a complex and poorly understood pathogenesis, is associated with lower extremity functional deficits, sports-related injuries, and reduced long-term quality of life. Factors such as abnormal Q-angle, meniscal tears, tibial position abnormalities, knee hyperextension, limited hip motion, altered periprosthetic muscle tension, and ligamentous injuries may also contribute to knee pain.

PFPS is a common musculoskeletal issue among adolescents, impacting daily activities like running, stair climbing, kneeling, and squatting, often leading to decreased physical activity compared to their peers. The use of Theraband and Pilates balls in the exercise protocols may have contributed to functional improvements by providing proprioceptive feedback and stimulating a range of sensory input, promoting optimal movement patterns. Pilates training may alleviate pain through stress reduction. The breathing exercises integral to Pilates can improve circulation, lung capacity, and oxygenation, potentially stimulating endorphin release and thus reducing pain. Increased flexibility, potentially a result of Pilates training, may further enhance physical performance and reduce the energy cost of joint movement, minimizing muscle tension and the risk of exercise-related injuries. Previous research has demonstrated that Pilates-based core strengthening exercises can improve physical and mental health-related quality of life in individuals with musculoskeletal conditions.

BFR training, by utilizing pressure devices, allows for high-load training effects with lower loads, which is beneficial in sports rehabilitation and musculoskeletal pain management. Strengthening the periarticular muscles can be crucial for PFPS patients, potentially reducing or eliminating pain, improving lower limb strength, restoring knee function, and increasing joint range of motion. BFR training may offer an effective intervention by promoting muscle strength and recruitment, increasing blood flow to periarticular muscles, and providing joint protection, all while maintaining a high level of safety and training efficiency.

This study acknowledges certain limitations. The relatively small sample size may have introduced random errors, potentially impacting the reliability of the findings. Future research with larger sample sizes is recommended. The absence of long-term follow-up limits the understanding of the sustained effects of the interventions. Furthermore, the study population's skew towards athletic individuals may limit the generalizability of the findings to other populations. Finally, the 12-week intervention period, while substantial, may be considered relatively short. Future studies could explore the benefits and potential risks of longer-term interventions to determine their optimal duration for therapeutic outcomes in PFPS.

CONCLUSION

The findings of this study demonstrate statistically significant improvements in both pain levels and functional status within both the Pilates exercise group and the Blood Flow Restriction (BFR) training group. However, a comparison of the mean values between the two groups suggests that the Pilates exercise intervention may have resulted in greater reductions in pain intensity and more substantial improvements in functional capacity compared to the BFR training protocol.

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