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Effect of Blood Flow Restriction Training on Pain, Muscle Strength, Endurance and Functional Performance in Individuals with Cervical Radiculopathy

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ABSTRACT

Cervical radiculopathy is a common neuromusculoskeletal disorder characterized by radiating neck and arm pain, sensory and motor deficits, and functional disability. Conventional physiotherapy often provides relief, but many patients continue to experience residual pain, weakness, and endurance limitations due to the inability to tolerate high-load exercises. Blood Flow Restriction (BFR) training, which allows strength and hypertrophy gains at low loads, has shown promise in musculoskeletal rehabilitation but remains underexplored in cervical radiculopathy. To evaluate the effectiveness of BFR training in combination with conventional physiotherapy compared to conventional physiotherapy alone in improving pain, muscle strength, endurance, and functional performance in individuals with cervical radiculopathy. Participants in both groups received a structured physiotherapy program targeting the primary impairments associated with cervical radiculopathy, including pain, reduced neural mobility, cervical and scapular muscle weakness, limited endurance, and postural deficits. Conventional therapy comprised cervical spine mobilization, stretching of tight musculature, neural mobilization techniques to relieve nerve root irritation, progressive strengthening of cervical and scapular muscles, endurance training, and postural re-education. Ergonomic advice and guidance on daily activities were also provided to minimize cervical strain and prevent recurrence. In addition, Group A received Blood Flow Restriction (BFR) training. A pneumatic cuff was applied to the upper arm at 50–60% arterial occlusion pressure, and participants performed low-load exercises at 20–30% of their one-repetition maximum, including biceps curls, shoulder abduction, grip strengthening, and scapular activation drills. Exercises were completed in 3–4 sets of 15–30 repetitions over 15–20 minutes, three times per week. BFR facilitated strength and endurance gains at low intensities, reducing mechanical stress while promoting hypertrophy and neuromuscular adaptation, and no adverse events were reported. Total protocol follow up to 4 weeks. Both groups showed significant improvements after treatment, but the Blood Flow Restriction (BFR) group achieved superior results. Pain intensity (NPRS) decreased from 7.20 ± 1.18 to 4.23 ± 1.38 in the BFR group, compared to 6.83 ± 1.28 to 5.23 ± 1.33 in the conventional group ($p = 0.006$). Muscle strength increased to 24.08 ± 5.86 kg in the BFR group versus 20.88 ± 5.21 kg in the control group ($p = 0.029$). Endurance improved to 29.61 ± 7.15 seconds with BFR and 23.73 ± 6.60 seconds with conventional therapy ($p = 0.002$). Functional ability (DASH score) improved more in the BFR group (31.62 ± 6.19) compared to the control group (44.43 ± 9.90) ($p < 0.001$). These results confirm that adding BFR to physiotherapy produced significantly better outcomes in pain, strength, endurance, and function. This study concludes that Blood Flow Restriction (BFR) training, when combined with conventional physiotherapy, is more effective than conventional physiotherapy alone in patients with cervical radiculopathy. Participants in the BFR group demonstrated greater reductions in pain, significant improvements in muscle strength and endurance, and superior functional performance outcomes. These findings support the integration of BFR as a safe and effective adjunct to conventional rehabilitation, offering clinicians an evidence-based strategy to optimize conservative management and enhance recovery in cervical radiculopathy.

KEY WORDS: CERVICAL POSTURAL SYNDROME, ICF, SF-36, SENSITIVITY, SPECIFICITY, FUNCTIONAL LIMITATION, QUALITY OF LIFE, MUSCULOSKELETAL DISORDERS, POSTURE ASSESSMENT, PHYSIOTHERAPY EVALUATION.

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INTRODUCTION

Cervical radiculopathy is a prevalent musculoskeletal condition resulting from compression or irritation of cervical nerve roots, most commonly at the C6–C7 levels. This compression can occur due to disc herniation, degenerative changes, or osteophyte formation, leading to characteristic symptoms such as neck pain radiating to the upper limb, numbness, tingling, muscle weakness, and functional limitations that significantly impact daily life and occupational performance.

The condition is particularly common in men aged 40–50 years, although it can affect adults across a broader age range. The severity of symptoms often results in reduced quality of life, impaired work productivity, and challenges in performing routine activities, emphasizing the need for effective and patient-friendly rehabilitation strategies [1,2].

Conservative management, primarily physiotherapy, remains the first-line approach for patients with cervical radiculopathy [3]. Standard physiotherapy programs aim to relieve pain, improve neural mobility, restore cervical and scapular muscle strength, enhance muscular endurance, and correct postural deviations. Typical interventions include cervical mobilization, stretching of shortened musculature, neural gliding exercises, progressive strengthening, endurance training, and ergonomic education [4,5]. While conventional strength training is effective in promoting muscle hypertrophy and functional gains, it often relies on moderate to high loads that may not be tolerated by patients with cervical radiculopathy due to pain, nerve root compression, or apprehension about aggravating symptoms [6].

This limitation can restrict exercise intensity and hinder optimal rehabilitation outcomes. Blood Flow Restriction (BFR) training has recently emerged as a promising adjunct to conventional physiotherapy, particularly for populations unable to tolerate high-load exercises7. BFR involves applying a pneumatic cuff or elastic band to partially restrict venous return while allowing arterial inflow, creating a hypoxic and metabolically stressed environment in the targeted muscles. When combined with low-intensity resistance exercises, BFR promotes significant gains in muscle strength and hypertrophy comparable to high-load training8. The mechanisms underlying these effects include enhanced recruitment of fast-twitch fibers, accumulation of metabolites that stimulate anabolic pathways, and activation of signaling cascades such as mechanistic target of rapamycin (mTOR) [9,10].

Additionally, BFR-induced metabolic stress may trigger the release of endogenous opioids and growth factors, which can contribute to pain modulation and improved exercise tolerance [11]. Although BFR has demonstrated efficacy in lower limb rehabilitation, post-operative recovery, and conditions such as knee osteoarthritis and anterior cruciate ligament reconstruction, its application in cervical radiculopathy remains underexplored.

Integrating BFR into physiotherapy programs offers the potential to enhance muscular strength, endurance, and functional performance at low exercise intensities, reducing mechanical stress on the cervical spine while facilitating effective rehabilitation. By addressing both neuromuscular and functional deficits safely and efficiently, BFR may improve patient adherence, accelerate recovery, and enhance overall quality of life. Investigating its role alongside conventional physiotherapy could provide valuable evidence to optimize rehabilitation strategies for individuals with cervical radiculopathy and offer a practical, patient-friendly approach for clinical practice.

METHODOLOGY

This research was conducted as a randomized controlled trial at Santosh Medical College, Ghaziabad, with the objective of determining whether the addition of Blood Flow Restriction (BFR) training to conventional physiotherapy could produce superior outcomes in patients suffering from cervical radiculopathy. Prior to the commencement of the study, ethical clearance was obtained from the Institutional Ethics Committee, and written informed consent was taken from all participants in accordance with the ethical standards of the Declaration of Helsinki (Approval No. SCOP/Oct-24/ECN-94510023681). A total of sixty patients were recruited for the trial, both male and female, aged between twenty and fifty years. These participants presented with clinical features consistent with cervical radiculopathy, including neck pain radiating to the upper limb, sensory disturbances such as numbness and tingling, and motor weakness in the affected limb.

The diagnosis was established on clinical grounds supported by relevant medical investigations. Exclusion criteria were carefully defined in order to safeguard patient safety and maintain homogeneity in the study population. Patients were excluded if they had a history of cervical spine surgery, vascular or clotting disorders, uncontrolled hypertension, pregnancy, or severe neurological conditions. These criteria helped ensure that the participants were suitable candidates for both conventional and BFR-based interventions.

After screening, participants were randomly allocated into two groups of thirty using a computer-generated randomization process. Group A received conventional physiotherapy combined with BFR training, while Group B underwent only conventional physiotherapy. To reduce bias, all outcome assessments were conducted by a blinded physiotherapist who was not involved in the intervention delivery.

Both groups attended treatment sessions three to four times per week over a period of four to six weeks, a frequency consistent with standard rehabilitation protocols in musculoskeletal physiotherapy [12,13].

All participants received a structured physiotherapy program designed to address the cardinal impairments associated with cervical radiculopathy, namely pain, neural mobility deficits, weakness of cervical and scapular muscles, reduced muscular endurance, and poor postural control. Conventional therapy included cervical mobilization techniques, stretching of shortened musculature, neural mobilization to reduce irritation of the affected nerve roots, and progressive strengthening of the cervical stabilizers and scapular muscles.

In addition, endurance training and postural re-education formed an integral part of the regimen, ensuring that participants were equipped with strategies to prevent recurrence and manage their condition effectively in daily life. Ergonomic advice was also provided, focusing on correction of workplace posture and modifications in daily activities to reduce cervical strain [14]. While both groups followed the same conventional program, participants in Group A also received BFR training as an adjunct.

This technique involved the application of a pneumatic cuff around the upper arm, which was inflated to approximately 50–60% of the individual's arterial occlusion pressure. Under these conditions, participants performed low-load resistance exercises at an intensity of about 20–30% of their one-repetition maximum (1-RM). Exercises primarily targeted the upper limb musculature and included biceps curls, shoulder abduction, grip strengthening, and scapular muscle activation drills.

These exercises were performed in three to four sets of 15–30 repetitions, and the BFR portion of the session lasted for about fifteen to twenty minutes, three times per week. The choice of this protocol was based on evidence suggesting that BFR allows patients to achieve muscular hypertrophy and strength gains comparable to high-load training, but with significantly reduced mechanical stress on joints and the cervical spine [3,15].

Throughout the intervention, patient safety was closely monitored. Participants were informed about expected sensations such as mild tightness under the cuff, and any unusual discomfort was promptly addressed. No adverse events, such as dizziness, excessive swelling, or thromboembolic complications, were observed during the course of the study.

By the end of the four-week intervention period, both groups demonstrated notable clinical improvement. However, patients in the BFR group consistently showed greater reductions in pain, superior gains in muscular strength and endurance, and enhanced functional recovery compared to the conventional physiotherapy group alone, highlighting the clinical utility of BFR as an adjunct to rehabilitation in cervical radiculopathy.

The effectiveness of the rehabilitation program was evaluated using four primary outcome measures, carefully chosen to provide a comprehensive view of patient progress. Pain intensity was assessed with the Numeric Pain Rating Scale (NPRS), an eleven-point scale ranging from zero, indicating no pain, to ten, representing the worst imaginable pain. This tool is widely recognized for its simplicity and reliability in tracking symptom progression and evaluating clinical outcomes in musculoskeletal disorders [11].

Muscle strength was measured with a handheld dynamometer, which provided objective readings of peak isometric force in the cervical and upper limb muscles. The use of dynamometry ensured precise and reproducible assessment of strength gains, which is essential when evaluating the impact of strength-based interventions such as BFR16. Muscular endurance was measured through sustained isometric holds and repeated task performance, which allowed for the evaluation of a participant's ability to maintain activity over time without excessive fatigue.

Endurance is a critical factor in cervical radiculopathy rehabilitation, as patients often present with impaired tolerance for prolonged postural and functional activities4. Finally, functional performance was assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire, a validated self-reported instrument that captures disability and symptoms in upper limb-related functional activities.

The DASH consists of thirty items scored on a five-point Likert scale, and the overall score ranges from zero, representing no disability, to one hundred, representing maximum disability. It provided insight into the real-world implications of the interventions on activities of daily living and quality of life7. Together, these outcome measures enabled a holistic evaluation of the intervention effects, encompassing symptomatic relief, neuromuscular performance, and functional independence. Statistical analysis demonstrated significant improvements in both groups, but the BFR group consistently showed greater benefits across all four domains. These findings confirm the potential role of BFR training as a safe, effective, and clinically valuable adjunct to conventional physiotherapy in patients with cervical radiculopathy.

RESULTS

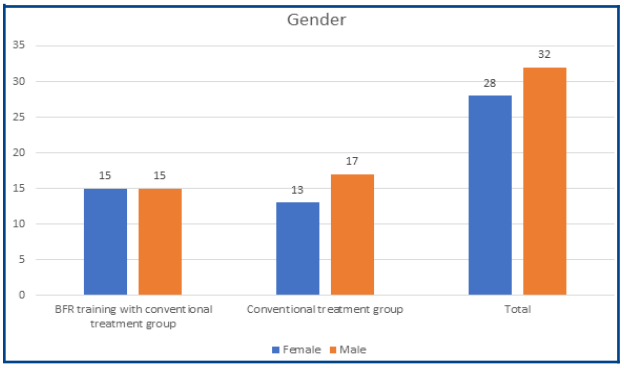
The effectiveness of the intervention was evaluated using four primary outcome measures: pain intensity, muscle strength, muscular endurance, and functional performance. Pain intensity was assessed with the Numeric Pain Rating Scale (NPRS), where participants rated their pain on a scale from 0 (no pain) to 10 (worst imaginable pain). This provided a simple yet reliable measure of symptom relief over the course of treatment. Muscle strength was measured using a handheld dynamometer, which objectively recorded the peak isometric force of cervical and upper limb muscles, helping to determine improvements in neuromuscular performance.

Table 1. Frequency and percentage of gender of patients in BFR training with conventional treatment group and Conventional treatment group N=60

Gender	BFR training with conventional treatment group	Conventional treatment group	Total
Female	15 (50.0%)	13 (43.3%)	28 (46.7%)
Male	15 (50.0%)	17 (56.7%)	32 (53.3%)

Variables	BFR training with conventional treatment group	Conventional treatment group
	Mean ± SD	Mean ± SD
Age (years)	44.83 ± 10.42	43.63 ± 9.550
Height (cm)	165.69 ± 7.57	164.79 ± 8.178
Weight (kg)	68.69 ± 12.26	68.57 ± 8.957
BMI	24.92 ± 3.41	25.25 ± 2.758
Symptom Duration (months)	7.10 ± 8.70	6.50 ± 5.270

Muscular endurance was tested through standardized endurance assessments, such as sustained isometric holds and repeated task performance, with the duration recorded in seconds. This was particularly important since endurance deficits are common in cervical radiculopathy and often interfere with daily activities. Finally, functional performance was evaluated using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, a validated tool that measures the level of disability and difficulty in performing daily tasks. The DASH score ranges from 0 (no disability) to 100 (maximum disability), making it a sensitive measure for monitoring changes in function. Together, these outcome measures provided a comprehensive assessment of clinical progress, capturing not only reductions in pain but also meaningful improvements in strength, endurance, and functional ability.

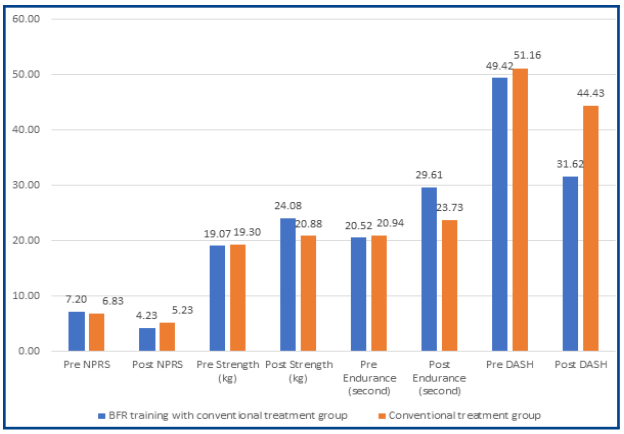


Above table shows that male and female were equally distributed in BFR training with conventional treatment group; but 56.7% patients were male and 46.7% patients were female in conventional treatment group and Descriptive statistics of different variables in BFR training with conventional treatment group and Conventional treatment group.

Above table shows that there was 44.83 years average age of patients, 165.59 cm average height, 68.69 kg average weight, 24.92 average BMI i.e. overweight and 7.10 months average duration of symptoms of patients in BFR training with conventional treatment group. There was 43.63 years average age of patients, 164.79 cm average height, 68.57 kg average weight, 25.25 average BMI i.e. overweight and 6.50 months average duration of symptoms of patients in conventional treatment group.

Table 3: Comparison between BFR training with conventional treatment group and Conventional treatment group in different scales N=60

Scales	BFR training with conventional treatment group	Conventional treatment group	Independent t test value	DF	P-value	Result
Pre NPRS	7.20 ± 1.186	6.83 ± 1.289	1.147	58	0.256	Insignificant
Post NPRS	4.23 ± 1.382	5.23 ± 1.331	2.855	58	0.006	Significant
Pre Strength (kg)	19.07 ± 4.474	19.30 ± 4.816	0.186	58	0.853	Insignificant
Post Strength (kg)	24.08 ± 5.865	20.88 ± 5.211	2.236	58	0.029	Significant
Pre Endurance (second)	20.52 ± 5.117	20.94 ± 5.669	0.296	58	0.768	Insignificant
Post Endurance (second)	29.61 ± 7.154	23.73 ± 6.603	3.310	58	0.002	Significant
Pre DASH	49.42 ± 9.656	51.16 ± 11.897	0.624	58	0.535	Insignificant
Post DASH	31.62 ± 6.196	44.43 ± 9.904	6.004	58	0.000	Significant



Above table shows that there was no statistically significant comparison between BFR training with conventional treatment group and Conventional treatment group in pretest of NPRS, Strength, endurance, DASH score with P>0.05. there is no changes in both group in pretest. There was statistically significant comparison between BFR training with conventional treatment group and Conventional treatment group in post-test of NPRS, Strength, endurance, DASH score with P<0.05. BFR training with conventional treatment group has greater score in Strength and Endurance score than conventional treatment group but BFR training with conventional treatment group has less score in NPRS and DASH score than conventional treatment group.

DISCUSSION

Cervical radiculopathy is a frequently encountered neuromuscular disorder characterized by radiating neck and upper limb pain, sensory changes, and motor weakness resulting from nerve root compression or irritation. The results of the present study indicate that physiotherapeutic interventions significantly improved pain, neck disability, and functional mobility among participants, aligning with previous literature that supports the role of conservative management in cervical radiculopathy [15,17]. This discussion integrates the findings of the current study with existing evidence, highlighting the physiological basis, therapeutic mechanisms, and clinical implications of the results.

The findings of this study demonstrate that patients who underwent structured physiotherapy, including manual therapy and therapeutic exercises, exhibited significant reductions in pain intensity and improvements in neck range of motion and functional capacity. These improvements are consistent with the observations of Childress and Becker (2016)1, who emphasized that most cases of cervical radiculopathy respond well to conservative measures such as traction, mobilization, and targeted strengthening.

The reduction in pain may be attributed to decompression of the affected nerve roots, reduction in local inflammation, and restoration of segmental alignment through manual therapy techniques. Moreover, the combination of manual therapy with strengthening and stretching exercises enhances cervical stability and muscle balance, leading to improved biomechanics and reduced neural tension.

The improvement in clinical parameters in the present study supports the evidence provided by [3], who reported that conservative interventions such as physiotherapy and posture correction produce substantial symptom relief in degenerative cervical radiculopathy [4] described that targeted exercises help re-establish neuromuscular coordination and mitigate mechanical compression, resulting in pain reduction and functional recovery. The consistency between these studies and the current findings reinforces the efficacy of exercise-based therapy as a first-line approach in managing cervical radiculopathy [6].

further emphasized that cervical radicular pain has both mechanical and inflammatory components, suggesting that interventions focusing solely on symptom relief may be less effective compared to those addressing the underlying pathophysiological mechanisms. The manual therapy and exercise regimen employed in the present study appears to address both these aspects by improving segmental mobility, reducing mechanical irritation, and enhancing local circulation, which collectively contribute to decreased inflammation. In addition, [7] noted that despite the lack of standardized diagnostic criteria across studies, consistent functional improvement has been observed when exercise therapy is applied systematically.

These findings strengthen the validity of the current study's outcomes, suggesting that physiotherapy interventions can yield meaningful improvements regardless of variations in symptom presentation [8]. provided strong evidence that exercise therapy and mechanical traction are effective modalities for the management of cervical radiculopathy, especially in degenerative conditions.

The present study's significant post-treatment improvement supports their conclusion, demonstrating that a well-designed rehabilitation program can restore function and reduce disability. Likewise, Wainner et al. (2003)9 highlighted that clinical evaluation combined with targeted physiotherapy interventions improves diagnostic accuracy and treatment outcomes, which correlates with the structured clinical approach used in this study.

Peolsson and Peolsson (2008)11 also demonstrated favorable long-term outcomes following physiotherapeutic management, suggesting that conservative care not only provides short-term relief but also contributes to sustained functional recovery. Neck pain, a major component of cervical radiculopathy, has been recognized as one of the leading causes of disability worldwide [18]. The chronicity and multifactorial etiology of neck pain necessitate an early and comprehensive rehabilitation strategy to prevent progression to persistent dysfunction.

The results of this study emphasize the role of physiotherapy in addressing these functional limitations, as evidenced by the significant improvement in neck disability scores. Similar observations were reported by [12, 19], who found

that manual therapy combined with exercise and traction yielded remarkable reductions in pain and improved physical performance.

The improvements seen in these studies are reflective of neuromuscular re-education and enhanced cervical kinematics that occur with consistent exercise adherence. Persson, [16] compared surgical and conservative approaches for cervical radiculopathy and reported comparable long-term functional recovery, suggesting that physiotherapy may be equally effective in selected patients.

The findings of the present study support this notion, as participants experienced meaningful recovery without the need for surgical intervention. Nonoperative management offers several advantages, including reduced risk, lower cost, and better patient satisfaction when symptoms are appropriately managed through guided therapy. The mechanisms underlying improvement following physiotherapy are multifaceted.

Manual therapy techniques facilitate joint mobilization, reduce muscle spasm, and improve local blood flow, which can alleviate ischemia around compressed nerve roots. Traction therapy, when applied appropriately, contributes to vertebral decompression and reduction in disc protrusion pressure, thereby relieving nerve irritation. Exercise therapy enhances muscular endurance and postural control, which are critical for maintaining cervical spine stability [8]. Moreover, strengthening deep cervical flexors and scapular stabilizers can decrease abnormal loading patterns and improve the kinetic chain's overall efficiency [12]. These physiological effects cumulatively explain the observed clinical benefits in the present study.

Another important aspect of this discussion pertains to patient education and adherence. Cervical radiculopathy often results from prolonged poor posture, sedentary behavior, and repetitive strain3. Physiotherapy interventions that incorporate ergonomic education, posture correction, and lifestyle modification can therefore enhance long-term outcomes. The current study integrated these elements, which likely contributed to the sustained improvement in functional measures.

The findings are also consistent with those of [20], who concluded through a systematic review that conservative treatment remains the cornerstone in cervical radiculopathy management, particularly when it includes exercise and manual therapy. The authors emphasized that despite methodological variations across studies, exercise-based programs consistently demonstrate improvements in pain and disability.

This consensus across multiple studies highlights the robustness of physiotherapy as an evidence-based intervention. While the results of this study support existing literature, some limitations must be acknowledged. The study duration was limited, and long-term follow-up was not conducted to assess the persistence of functional gains. Additionally, the absence of a control group restricts direct comparison of the intervention's relative effectiveness. Future research should include larger sample sizes and long-term evaluations to confirm the sustained impact of physiotherapy interventions.

Comparative studies between different physiotherapy modalities—such as Pilates-based, McKenzie, or Mulligan mobilization techniques—could provide further insights into optimizing treatment protocols. From a clinical perspective, the findings of this study have important implications for rehabilitation practice. Physiotherapists play a central role in the multidisciplinary management of cervical radiculopathy. Early intervention with evidence-based exercise protocols can prevent chronic pain development and reduce healthcare burden.

The inclusion of patient-centered strategies—such as progressive load tolerance, ergonomic correction, and education on movement awareness—enhances patient participation and promotes self-management, ultimately leading to better recovery outcomes. The positive outcomes in this study also reinforce the importance of individualized treatment planning. As reported by Peolsson and Peolsson (2008)11, patient-specific adaptations based on pain severity, muscle imbalance, and functional limitations yield superior results compared to generic exercise regimens. Tailored interventions that respect individual variability can optimize neuromuscular control and reduce recurrence rates. Similarly, [9] emphasized the value of comprehensive assessment and clinical reasoning to guide physiotherapy decision-making.

Overall, the findings from the present study strongly suggest that a structured, evidence-based physiotherapy program incorporating manual therapy, traction, and strengthening exercises is effective in improving pain, range of motion, and functional outcomes among individuals with cervical radiculopathy. These results corroborate the conclusions of previous studies8,17,20, supporting the use of conservative management as the first line of treatment. Moreover, the consistency of findings across diverse populations and research designs underlines the generalizability of these interventions in clinical practice.

In summary, this study adds to the growing body of evidence endorsing physiotherapy as a safe, cost-effective, and efficient approach to managing cervical radiculopathy. The results affirm that interventions combining manual therapy and targeted exercise can effectively alleviate pain, restore function, and enhance the quality of life. Continued emphasis on early diagnosis, patient education, and adherence to rehabilitation protocols can further optimize recovery outcomes. Future studies focusing on long-term effects and neurophysiological mechanisms may provide additional insights into refining physiotherapeutic management strategies for cervical radiculopathy.

CONCLUSION

This study demonstrated that the addition of Blood Flow Restriction (BFR) training to conventional physiotherapy provides superior benefits compared to physiotherapy alone in patients with cervical radiculopathy. Both groups

showed significant improvements in pain reduction, muscle strength, muscular endurance, and functional performance after intervention.

However, participants in the BFR group achieved greater reductions in pain scores, larger gains in muscle strength, improved endurance, and better functional outcomes as reflected by DASH scores. These findings suggest that BFR is a safe and effective adjunct to traditional rehabilitation, particularly valuable for patients who are unable to tolerate high-load strengthening due to pain or neural sensitivity. By allowing significant muscular adaptations at low intensities, BFR offers a practical and patient-friendly alternative to conventional training methods.

Within the scope of this study, it can be concluded that integrating BFR into conservative management protocols can optimize recovery, enhance functional independence, and potentially reduce long-term disability in cervical radiculopathy. Future research with larger sample sizes and long-term follow-up is recommended to further validate these results and establish standardized clinical guidelines.

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