

Added Effect of Blood Flow Restriction Training to Vinyasa Yoga on Lower-Limb Function in Sedentary Adults

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Abstract: *Sedentary behavior may adversely affect muscle strength, flexibility, and functional capacity. This study investigated whether adding blood flow restriction training to Vinyasa Yoga produced additional improvements in lower-limb function compared with Vinyasa Yoga alone. Thirty sedentary adults completed a four-week intervention and were allocated equally to combined blood flow restriction plus Vinyasa Yoga or Vinyasa Yoga alone. Training was conducted three times weekly. Quadriceps and hamstring strength, lower-limb flexibility, and functional capacity were assessed before and after intervention using appropriate standardized measures. Both groups demonstrated statistically significant improvements across all assessed outcomes after four-weeks. However, comparisons of change between-groups showed no statistically significant differences. Some measures demonstrated numerically larger changes with the combined intervention, but these differences were not statistically significant. These findings suggest that short-term Vinyasa Yoga can improve lower-limb physical function in sedentary adults, while an additional benefit from blood flow restriction training was not demonstrated in the present sample.*

Keywords: Vinyasa Yoga, Blood Flow Restriction Training, Muscle strength, Flexibility, Functional capacity

1. Introduction

Prolonged sedentary behavior is linked to multiple adverse health outcomes, including increased risk of all-cause and cardiovascular mortality, certain cancers, and metabolic disorders such as type 2 diabetes, hypertension, and dyslipidemia. It also contributes to musculoskeletal problems like joint pain and osteoporosis, as well as mental health issues such as depression and cognitive decline. Addressing physical inactivity through regular exercise is therefore a public health priority ¹.

Physical inactivity is also a significant concern in India. Findings from the ICMR-INDIAB study showed that 54.4% of the participants assessed were physically inactive, with the number of inactive individuals extrapolated to approximately 392 million across the country. The study also reported particularly high levels of inactivity in urban areas and limited participation in recreational physical activity ². These findings emphasize the need for simple and accessible exercise-based approaches that can improve physical fitness among adults with low levels of physical activity.

Blood Flow Restriction Training (BFRT) is a low-load exercise method that partially restricts blood flow to working muscles using pneumatic cuffs. The resulting physiological stress may

promote adaptations in muscle strength and size despite the use of relatively low external loads. This makes BFRT a potentially useful exercise approach when higher training loads may not be appropriate or well tolerated ^{3, 4}.

Vinyasa yoga is a dynamic form of Hatha yoga that integrates breath-synchronized movement. It is characterized by a series of postures (asanas) performed in a sequence, linked by breath. Vinyasa yoga, with its continuous flow of movements, provides an effective workout for enhancing muscular endurance, muscle strength and overall physical fitness ⁵.

Both BFRT and Vinyasa Yoga therefore have the potential to contribute to improvements in physical fitness, but the effect of combining these two approaches in sedentary adults has not been established in the context of the outcomes assessed in the present study. The present study was undertaken to compare the effects of Vinyasa Yoga combined with BFRT with Vinyasa Yoga alone on lower-limb muscle strength, flexibility and functional capacity in sedentary adults.

2. Literature Survey

Previous research has shown that Vinyasa Yoga may improve several components of physical fitness. Shrikant et al. reported improvements in muscular endurance, static balance, and

flexibility following Vinyasa Yoga training; however, their participants were young, trained yoga practitioners rather than sedentary adults, limiting the generalizability of the findings to an inactive population⁵. Studies conducted among young soccer players have also reported improvements in muscular strength and other physical fitness parameters following Vinyasa flow yoga, although these studies focused on athletic populations rather than sedentary individuals^{6,7}.

Blood Flow Restriction Training (BFRT) has also been investigated as a low-load exercise approach for improving lower-limb muscular performance. Kang et al. found that bodyweight exercises combined with BFRT could improve lower-extremity muscle function and hypertrophy in college students⁸. In addition, a systematic review and meta-analysis by Yang et al. reported that BFRT was associated with improvements in strength, power, speed, endurance, and body composition among athletes⁹. However, the available evidence has largely focused on athletes, resistance-based exercise, or conventional bodyweight exercises, with limited research involving sedentary adults or yoga-based exercise.

3. Problem Definition

A sedentary lifestyle can lead to reduced lower-limb muscle strength and functional capacity. Although yoga can improve flexibility, balance, and movement, its effects on muscle strength may be limited. Blood Flow Restriction Training (BFRT) allows strength training with low loads and may help improve muscle strength and functional capacity. However, there is limited research on combining BFRT with Vinyasa Yoga in sedentary adults. Therefore, this study aimed to examine whether adding BFRT to Vinyasa Yoga could provide greater improvements in muscle strength, flexibility, and functional capacity than Vinyasa Yoga alone.

4. Methodology

Study design and setting

An experimental study was conducted among sedentary adults in a community setting. The intervention was carried out over a period of four-weeks, with three supervised sessions conducted each week, giving a total of 12 sessions. The study was conducted after obtaining approval from the Institutional Review Board (IRB). Participants were recruited from the local community through personal contacts and referrals from family, friends and colleagues.

Participants

Adults aged 20-40 years who were sedentary and willing to participate were considered for the study. Physical activity level was assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF). Participants reporting less than 600 MET-min/week of physical activity were considered sedentary and eligible for the study.

Participants were included if they were aged 20-40 years, willing to participate and provide written informed consent, had a resting heart rate below 100 beats/min, resting blood pressure

below 140/90 mmHg, and an ankle-brachial index (ABI) between 1.0 and 1.4.

Participants were excluded if they had severe or uncontrolled hypertension, sickle cell anaemia, varicose veins, deep vein thrombosis, lower-limb musculoskeletal injury, uncontrolled diabetes, respiratory disorders, were taking anticoagulant medication, were pregnant or lactating, had a body mass index greater than 27.5 kg/m², had thalassemia, or were regularly participating in yoga, structured exercise or other regular physical activity. Individuals with contraindications to Blood Flow Restriction Training (BFRT) or yoga were also excluded.

Written informed consent was obtained from all participants before their enrolment in the study.

Sample size

The sample size was initially calculated as 52 participants, with 26 participants planned for each group. The calculation was based on an expected effect size of 0.8, $\alpha=0.05$ and $\beta=0.20$, with an allowance for a 5% dropout rate.

A total of 52 participants were initially enrolled and allocated to the two groups. During the intervention, 22 participants withdrew due to inconsistent participation and their decision to discontinue the study. As a result, 30 participants completed the four-week intervention and were included in the final analysis, with 15 participants in each group.

Sample Recruitment

Participants who met the inclusion and exclusion criteria were recruited from the local community through personal contacts and referrals from family, friends, and colleagues. After completing the screening process and providing informed consent, participants were randomly allocated to either Group A or Group B using allocation chits. Group A received Vinyasa Yoga combined with Blood Flow Restriction Training (BFRT), while Group B received Vinyasa Yoga alone.

The investigator was responsible for participant enrolment and conducted the outcome assessments. The outcome assessor was not blinded to the group allocation.

Sampling technique: Participants who met the inclusion and exclusion criteria were recruited from the local community using convenience sampling.

Protocol

Group A: Vinyasa Yoga combined with BFRT

Participants in Group A performed a Vinyasa Yoga programme combined with BFRT three times per week for four-weeks. Each session consisted of a 5 minute warm up using Sukshma Vyayama, approximately 20 minutes of Vinyasa Yoga and a 5 minute cool down.

Pneumatic cuffs were placed around the proximal thighs bilaterally. Limb occlusion pressure (LOP) was determined using a Doppler, and the cuffs were inflated to approximately

60% of the individual limb occlusion pressure (LOP). The cuffs remained inflated during each flow and were deflated during the rest period between flows. The total duration of cuff occlusion during each session was approximately 15–20 minutes.

Group B: Vinyasa Yoga alone

Participants in Group B performed the same Vinyasa Yoga programme three times per week for four-weeks. Each session consisted of a 5 minute warm up using Sukshma Vyayama, approximately 20 minutes of Vinyasa Yoga and a 5 minute cool down.

The protocol consisted of three flows.

Flow 1 included three rounds of :

Utkatasana (Chair Pose), Anjaneyasana (Low Lunge), Virabhadrasana II (Warrior II), Ashta Chandrasana (Crescent Lunge), Utkata Konasana (Goddess Pose), Parivrtta Anjaneyasana (Low Lunge Twist), and Adho Mukha Svanasana (Downward Dog).

Flow 2 consisted of three rounds of Surya Namaskar.

Flow 3 consisted of three rounds of the same sequence as Flow 1.

Utkatasana (Chair Pose), Anjaneyasana (Low Lunge), Virabhadrasana II (Warrior II), Ashta Chandrasana (Crescent Lunge), Utkata Konasana (Goddess Pose), Parivrtta Anjaneyasana (Low Lunge Twist), and Adho Mukha Svanasana (Downward Dog).

Outcome measures

Outcome measures were assessed at baseline before the intervention and reassessed after completion of the four-week intervention.

Lower-limb muscle strength:

Quadriceps and hamstring muscle strength was assessed bilaterally using a push-pull dynamometer and recorded in kilogram force (kgf). The quadriceps were assessed first, followed by the hamstrings. Both the right and left limbs were assessed.

Push pull dynamometer - to assess Muscle strength of the lower-limb (quadriceps and hamstrings) shows:

- Test-retest reliability: ICC $\approx$ 0.89–0.99 (excellent reliability)
- Instrumental validity: ICCs & correlations $\approx$ 0.80–0.99 (strong) ¹⁰.

Flexibility:

Hamstring flexibility was assessed using the V Sit-and-Reach Test. The test was performed at baseline and after the intervention, with the distance reached recorded in centimetres. V Sit-and-Reach Test - to assess the Flexibility of the lower-limb Shows excellent test-retest reliability ($r = 0.98$, $P < 0.05$) and moderate criterion-related validity for hamstring extensibility ^{11, 12}.

Functional capacity:

Functional capacity was assessed using the 6 Minute Walk Test (6MWT). The test was performed at baseline and after completion of the four-week intervention. The distance achieved during the test was expressed as a proportion of the predicted 6 minute walking distance and used for analysis.

6-Minute Walk Test - to assess the Functional capacity High test-retest reliability ($r \approx 0.93$) in healthy elderly participants ($P < 0.0001$) ¹³.

Study procedure

Following IRB approval, participants were screened according to the predefined eligibility criteria. Eligible participants provided written informed consent and underwent baseline assessment of quadriceps and hamstring strength, flexibility and functional capacity.

Participants were then allocated to either Group A or Group B. Both groups subsequently completed their respective supervised exercise programmes three times per week for four-weeks.

All participants who completed the intervention underwent the same outcome assessments at the end of the four-week period. The data obtained at baseline and post-intervention were used for statistical analysis.





Figure 1: Intervention protocol performed with participants

Statistical analysis

The distribution of the data was assessed using the Shapiro Wilk test. Within-group changes from baseline to post-intervention were analysed using the paired t-test for normally distributed data and the Wilcoxon signed rank test for non normally distributed data.

For the primary between-group comparison, change scores were calculated by subtracting the baseline value from the post-intervention value. Change scores were compared between the two groups using the unpaired t-test when the data were normally distributed and the Mann Whitney U test when the normality assumption was not met. A P value of <0.05 was considered statistically significant.

5. Results

Participants

A total of 30 sedentary adults completed the four-week intervention and were included in the final analysis, with 15 participants in each group. Group A received Blood Flow Restriction Training (BFRT) combined with Vinyasa Yoga, while Group B received Vinyasa Yoga alone. The age and sex distribution of participants in the two groups is presented in Figures 2 and 3. The sample was predominantly female, with participants distributed across the 20-40 year age range.

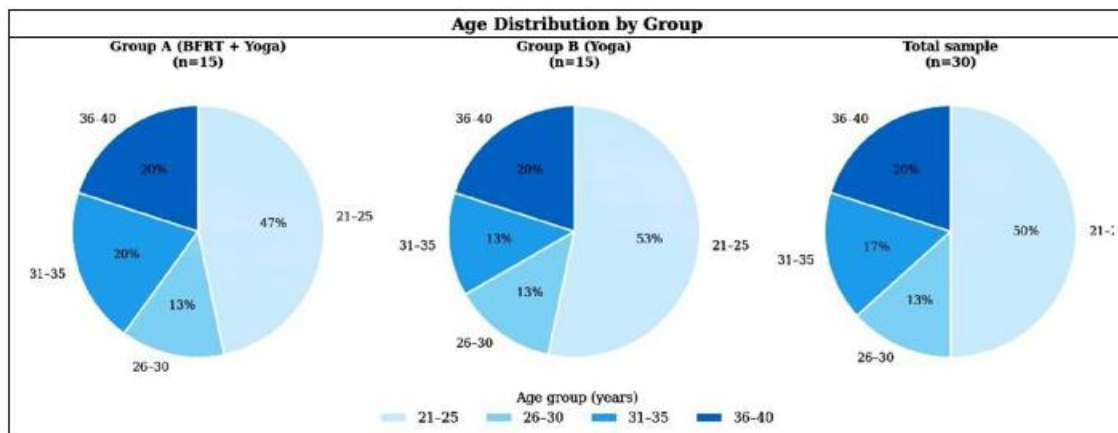


Figure 2: Age distribution of participants in each group

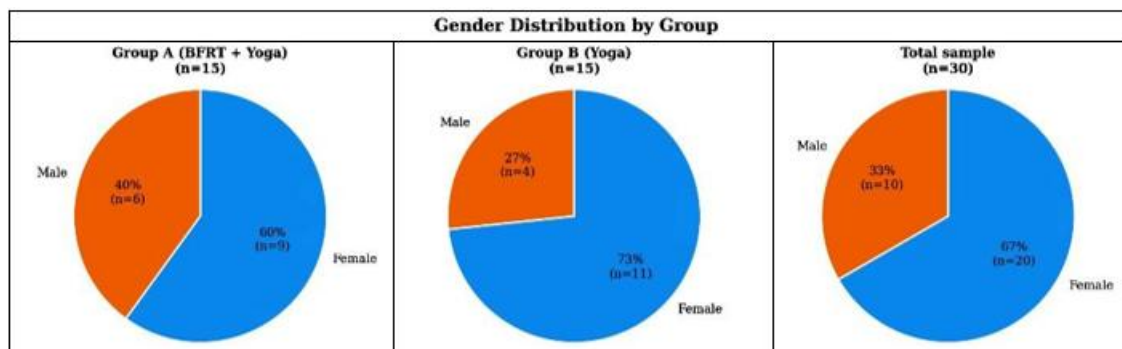


Figure 3: Gender wise distribution of participants in each group

Within-group comparison

Both groups demonstrated statistically significant improvements in all assessed outcomes following the four-week intervention ($P < 0.001$). Significant improvements were observed in quadriceps and hamstring muscle strength, V Sit-

and-Reach flexibility, and functional capacity measured by the 6-Minute Walk Test. The detailed pre and post-intervention results, including mean changes and test statistics, are presented in Table 1.

Table 1: Within-group comparison of outcome measures before and after the four-week intervention.

Outcome	Group	Pre - intervention, Mean $\pm$ SD	Post - intervention, Mean $\pm$ SD	Mean change	Test statistic	P value
Quadriceps R (kgf)	A	15.87 $\pm$ 2.48	21.47 $\pm$ 3.42	5.6	V=120	<0.001
Quadriceps R (kgf)	B	15.07 $\pm$ 3.28	19.60 $\pm$ 3.70	4.53	t(14) = 10.17	<0.001
Quadriceps L (kgf)	A	15.67 $\pm$ 3.20	20.47 $\pm$ 3.52	4.8	V = 120	<0.001
Quadriceps L (kgf)	B	14.40 $\pm$ 3.16	18.73 $\pm$ 3.52	4.33	t(14) = 10.01	<0.001
Hamstring R (kgf)	A	11.13 $\pm$ 1.46	14.07 $\pm$ 1.39	2.93	V = 120	<0.001
Hamstring R (kgf)	B	10.27 $\pm$ 3.04	13.20 $\pm$ 2.43	2.93	V = 120	<0.001
Hamstring L (kgf)	A	10.67 $\pm$ 1.50	13.20 $\pm$ 1.82	2.53	t(14) = 8.26	<0.001
Hamstring L (kgf)	B	10.00 $\pm$ 3.30	12.67 $\pm$ 2.92	2.67	V = 120	<0.001
V Sit-and-Reach (cm)	A	-6.47 $\pm$ 7.60	0.77 $\pm$ 7.84	7.23	t(14)=9.59	<0.001
V Sit-and-Reach (cm)	B	-6.70 $\pm$ 10.42	0.00 $\pm$ 10.32*	6.7	t(14)=8.89	<0.001
6MWT (% predicted)	A	0.845 $\pm$ 0.118	0.926 $\pm$ 0.119	0.081	t(14)=7.88	<0.001
6MWT (% predicted)	B	0.752 $\pm$ 0.063	0.815 $\pm$ 0.068	0.063	t(14)=6.33	<0.001

Note. Values are Mean $\pm$ SD. The test statistic reported is the one appropriate to the distribution of the difference scores: the paired t-test (t, with degrees of freedom in parentheses) where the Shapiro Wilk test indicated normality, and the Wilcoxon signed-rank test (V) otherwise. 6MWT expressed as proportion of predicted; kgf = kilogram-force; R = right; L = left. $p < 0.05$ was considered statistically significant.

Between-group comparison

The changes in outcomes were compared between the two groups by calculating the difference between post-intervention and baseline values. No statistically significant differences were found between the groups for any of the assessed outcomes ($P > 0.05$).

Although Group A showed slightly greater improvements in right and left quadriceps strength and functional capacity, these differences were not statistically significant. Changes in hamstring strength and flexibility were similar between the two groups. The detailed results are presented in Table 2 and Figures 4-9.

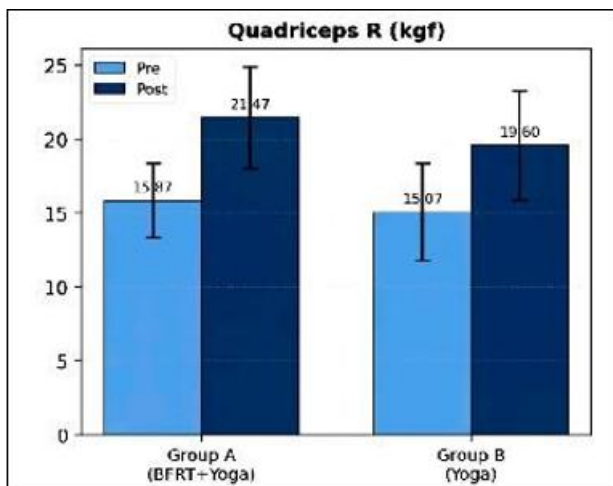


Figure 4: Pre and Post-Intervention Comparison of Right Quadriceps Muscle Strength between-group A and Group B

Mean $\pm$ SD of right quadriceps muscle strength (kgf) following the four-week intervention in Group A (BFRT + Yoga) and Group B (Yoga).

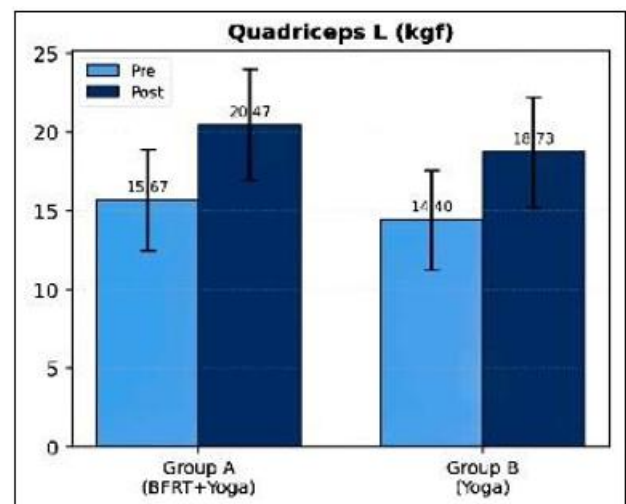


Figure 5: Pre and Post-Intervention Comparison of Left Quadriceps Muscle Strength between-group A and Group B

Mean $\pm$ SD of left quadriceps muscle strength (kgf) following the four-week intervention in Group A (BFRT + Yoga) and Group B (Yoga).

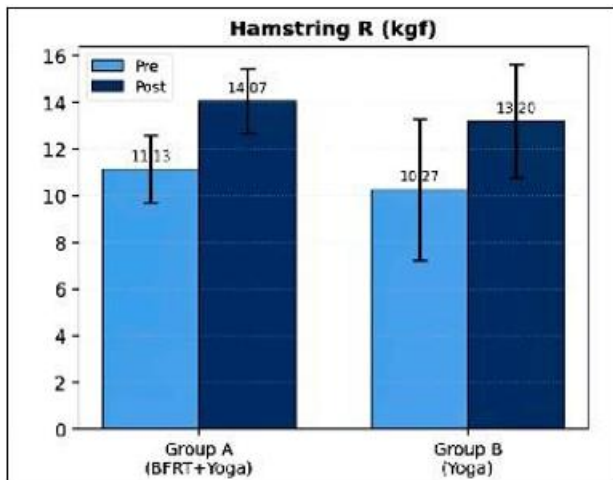


Figure 6: Pre and Post-Intervention Comparison of Right Hamstring Muscle Strength between-group A and Group B

Mean ± SD of right hamstring muscle strength (kgf) following the four-week intervention in Group A (BFRT + Yoga) and Group B (Yoga).

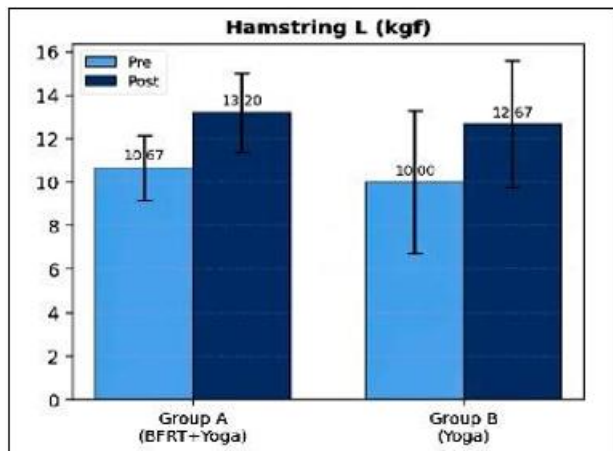


Figure 7: Pre- and Post-Intervention Comparison of Left Hamstring Muscle Strength between-group A and Group B

Mean ± SD of left hamstring muscle strength (kgf) following the four-week intervention in Group A (BFRT + Yoga) and Group B (Yoga).

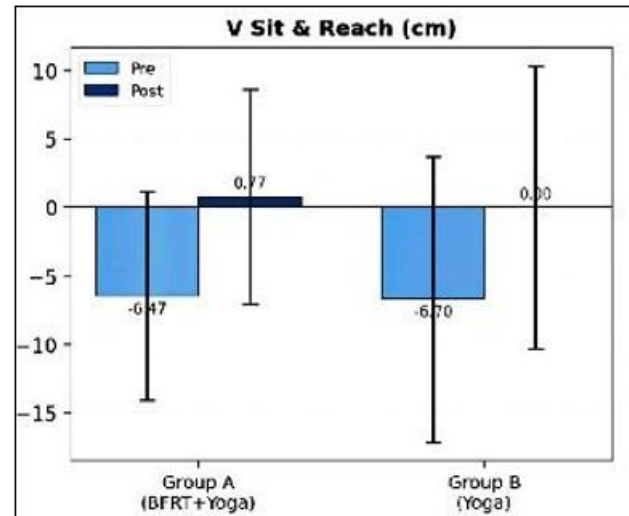


Figure 8: Pre and Post-Intervention Comparison of Flexibility between-group A and Group B

Mean ± SD of V Sit-and-Reach scores following the four-week intervention in Group A (BFRT + Yoga) and Group B (Yoga), representing post-intervention flexibility.

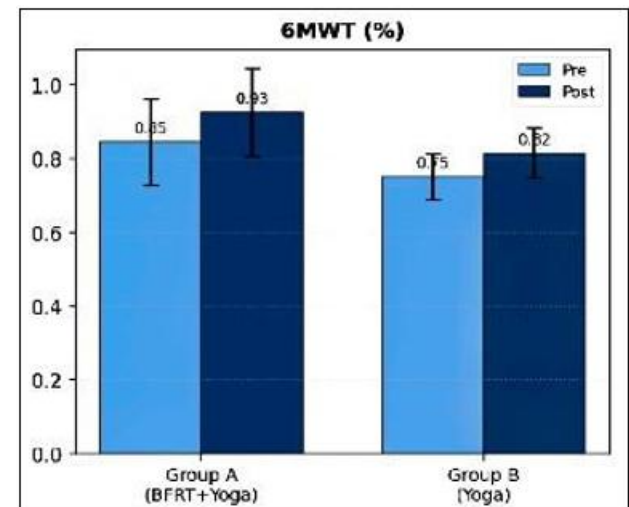


Figure 9: Pre and post-Intervention Comparison of Functional Capacity between-group A and Group B

Mean ± SD of 6MWT expressed as the proportion of predicted distance in Group A (BFRT + Yoga) and Group B (Yoga) before and after the four-week intervention.

Table 2: Between-group comparison of change scores (post minus pre) for Group A versus Group B

Outcome	Group A change (Mean ± SD)	Group B change (Mean ± SD)	Test statistic	p-value	Sig.
Quadriceps R (kgf)	5.60 ± 1.96	4.53 ± 1.73	U = 148	0.136	ns
Quadriceps L (kgf)	4.80 ± 1.66	4.33 ± 1.68	U = 131	0.438	ns
Hamstring R (kgf)	2.93 ± 0.88	2.93 ± 1.44	U = 124	0.612	ns
Hamstring L (kgf)	2.53 ± 1.19	2.67 ± 1.40	U = 116	0.913	ns
V Sit & Reach (cm)	7.23 ± 2.92	6.70 ± 2.92	t(28.00) = 0.50	0.621	ns
6MWT (%)	0.081 ± 0.040	0.063 ± 0.039	t(27.98) = 1.23	0.229	ns

Note. Values are Mean ± SD of the change (post-intervention minus pre-intervention). The test statistic is the unpaired t-test (t, with degrees of freedom in parentheses) where both groups were normally distributed and the Mann Whitney U test (U) otherwise. ns = not significant ($p \geq 0.05$). Kgf = kilogram force; R = right; L = left.

6. Discussion

This study examined whether adding Blood Flow Restriction Training (BFRT) to Vinyasa Yoga produced greater improvements in lower-limb muscle strength, flexibility, and functional capacity than Vinyasa Yoga alone in sedentary adults. Both groups showed statistically significant improvements in all assessed outcomes following the four-week intervention. However, the between-group comparison did not show a statistically significant difference for any outcome. Although the BFRT and Yoga group showed numerically greater improvements in functional capacity and quadriceps strength, it was not statistically significant.

The improvements observed in the Vinyasa Yoga group suggest that the yoga programme itself may have provided sufficient physical stimulus to improve lower-limb strength, flexibility, and functional capacity. Vinyasa Yoga involves repeated transitions between postures, weight-bearing positions, and controlled movements, which may challenge the lower-limb musculature while requiring movement through different ranges of motion. Previous research supports the potential of yoga to improve components of physical fitness. In a randomized controlled trial involving sedentary adults, yoga produced significant improvements in strength, flexibility, balance, and mobility following an eight week intervention¹⁴.

A systematic review and meta analysis of randomized controlled trials reported that yoga also reported improvements in lower-limb strength and flexibility when compared with inactive controls¹⁵. In these studies, inactive controls did not participate in an active exercise intervention. Since both groups in the present study participated in Vinyasa Yoga, the findings from this review provide support for the improvements observed in both groups, but they do not directly address whether BFRT provides an additional benefit when combined with yoga.

Both groups demonstrated significant improvements in quadriceps and hamstring strength. The improvement in the Yoga only group is noteworthy because the intervention did not involve conventional resistance training. Repeated weight bearing and lower-limb loading during Vinyasa Yoga may have provided an adequate stimulus for strength adaptation, particularly in participants who were not regularly engaged in physical activity. Evidence from previous yoga studies has demonstrated similar improvements in muscular strength following yoga-based exercise^{14, 16}.

In contrast, adding BFRT to the Vinyasa Yoga programme did not result in significantly greater improvements in quadriceps or hamstring strength. BFRT has been shown in previous research to improve muscle strength when combined with low load exercise^{17, 18}. However, much of this evidence comes from BFRT protocols involving structured resistance exercise rather than yoga-based exercise. The response to BFRT may also vary according to factors such as cuff pressure, exercise intensity, duration, and the type of exercise performed¹⁸. In the present study, both groups received the same Vinyasa Yoga

programme, with BFRT being the only additional component in Group A. It is therefore possible that the stimulus provided by Vinyasa Yoga was sufficient to produce improvements in strength, limiting the additional effect from BFRT that could be detected over four-weeks.

Flexibility, assessed using the V Sit-and-Reach Test, also improved significantly in both groups, with no significant between-group difference. This finding is consistent with previous evidence supporting the improvements on flexibility post yoga intervention. Regular performance of yoga postures through repeated and progressively tolerated ranges of motion may contribute to improvements in flexibility through changes in stretch tolerance and muscle-tendon characteristics^{19, 20}. Since both groups in the present study performed the same Vinyasa Yoga programme, the similar improvement in V Sit-and-Reach Test performance may be primarily related to repeated exposure to these movements rather than the addition of BFRT.

Functional capacity, measured as the proportion of predicted 6MWT distance, also improved significantly in both groups. Although the mean improvement was numerically greater in the BFRT and Yoga group than in the Yoga only group, the between-group difference was not statistically significant. Previous research has reported improvements in functional capacity following yoga-based interventions²¹. The dynamic nature of Vinyasa Yoga, which involves repeated postural transitions and sustained lower-limb activity, may lead to improvements in muscular endurance. The breathing component of yoga may also contribute to improved respiratory control during exercise. Previous research has reported improvements in pulmonary function and respiratory muscle strength following yoga-based interventions, which provides a possible physiological basis for improvements in exercise related functional capacity²². Therefore, the improvement in 6MWT performance in both groups may reflect adaptations associated with the common Vinyasa Yoga programme. However, the present findings do not demonstrate an additional effect of BFRT on functional capacity.

Overall, the findings indicate that four-weeks of Vinyasa Yoga was associated with improvements in lower-limb strength, flexibility, and functional capacity in sedentary adults. Although some outcomes showed numerically greater improvements with the addition of BFRT, the absence of statistically significant between-group differences means that BFRT cannot be considered superior to Vinyasa Yoga alone based on these current findings.

7. Conclusion

Vinyasa yoga over 4 weeks resulted in improvements in lower-limb muscle strength, flexibility and functional capacity. Although the addition of blood flow restriction training led to greater numerical improvements in the outcomes, it was not statistically significant.

8. Future Research Scope

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Future studies should use larger samples and longer interventions to assess the effectiveness of combining BFRT with Vinyasa Yoga. Also, future studies could determine if there are differences in the amount of added benefits that result from combining BFRT with yoga-based exercises depending upon the cuff pressure of BFRT or intensity of the exercise. Finally, future studies should also include blind assessment of outcomes and sufficient follow-up time to help establish whether or not the positive effects of combining these two methods last over time.

9. Limitations

This study has several limitations. First, the final sample consisted of 30 participants instead of the initially calculated 52, which may have reduced the statistical power to detect between-group differences. Therefore, the lack of a statistically significant additional effect of BFRT should be interpreted cautiously. Second, the intervention was limited to four-weeks, so the longer-term effects could not be assessed. Third, participants were recruited from the community using convenience sampling, which may limit the generalizability of the findings to other populations. Lastly, the study included only sedentary adults aged 20-40 years; therefore, the findings may not be applicable to older adults, physically active individuals, or people with health conditions. In addition, the outcome assessor was not blinded to group allocation, which may have introduced measurement bias.

Clinical and public health relevance

The findings have practical relevance for sedentary adults because both groups participated in a relatively short, supervised exercise programme and demonstrated improvements in all the measured outcomes. Vinyasa Yoga may be a feasible form of exercise for individuals who are not regularly engaged in structured physical activity. The present study does not demonstrate an additional benefit from BFRT when combined with this particular Vinyasa Yoga programme. Further research is required to determine whether BFRT may provide additional benefits with different training durations, exercise intensities, and cuff pressures.

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Declarations

Funding: No funding was received for this study.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: The study was approved by the Institutional Ethics Committee of KJ Somaiya College of Physiotherapy (IEC Registration No. EC/NEW/INST/2023/3576) (Ref. no. - KJSCPT/922-A/25)

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