

# Rhythmic Auditory Stimulation Combined with Strength Training to Enhance Lower-Limb Function in Patients with Peripheral arterial disease along with intermittent Claudication: A Randomized Controlled Trial

PAVITHRA J.D<sup>1</sup>, HARINI.K<sup>2</sup>, ARJUN.S<sup>3</sup>

ASSISTANT PROFESSOR<sup>1,2,3</sup>

SWAMY VIVEKANANDHA PHYSIOTHERAPY COLLEGE, NAMAKKAL, TAMILNADU

AFFILIATED TO THE TAMILNADU Dr.MGR MEDICAL UNIVERSITY, CHENNAI

[pavi050321@gmail.com](mailto:pavi050321@gmail.com)<sup>1</sup>, [harinikumarpt@gmail.com](mailto:harinikumarpt@gmail.com)<sup>2</sup>, [arjunbpt21@gmail.com](mailto:arjunbpt21@gmail.com)<sup>3</sup>

## ABSTRACT

**BACKGROUND AND PURPOSE:** Intermittent claudication is a cramping muscular pain in the lower limbs induced by exercise, which is relieved by rest. The pain is normally induced after walking a defined distance, unless tissue oxygen demand is increased due to an incline or increased walking speed. The pain is due to insufficient oxygen delivery to the tissues, and the location of the pain is dictated by the distribution of the disease.

**AIMS & OBJECTIVES:** To determine the effectiveness of rhythmic auditory stimulation along with strength training to improve lower limb function for patients with intermittent claudication.

**STUDY DESIGN** – Randomized Controlled Trial.

**METHOD** -A sample of 30 participants aged between 30 to 45 years, diagnosed with intermittent claudication due to peripheral artery disease. The participants was selected and randomly divided into 2 groups. Group A received rhythmic auditory stimulation along with strength training, while Group B underwent knee alignment oriented dynamic balance exercise. Outcomes were assessed by using 6- minute walk test, walking impairment questionnaire recorded before and after the intervention period.

**RESULTS:** As a result, Rhythmic Auditory Stimulation Combined with Strength Training is more effective to improve Lower-Limb Function in Patients with peripheral arterial disease along with intermittent Claudication

**KEYWORDS:** rhythmic auditory stimulation, strength training, knee alignment oriented dynamic balance exercise, intermittent claudication, peripheral artery disease.

## INTRODUCTION

Peripheral artery disease (PAD) is a chronic atherosclerotic condition characterized by narrowing or obstruction of arteries in the lower extremities, leading to reduced blood flow to muscles and tissues. PAD affects approximately 8–12% of adults worldwide, with prevalence increasing with age, diabetes, smoking, and hypertension. Intermittent claudication (IC), which usually relates to lower extremity skeletal muscle pain that happens during exercise, is the most frequent presenting symptom. When there is not enough oxygen delivered to support the skeletal muscles' metabolic needs, IC develops. Rest relieves the pain, which is typically found in the affected leg's calf muscles. This happens because the muscles need extra oxygen when exercising. Normally, the arteries would be able to increase the amount of blood flow, which might increase the amount of oxygen reaching the exercised muscle. But in PAD, the artery is unable to react to the increased oxygen demand of the muscles. Therefore, the muscles are deprived of oxygen, leading to muscle pain that subsides with rest.

The pain is usually burning or cramp-like, mainly in the calves and buttocks. The site of pain is usually distal to the site of arterial occlusion. The pain during rest is due to severe occlusion. Pain is more severe at night, Shiny, hairless skin of the legs, Pallor and absent pulse, mainly of the lower limbs, potentially ischemic leg, Reduced skin temperature - the affected limb may feel cold,

Trophic changes will be present in nails, limb becomes pale on elevation, Lack of exercise endurance, Prolonged wound healing, Impotence, Blue toe syndrome.

Complications such as gangrene and critical limb ischemia can occur in those with severe PAD. Critical limb ischemia occurs when the artery's blockage is so severe that the blood cannot keep the tissue oxygenated while it is at rest. This may result in numbness in the affected foot and toes, coldness, or pain when at rest. Gangrene, erectile dysfunction, arterial insufficiency ulcers, and loss of lower limb tissue (amputation) are additional consequences of severe PAD. Gangrene of the feet affects people with diabetes at a rate thirty times higher than that of the general population. Many of these severe complications, such as those leading to amputation, are irreversible, resulting in intermittent claudication (IC), defined as exercise-induced leg pain relieved by rest. IC significantly limits walking ability, functional independence, and quality of life. Exercise therapy is the first-line conservative intervention for PAD, with supervised walking programs demonstrating improvements in maximal walking distance (MWD) and daily physical activity.

Recent advances suggest multimodal approaches integrating neuromuscular entrainment strategies and strength training may enhance rehabilitation outcomes. In particular, Rhythmic Auditory Stimulation (RAS) — auditory cues delivered via music or metronome has been shown to improve gait parameters and walking distance in neurologically impaired populations, such as Parkinson's disease and stroke. RAS may enhance walking rhythm, cadence, and motivation, potentially mitigating fatigue and ischemic pain in PAD.

Meanwhile, progressive lower-limb strength training has demonstrated significant gains in muscle mass, strength, and functional capacity in PAD, complementing aerobic walking programs. However, literature on combining RAS-guided walking with strength training specifically in claudication is scarce, representing a significant research gap.

Intermittent Claudication (IC)

Intermittent claudication (IC) is the classic symptom of PAD, manifesting as reproducible leg pain, cramping, or fatigue during exertion that is relieved by rest. IC typically occurs in the calf muscles but may also affect the thighs or buttocks depending on arterial involvement. The severity of IC is often assessed using graded treadmill tests, 6-minute walk distance (6MWD), and disease-specific questionnaires such as the Walking Impairment Questionnaire

IC limits patients' ability to perform routine activities, reduces exercise tolerance, and contributes to sedentary behavior, which can accelerate cardiovascular decline. Importantly, IC severity does not always correlate directly with arterial blockage; micro vascular dysfunction, muscular metabolic deficits, and impaired walking mechanics.

### Methods :

A sample of 30 participants, aged between 30 to 45 years, was selected by using a simple random sampling method. The participants were randomly divided into 2 groups. Group A received rhythmic auditory stimulation along with strength training, while Group B underwent knee alignment oriented dynamic balance exercise. The patients underwent treatment sessions lasting 1 hour each, 5 days per week, over a total period of 4 weeks, amounting to 20 sessions. The study focused on individuals diagnosed with peripheral arterial disease along with intermittent claudication.

### Inclusion criteria:

- Aged between 30-45 years
- Diagnosed PAD with intermittent claudication ( $ABI \leq 0.90$  or imaging confirmation).
- Able to walk on treadmill and participate in exercise sessions.
- Ability to walk on treadmill / overground for at least 2 minutes.
- Stable medications for  $\geq 4$  weeks.

### Exclusion criteria:

- Critical limb ischemia, recent revascularization ( $<3$  months), unstable cardiovascular disease (recent MI, unstable angina), uncontrolled hypertension, severe pulmonary disease preventing exercise, significant neurological or orthopedic conditions limiting walking, severe cognitive impairment, Participation in supervised RT within prior 3 months, severe PAD

**PROCEDURE AND PROTOCOLS:****Group A -Rhythmic auditory stimulation:**

Patients walk along with the beats of the metronome for about 30 minutes. The duration may progress upto 5-15 minutes over weeks. Rest between walk depends upon the claudication.

**Strength training:**

Strength training includes Calf raises (standing/seated), leg press/squats, step-ups, hamstring curls, glute bridges; 2–3 sets  $\times$  8–15 reps, moderate intensity, progressive overload on weeks

**Group B: Knee-Alignment-Oriented Dynamic Balance Exercise**

Participants in Group B received knee-alignment-oriented dynamic balance exercises which includes Weight shifting – forward/backward and lateral, Mini squat with knee tracking, Obstacle stepping, Walking around cones, Clock-reach exercise, star excursion balance exercise were designed to improve lower-limb control, dynamic stability, and functional movement

**DATA ANALYSIS****Six Minute Walk Test:****Within group analysis**

| GROUP   | Mean     |           | Standard deviation |           | Paired “t” value | p value |
|---------|----------|-----------|--------------------|-----------|------------------|---------|
|         | Pre-test | Post-test | Pre-test           | Post-test |                  |         |
| GROUP-A | 292.0m   | 342.0m    | 8.7m               | 8.9m      | 47.61            | < .001  |
| GROUP-B | 289.2m   | 316.8m    | 7.7m               | 7.9m      | 22.06            | < .001  |

**Interpretation of Group A – 6MWT**

The mean 6-Minute Walk Test distance in Group A increased from  $292.0 \pm 8.7$  m in the pre-test to  $342.0 \pm 8.9$  m in the post-test, with a mean improvement of 50.0 m. The paired t-test demonstrated a statistically significant difference between pre-test and post-test scores ( $t = 47.61$ ,  $p < 0.001$ ).

Therefore, the results indicate that rhythmic auditory stimulation combined with strength training significantly improved functional walking capacity in Group A.

**Interpretation of Group B – 6MWT**

In Group B, the mean 6-Minute Walk Test distance increased from  $289.2 \pm 7.7$  m at pre-test to  $316.8 \pm 7.9$  m at post-test, representing a mean improvement of 27.6 m. The paired t-test demonstrated a statistically significant difference between pre-test and post-test scores ( $t = 22.06$ ,  $p < 0.001$ ).

Therefore, the results indicate that knee-alignment-oriented dynamic balance exercise significantly improved functional walking capacity in Group B.

**Between group analysis**

| 6MWT         | Group A | Group B | Mean difference | Independent “t” value | p-value | Significance    |
|--------------|---------|---------|-----------------|-----------------------|---------|-----------------|
| Pre- test    | 292.0m  | 289.2   | 2.8m            | 0.91                  | 0.370   | Not significant |
| Post- test   | 342.0m  | 316.8m  | 25.2m           | 8.216                 | < .001  | significant     |
| Change score | 50.0m   | 27.6m   | 22.4m           | 13.71m                | < .001  | significant     |

At baseline, there was no statistically significant difference between Group A and Group B in 6-Minute Walk Test scores ( $t = 0.91$ ,  $p = 0.370$ ). This indicates that the two groups were statistically comparable with respect to functional walking capacity before the intervention.

Following the intervention, a statistically significant difference was observed between the groups in post-test 6-Minute Walk Test scores ( $t = 8.21$ ,  $p < 0.001$ ). Group A demonstrated a higher mean post-test walking distance ( $342.0 \pm 8.9$  m) compared with Group B ( $316.8 \pm 7.9$  m).

Furthermore, comparison of the change scores demonstrated a statistically significant between-group difference ( $t = 13.71$ ,  $p < 0.001$ ). The mean improvement was 50.0 m in Group A compared with 27.6 m in Group B. Therefore, the findings indicate that participants receiving rhythmic auditory stimulation combined with strength training demonstrated significantly greater improvement in functional walking capacity compared with participants receiving knee-alignment-oriented dynamic balance exercise.

### Walking Impairment Questionnaire:

#### Within group analysis

| GROUP   | Mean     |           | Standard deviation |           | Paired “t” value | p      |
|---------|----------|-----------|--------------------|-----------|------------------|--------|
|         | Pre-test | Post-test | Pre-test           | Post-test |                  |        |
| GROUP-A | 38.0     | 57.0      | 1.2                | 1.5       | 108.72           | < .001 |
| GROUP-B | 36.6     | 49.6      | 1.2                | 1.7       | 54.66            | < .001 |

#### Interpretation of Group A – WIQ

The mean Walking Impairment Questionnaire score in Group A increased from  $38.0 \pm 1.2$  at pre-test to  $57.0 \pm 1.5$  at post-test, with a mean improvement of 19.0 points. The paired t-test demonstrated a statistically significant difference between pre-test and post-test scores ( $t = 108.72$ ,  $p < 0.001$ ).

Therefore, the results indicate that rhythmic auditory stimulation combined with strength training significantly improved walking ability as measured by the Walking Impairment Questionnaire in Group A.

#### Interpretation of Group B – WIQ

The mean Walking Impairment Questionnaire score in Group B increased from  $36.6 \pm 1.2$  at pre-test to  $49.6 \pm 1.7$  at post-test, with a mean improvement of 13.0 points. The paired t-test demonstrated a statistically significant difference between pre-test and post-test scores ( $t = 54.66$ ,  $p < 0.001$ ).

Therefore, the results indicate that knee-alignment-oriented dynamic balance exercise significantly improved walking ability as measured by the Walking Impairment Questionnaire in Group B.

#### Between group analysis:

| WIQ          | Group A | Group B | Mean difference | Independent “t” value | p-value | Significance |
|--------------|---------|---------|-----------------|-----------------------|---------|--------------|
| Pre- test    | 38.0    | 36.6    | 1.4             | 3.08                  | 0.005   | significant  |
| Post- test   | 57.0    | 49.6    | 7.4             | 12.62                 | <0.001  | significant  |
| Change score | 19.0    | 13.0    | 6.0             | 20.33                 | <0.001  | significant  |

The post-test analysis demonstrated a statistically significant difference between Group A and Group B ( $t = 12.62$ ,  $p < 0.001$ ). Group A demonstrated a higher mean post-test WIQ score ( $57.0 \pm 1.5$ ) compared with Group B ( $49.6 \pm 1.7$ ).

The change-score analysis further demonstrated a statistically significant difference between the groups ( $t = 20.33$ ,  $p < 0.001$ ). Group A showed a mean improvement of 19.0 points, whereas Group B demonstrated a mean improvement of 13.0 points.

Although significant differences were observed in post-test and change scores, a significant baseline difference in WIQ scores was also present between the groups. These findings indicate that rhythmic auditory stimulation combined with strength training resulted in a significantly greater improvement in walking-related functional ability compared with knee-alignment-oriented dynamic balance exercise.

### Discussion

The findings of this present study demonstrate that the combination of Rhythmic Auditory Stimulation (RAS) and strength training produced significant improvements in walking capacity, gait parameters, and lower-limb muscle strength in individuals with Peripheral Artery Disease (PAD) experiencing intermittent claudication than knee alignment oriented

dynamic balance exercise. The improvements may be attributed to the entrainment effect of rhythmic cues, which enhances motor coordination, stride consistency, and temporal gait control by facilitating neural synchronization between auditory and motor pathways via the reticulospinal and corticospinal systems.

Strength training targeting the calf muscles, quadriceps, hamstrings, and plantar flexors is known to improve perfusion efficiency, muscle oxidative capacity, and delay fatigue onset during ambulation. When combined with rhythmic cueing, the intervention appears to optimize oxygen utilization and gait biomechanics, thereby reducing claudication symptoms. Previous studies have also shown that external auditory cueing improves walking speed, cadence, and endurance in neuromotor populations, and the current findings extend these benefits to PAD-related gait impairments.

Additionally, the improvement in Walking Impairment Questionnaire (WIQ) and 6-Minute Walk Test scores suggests meaningful functional gains that translate to daily life, indicating that the combined protocol may contribute to enhanced quality of life and independence.

## Conclusion

The results of the study suggest that Rhythmic Auditory Stimulation combined with structured strength training is an effective and clinically feasible intervention for improving lower-limb function, walking ability, and reducing claudication pain in patients with Peripheral Artery Disease. This dual-modality approach enhances gait rhythm, neuromuscular activation, and muscular endurance more effectively than knee alignment oriented dynamic balance exercise.

Implementing RAS-based strength programs within rehabilitation settings may serve as a valuable non-invasive strategy for optimizing functional outcomes in claudication. Future research with larger sample sizes, long-term follow-up, and comparison against conventional supervised exercise therapy is recommended to further validate these findings.

## References:

1. McDermott, M. M., & Newman, A. B.,(2007). Peripheral arterial disease in older adults: Epidemiology, clinical presentation, and prognosis. *Circulation*.116(9), 1129–1145.
2. Norgren, L., Hiatt, W. R., Dormandy, J. A., *et.al.*, (2007). Inter-society consensus for the management of peripheral arterial disease (TASC II). *Journal of Vascular Surgery*, 45(Suppl S), S5–S67.
3. Criqui, M. H., & Aboyans, V.,(2015). Epidemiology of peripheral artery disease. *Circulation Research*, 116(9), 1509–1526.
4. Parmenter, B. J., Raymond, J., Dinnen, P & Fiatarone Singh, M. A.,(2011). Resistance and aerobic exercise for peripheral arterial disease: A randomized controlled trial. *European Journal of Vascular and Endovascular Surgery*, 42(1), 45–52.
5. Collins, T., *et al.* (2021). Rhythmic auditory stimulation increases walking distance in patients with intermittent claudication: A feasibility study. *Journal of Cardiopulmonary Rehabilitation and Prevention*, 41(6), 369–375.
6. Hiatt, W. R., Wolfel, E. E., Meier, R. H., & Regensteiner, J. G. (1994). Superiority of treadmill walking exercise versus strength training for patients with peripheral arterial disease: Implications for the mechanism of the training response. *Circulation*, 90(4), 1866–1874.
7. Bronas, U. G., Everett, S., Steffen, A., Briller, J., Hannan, M., Hernandez, A., & Collins, E. (2018). Rhythmic auditory music stimulation enhances walking distance in patients with claudication: A feasibility study. *Journal of Cardiopulmonary Rehabilitation and Prevention*, 38(4), E1–E5.
8. Thaut, M. H., McIntosh, G. C., & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. *Frontiers in Psychology*, 5, 1185.
9. Gerhard-Herman, M. D., Gornik, H. L., Barrett, C., *et al.* (2017). 2016 AHA/ACC guideline on the management of patients with lower extremity peripheral artery disease. *Journal of the American College of Cardiology*, 69(11), e71–e126.
10. Rahman, H., Leutzinger, T., Hassan, M., *et al.* (2024). Peripheral artery disease causes consistent gait irregularities regardless of the location of leg claudication pain. *Annals of Physical and Rehabilitation Medicine*, 67(3), 101793.
11. Fowkes, F. G. R., Rudan, D., Rudan, I., *et al.* (2013). Comparison of global estimates of prevalence and risk factors for peripheral artery disease in 2000 and 2010. *The Lancet*, 382(9901), 1329–1340.

12. Hiatt, W. R. (2001). Medical treatment of peripheral arterial disease and claudication. *New England Journal of Medicine*, 344(21), 1608–1621.
13. Gardner, A. W., & Poehlman, E. T. (1995). Exercise rehabilitation programs for the treatment of claudication pain. *JAMA*, 274(12), 975–980.
14. McDermott, M. M., Ades, P., Guralnik, J. M., et al. (2009). Treadmill exercise and resistance training in patients with peripheral arterial disease with and without intermittent claudication: A randomized controlled trial. *JAMA*, 301(2), 165–174.
15. Ritti-Dias, R. M., Wolosker, N., de Moraes Forjaz, C. L., et al. (2010). Strength training increases walking tolerance in intermittent claudication patients: Randomized trial. *Journal of Vascular Surgery*, 51(1), 89–95.
16. Gardner, A. W., Parker, D. E., Montgomery, P. S., Scott, K. J., & Blevins, S. M. (2011). Efficacy of quantified home-based exercise and supervised exercise in patients with intermittent claudication.
17. Diane Treat-Jacobson, D., McDermott, M. M., Bronas, U. G., et al. (2019). Optimal exercise programs for patients with peripheral artery disease: A scientific statement from the American Heart Association. *Circulation*, 139(4), e10–e33.
18. Harwood, A. E., Pymer, S., Ingle, L., et al. (2020). Exercise training for intermittent claudication: A narrative review and summary of guidelines for practitioners. *BMJ Open Sport & Exercise Medicine*, 6, e000897.
19. Thaut, M. H., McIntosh, G. C., & Rice, R. R. (1997). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. *Movement Disorders*, 12(2), 163–170.
20. Thaut, M. H., McIntosh, G. C., & Hoemberg, V. (2015). Neurobiological foundations of neurologic music therapy: Rhythmic entrainment and the motor system. *Frontiers in Psychology*, 5, 1185.
21. Nombela, C., Hughes, L. E., Owen, A. M., & Grahn, J. A. (2013). Into the groove: Can rhythm influence Parkinson's disease? *Neuroscience & Biobehavioral Reviews*, 37(10), 2564–2570.
22. Ghai, S., Ghai, I., Schmitz, G., & Effenberg, A. O. (2018). Effect of rhythmic auditory cueing on parkinsonian gait: A systematic review and meta-analysis. *Scientific Reports, analysis*. 8(1):506
23. Wittwer, J. E., Webster, K. E., & Hill, K. (2013). Rhythmic auditory cueing to improve walking in patients with neurological conditions. *Cochrane Database of Systematic Reviews*.
24. Braun Janzen, Thenille & Koshimori, Yuko & Richard Williams, Nicole & Thaut, Michael. (2022). Rhythm and Music-Based Interventions in Motor Rehabilitation: Current Evidence and Future Perspectives. *Frontiers in Human Neuroscience*. 15. 789467. 10.3389/fnhum.2021.789467.
25. Bronas UG, Everett S, Steffen A, Briller J, Hannan M, Hernandez A, Collins E. Rhythmic Auditory Music Stimulation Enhances Walking Distance in Patients With Claudication: A FEASIBILITY STUDY. *J Cardiopulm Rehabil Prev*. 2018 Jul;38(4):E1-E5.
26. McDermott, M. M., Liu, K., Greenland, P., et al. (2004). Functional decline in peripheral arterial disease: Associations with the ankle brachial index and leg symptoms. *JAMA*, 292(4), 453–461.
27. Gardner, A. W., Montgomery, P. S., & Parker, D. E. (2011). Physical activity is a predictor of all-cause mortality in patients with intermittent claudication.
28. Gardner, A. W., Montgomery, P. S., & Parker, D. E. (2010). Changes in exercise performance and gait biomechanics following exercise rehabilitation in patients with intermittent claudication.
29. Lane, R., Harwood, A., Watson, L., & Leng, G. C. (2017). Exercise for intermittent claudication. *Cochrane Database of Systematic Reviews*, CD000990.
30. Parmenter, B. J., Dieberg, G., Smart, N. A., & Fiatarone Singh, M. A. (2015). Exercise training for management of peripheral arterial disease: A systematic review and meta-analysis