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# Effect of Adding Warm Compression to Exercise Therapy on Severity and Functional Status among Patients with Chronic Limb-Threatening Ischemia

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## ABSTRACT

**Background:** Chronic Limb-Threatening Ischemia (CLTI) is a serious form of peripheral artery disease. Significantly influencing their quality of life and functional abilities and causing increased risk for limb amputation. **Objectives:** To evaluate the effect of adding warm compression to exercise therapy on limb ischemia severity and physical functional health status among patients with CLTI. **Methods:** A quasi-experimental study design was used. One hundred patients from the Vascular Surgery Department of Assiut University Hospital, Assiut University, Egypt, were selected as a purposive sample (50 in the control group and 50 in the study group). A patient assessment form, a standardized classification system for CLTI severity assessment, and a physical functional health status assessment form were used to collect the data. **Results:** Statistically significant differences were found between both groups at 1 and 6 months postoperatively regarding the stage of CLTI severity ($p<0.001$ and $p<0.001$, respectively). Also, there are statistically significant differences between the two times (1st and 6th month postoperative) between both studied groups regarding the mean physical functional health status ($P<0.001$**). **Conclusion:** The study findings indicated that the implementation of exercise and warm compression positively influenced postoperative patient outcomes. The study suggests that exercise and warm compression should be regarded as an essential component of the standard hospital therapy for patients with CLTI.

***Keywords: Chronic Limb-Threatening Ischemia (CLTI); Exercises Therapy; Warm Compression Therapy***

## INTRODUCTION

Peripheral Arterial Disease (PAD) is a major global health concern that significantly affects patients' functional status and quality of life. It is primarily caused by atherosclerotic narrowing or occlusion of peripheral arteries, most commonly involving the lower extremities. The presence of cardiovascular risk factors, particularly Diabetes Mellitus (DM), hypertension, and smoking, increases the likelihood of PAD progression to CLTI, which represents the most advanced clinical manifestation of the disease. CLTI is associated with poor prognosis, including a high risk of lower-limb amputation and increased mortality (Conte *et al.,* 2019). Clinically, CLTI is characterized by chronic ischemic rest pain, non-healing lower-extremity wounds, or gangrene attributable to PAD. Early recognition and appropriate management are essential to reduce limb-related complications and improve patient outcomes (Gornik *et al.,* 2024).

The prevalence of PAD has increased in recent years, which is partly attributed to the growing burden of DM and the aging population. PAD affects millions of individuals worldwide, with clinical presentations ranging from asymptomatic disease to severe manifestations such as tissue loss (Berchiolli *et al.,* 2023). Among patients with CLTI, the risk of adverse outcomes remains substantial. Patients may experience a high risk of major amputation and mortality, highlighting the need for early assessment and effective management strategies (Lee *et al.,* 2022).

Exercise therapy is widely recommended as an important component of conservative management for patients with PAD. Structured exercise interventions have been shown to improve walking capacity, functional performance, and symptom severity in individuals with PAD (Mazzolai *et al.,* 2024). Exercise may contribute to improved lower-limb perfusion through physiological adaptations, including enhanced collateral circulation and vascular function. Other supportive interventions, such as foot-care strategies and relaxation techniques, may also help promote limb health and reduce PAD-related complications (Zaki *et al.,* 2023).

Recommended exercise modalities for patients with PAD include supervised walking programs, treadmill training, resistance exercises, and range-of-motion (ROM) exercises. These interventions are considered essential components of non-invasive PAD management aimed at improving functional outcomes and reducing disease burden (Mazzolai *et al.,* 2024).

Warm compresses are considered a non-pharmacological supportive intervention that may improve local comfort and promote peripheral circulation by providing controlled warmth to the affected lower limb. Local heat application has been reported to enhance blood flow, support tissue metabolism, reduce discomfort, and improve soft tissue flexibility. The therapeutic effect of warm compresses may depend on the duration and intensity of application, with several studies reporting beneficial effects after approximately 20 minutes of use (Zanoli *et al.,* 2024).

The potential benefits of warm therapy may be related to physiological responses to heat, including vasodilation and improved local circulation. Previous research has suggested that heat application may influence blood flow characteristics and support tissue repair processes by improving the delivery of oxygen and inflammatory cells to affected areas (Mohammed *et al.,* 2022).

Nurses play an essential role in preventing foot ulcers and lower-limb amputations among patients with PAD through patient education, early risk assessment, screening of vulnerable individuals, and provision of appropriate care. Effective nursing interventions include promoting foot-care practices, encouraging adherence to follow-up visits, and supporting optimal diabetes management to reduce the risk of PAD-related complications (Zhou & Zhou, 2024). In addition, involving patients and their families in the care process may improve self-management behaviors and enhance long-term outcomes (Zaki *et al.,* 2023).

**Significance of the Study**

The prevalence of PAD and its most severe manifestation, CLTI, has increased in recent years. Patients with CLTI represent a high-risk population with substantial rates of major amputation and mortality (Berchiolli *et al*., 2023). Approximately 150 patients with CLTI were managed at the Vascular Surgery Department, Assiut University Hospital in 2023, with a large proportion presenting with advanced ischemia (Rutherford stages 4–6) (Rutherford *et al*., 1997). CLTI leads to persistent functional impairment, significantly limiting daily activities and negatively affecting patients' quality of life. Despite advances in revascularization and medical therapy, many patients with CLTI continue to experience poor functional outcomes and impaired physical functional health status. There is limited evidence regarding the effectiveness of adjunct noninvasive interventions, particularly the combined use of warm compression and exercise, for improving clinical and functional outcomes in patients with CLTI. Therefore, this study aims to assess the combined effects of warm compression and exercise on outcomes in patients with CLTI.

**Study Objectives**

1. To evaluate the effect of a combined exercise and warm compression intervention on CLTI severity among patients with chronic limb-threatening ischemia.
2. To assess the effect of the intervention on physical functional health status among the studied patients.

**Research Hypotheses**

**$H_1$:** The grade of CLTI will be improved in the study group after implementing exercise and compression

therapy compared to the control group.

**$H_2$:** Functional health status will be improved in the study group after implementing exercise and compression therapy more than in the control group.

## METHODOLOGY

### Research Design

A quasi-experimental design with a study group and a control group was used to evaluate the effect of the intervention (Polit & Beck, 2021).

### Setting

The study was conducted at the Vascular Surgery Department of Assiut University Hospital.

### Sample

A purposive, non-probability sample of 100 patients of both sexes was recruited and assigned into two groups: a control group (n=50) and a study group (n=50). Participants were selected according to the following inclusion criteria: patients diagnosed with CLTI classified as Rutherford categories 4, 5, and 6 based on the Rutherford classification system (Rutherford *et al.,* 1997). The study was conducted among patients admitted/presenting between June 2024 and January 2025. Participants' ages ranged from 20 to less than 65 years.

### Exclusion Criteria

Patients suffered from acute lower limb ischemia.

### Sample Size

The study included one hundred patients with CLTI who attended the Vascular Department at Assiut University Hospitals, Egypt. The sample size was determined using power analysis to ensure adequate statistical validity. Calculation was performed using G*Power software (Faul *et al*., 2007), based on Cohen's criteria for effect size estimation (Cohen, 1988). Assuming a medium effect size (Cohen's $d$=0.5), a statistical power of 80% ($\beta$=0.20), and a significance level of 5% ($\alpha$=0.05), the minimum required sample size was estimated to be 50 patients per group, resulting in a total of 100 participants. This sample size was considered sufficient to detect statistically significant differences in CLTI severity and functional outcomes between the studied groups.

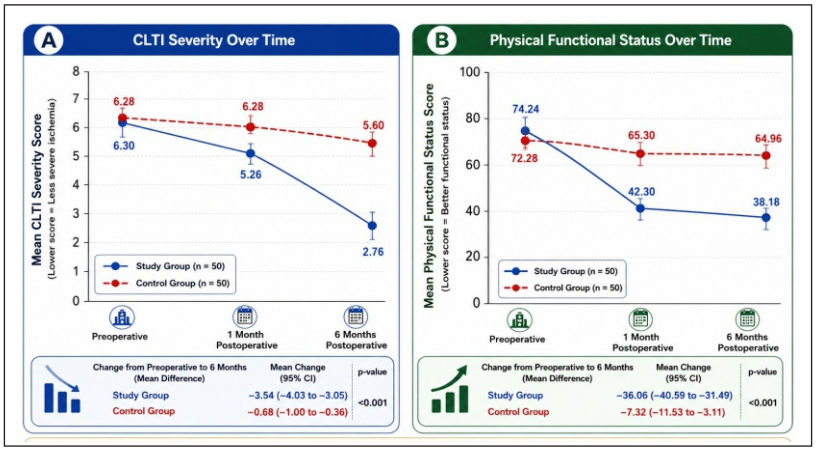


***Figure 1: Group Allocation and Follow-up Assessment of CLTI Severity and Physical Functional Status***

Figure 1 illustrates the study methodology, including patient selection, group allocation, intervention implementation, and follow-up assessment. A total of 100 patients with CLTI were assigned into two groups. The study group received the combined exercise and warm compression intervention, while the control group received routine hospital care. Outcomes were assessed before surgery and during postoperative follow-up at one and six months.

**Data Collecting Tools**

*Tool I: Patient Assessment Questionnaire*

It was developed by the researcher based on relevant literature and previous studies related to CLTI and peripheral vascular disease (Azmy *et al.,* 2022). The questionnaire content was guided by the clinical characteristics and risk factors associated with PAD and CLTI (Conte *et al.,* 2019). It consisted of two parts:

*Part 1: Patient Personal Data*

This part included demographic characteristics such as age, gender, working status, and educational level.

*Part 2: Medical Features*

This part covered relevant clinical characteristics and risk factors, including hypertension, cardiovascular disease, DM, atherosclerosis, smoking, and obesity.

*Tool II: Rutherford Classification for CLTI Assessment*

The Rutherford classification is a widely used clinical system for categorizing the severity of PAD and CLTI. It classifies patients according to clinical manifestations, including asymptomatic disease, claudication, rest pain, tissue loss, and gangrene (Rutherford *et al.,* 1997).

*The Rutherford classification*

It consists of seven categories: Stage 0 (asymptomatic), Stage 1 (mild claudication), Stage 2 (moderate claudication), Stage 3 (severe claudication), Stage 4 (rest pain), Stage 5 (minor tissue loss with ischemic ulceration not exceeding the digits), and Stage 6 (major tissue loss or extensive ischemic ulceration/gangrene). In the current study, patients with stages 4, 5, and 6 were included.

*Tool III: Physical Functional Status Assessment Questionnaire*

This tool was adapted from the Functional Status Assessment developed by Jette *et al.* (1986) and the Duke Activity Status Index (Hlatky *et al.,* 1989). It was used to assess patients' ability to perform routine daily physical activities and their level of functional independence.

The questionnaire consisted of 14 items assessing activities of daily living, including washing, dressing, personal grooming, eating, transferring, toileting, continence, and walking.

*Scoring System and Rating of Item*

Each item was rated using a 6-point Likert scale ranging from 1 to 6 and reflecting the frequency with which the patient was able to perform the activity, as follows: 1 = Not at all; 2 = A little of the time; 3 = Some of the time; 4 = A good bit of the time; 5 = Most of the time; 6 = All of the time.

The total score was calculated by summing the responses of all items. Higher scores indicated better functional ability and greater independence, while lower scores reflected increased functional limitation and dependence. The total score was interpreted as follows: independent (28–42), slightly dependent (14 to <28), and dependent (<14).

**Content Validity**

The content validity of the study tools was assessed by a panel of five experts, including two professors of vascular and endovascular surgery and three professors of adult nursing. The experts evaluated the tools for

clarity, relevance, comprehensiveness, applicability, and simplicity (Polit & Beck, 2021).

**Reliability**

The reliability of the measurement tools was assessed using Cronbach's alpha to determine internal consistency. Tool III demonstrated good reliability, with a Cronbach's alpha coefficient of 0.85. In addition, inter-rater agreement was used to assess the consistency of patient classification according to Tool II.

**Pilot Study**

A pilot study was conducted on 10% of the total sample (five patients from each group) to assess the clarity, applicability, and feasibility of the study tools. Based on the pilot results, necessary modifications were made. Participants included in the pilot study were excluded from the final sample to avoid potential bias.

The director of the department granted formal approval and administrative clearance to carry out this study of the Vascular Surgery Department at Assiut University Hospital. Patients who took part in the trial gave their informed consent after being fully informed about the procedures and purpose of the investigation, and the booklet was explained to them (study group). This study was conducted in five phases:

*Preparatory stage*: This stage involved reviewing national and regional studies from articles, periodicals, and journals to develop the study tools for data collection (Azmy *et al*., 2022; Mohammed *et al*., 2022).

*Planning stage*: Based on the assessment findings and relevant literature, an educational booklet was developed by the researcher to guide the intervention content and provide patients with the necessary instructions.

*Implementation stage (fieldwork)*: The study was conducted from June 2024 to January 2025. Eligible patients who met the inclusion criteria were identified on the first day of admission to the Vascular Surgery Department. Data collection and intervention implementation were carried out according to the developed study protocol.

*For both groups*: Each patient was approached by the researcher, and a personal interview was conducted to collect the required baseline data. Data were collected at three time points: the first assessment was performed preoperatively during hospital admission using Tools I, II, and III. The second and third assessments were conducted during postoperative follow-up visits at the Vascular Outpatient Clinic at the first and sixth months, respectively, using Tools II and III to evaluate clinical and functional outcomes. Patients' telephone numbers were obtained to arrange follow-up appointments and ensure completion of data collection after discharge.

*Control Group*

Patients in the control group received routine hospital care, including preoperative assessment of comorbidities such as DM, hypertension, and cardiovascular disease, in addition to the required vascular investigations. Postoperative care included monitoring of limb perfusion, wound condition, pain management, prescribed anticoagulant therapy, and prevention of infection and thrombotic complications.

*Study Group (Intervention Group)*

In addition to routine hospital care, patients in the study group received three educational sessions. Each session lasted approximately 40 minutes and included explanation and demonstration of the booklet instructions in simple Arabic language. The educational booklet focused on exercise practices and warm compress application for patients with CLTI and consisted of the following components:

Part I: Nursing instructions about the definition of CLTI, causes, stages, prevention, and management.

Part II: Exercises training about walking, range of motion, muscle strengthening, Burgers–Allen exercise, and resistance training.

Part III: Nursing instructions about warm compression therapy.

The intervention was designed as a combined supportive care program consisting of structured lower-limb exercises, warm compression therapy, and patient education. Postoperatively, it was continued for six months following confirmation of proper wound healing. The aim was to evaluate the overall effect of this integrated intervention on clinical and functional outcomes among patients with CLTI.

**Structure and Content of the Intervention Sessions**

*Initial Intervention Session (Preoperative Session)*: The first educational session was conducted on the preoperative day. Each patient in the study group was approached individually, with a family member included when appropriate. The researcher explained the booklet instructions, including CLTI care, prescribed exercises, and the use of warm compress therapy.

*Second Intervention Session (Postoperative Session)*: During the postoperative period, patients in the study group received training on the correct application of warm compress therapy. The technique was demonstrated by the researcher with assistance from physiotherapy and nursing staff to ensure proper application. Patients were instructed to maintain the recommended temperature (40–45°C), apply the therapy for 20 minutes three times daily according to the study protocol, monitor skin condition before and after application, follow safety precautions, and report any discomfort.

**Final Intervention Session (Postoperative Session)**

During the postoperative period, patients in the study group received a structured lower-limb exercise program. The program was implemented and supervised by the researcher in collaboration with a physiotherapist and a vascular physician. Patients were educated about the type, purpose, technique, duration, and frequency of each exercise according to the prescribed exercise schedule.

The researcher demonstrated each exercise and provided hands-on training to ensure correct performance, proper limb positioning, and adherence to the recommended repetitions and duration. Patients were instructed to follow the exercise timetable, monitor their response, and report any discomfort or unusual symptoms. The exercise program was individualized and progressively adjusted according to each patient's tolerance, functional capacity, and vascular condition.

***Table 1: Components of the Lower Limb Exercise Program***

| Type of Exercise | Purpose | Duration and Frequency | Implementation Guidelines |
|---|---|---|---|
| **Walking Exercises** | Improve circulation, endurance, and functional mobility | 10–30 min/session initially, progressing to 30–60 min; ≥3 sessions/week | Supervised treadmill or floor walking; stop when moderate pain occurs, resume after rest; correct footwear and safety; gradually increase speed |
| **Buerger-Allen Exercise (BAE)** | Enhance lower limb circulation | 10–15 min/session, 2–3 times/ day | Three positions (elevation, dependency, and horizontal) were performed according to tolerance; the patient was taught the correct technique |
| **ROM Exercises** | Maintain joint flexibility and prevent stiffness | 2–3 times/ day | Ankle dorsiflexion/plantar flexion, big toe extension; supervise correct movement and avoid pain |
| **Strength Exercises** | Promote circulation, flexibility, and muscle activation | 2 times/ day, up to 10 repetitions each | Ankle pumps, straight leg raises, hip abduction, and static quadriceps; monitor form and adherence |

**Adherence and Patient Compliance with the Intervention and Outcome Assessment**

Adherence to the exercise regimen and warm compress application was monitored through scheduled telephone follow-up and regular outpatient clinic visits. During follow-up visits, patients were re-evaluated to assess their clinical condition and functional status. Improvement was determined by comparing the post-intervention Rutherford classification stage with the baseline assessment, in addition to evaluating changes in

functional status and the level of independence in activities of daily living.

**Evaluation and Follow-up Stage**

During this stage, the effect of the intervention, including exercise and warm compression therapy, on CLTI outcomes was evaluated. Both study and control groups were reassessed by comparing baseline measurements with follow-up assessments conducted at one and six months postoperatively using Tools II and III.

**Outcomes**

*Primary Outcomes*

Improvement in CLTI severity stage was assessed at one- and six-months post-intervention to evaluate changes in the severity of CLTI. Improvement in physical functional status was measured using the physical functional health status scale to determine the level of independence in activities of daily living.

*Secondary Outcomes*

Improvement in physical functional status over time, in addition to CLTI severity stage progression, was considered a secondary outcome to evaluate the overall effect of the intervention on patients' clinical condition. The selected outcomes provide an assessment of the clinical and functional effects of the combined interventions (warm compression therapy and structured exercise) in patients with advanced CLTI.

**Statistical Analysis**

Data were organized, tabulated, and analyzed using the Statistical Package for the Social Sciences (SPSS), version 24. Categorical variables were presented as frequencies and percentages, while continuous variables were presented as mean ± Standard Deviation (SD). The Chi-square ($\chi^2$) test and Fisher's exact test were used for categorical variables, and the independent samples t-test was used for baseline comparison of continuous variables between groups.

Changes in continuous outcomes over time, including CLTI severity and physical functional health status scores, were analyzed using Repeated-Measures Analysis of Variance (RM-ANOVA). Post hoc comparisons were performed using estimated marginal means. Effect sizes were reported using partial eta squared (Partial $\eta^2$), and 95% Confidence Intervals (CI) were provided where applicable.

A two-tailed $p$-value <0.05 was considered statistically significant, while $p$<0.001 indicated a highly statistically significant difference. Values of $p\geq0.05$ were considered non-significant. Percentages were reported using one decimal place for consistency.

**Ethical Consideration**

The research obtained ethical clearance from the Faculty of Nursing at Assiut University, Egypt with Reference Number 1120240789 on 25th March 2024.

**RESULTS**

***Table 2: Mean Age by Group (n=100)***

| Variables | Case Study | Mean ± SD | *T*-test | Sig. |
|---|---|---|---|---|
| **Age** | Study group | 59.60±6.455 | 0.902 | 0.369 |
| | Control group | 58.44±6.405 | | |

*SD=Standard Deviation; p-value was calculated using the independent samples t-test; NS=non-significant difference (p≥0.05)*

Table 2 shows there was no significant difference between the two groups in terms of age.

***Table 3: Demographic Characteristics of Study and Control Groups (n=100)***

| Demographic Characteristics | Study Group (n=50) n (%) | Control Group (n=50) n (%) | Chi-square ($\chi^2$) | *P*-value |
|---|---|---|---|---|
| **Gender** | | | | |
| Male | 38 (76.0) | 35 (70.0) | 0.457 | 0.653 |
| Female | 12 (24.0) | 15 (30.0) | | |
| **Age Group** | | | | |
| <40 | 1 (2.0) | 1 (2.0) | 0.846 | 0.369 |
| 40-<50 | 4 (8.0) | 3 (6.0) | | |
| 50-<60 | 33 (66.0) | 32 (64.0) | | |
| 60-65 | 12 (24) | 14 (28.0) | | |
| **Education Level** | | | | |
| Illiterate | 9 (18.0) | 10 (20.0) | 0.199 | 0.978 |
| Read and Write | 8 (16.0) | 7 (14.0) | | |
| Primary School | 9 (18.0) | 8 (16.0) | | |
| Secondary School | 24 (48.0) | 25 (50.0) | | |
| **Occupation** | | | | |
| Office Work | 3 (6.0) | 1 (2.0) | 5.952 | ٠.429 |
| Farmer | 5 (10.0) | 9 (18.0) | | |
| Machinery | 1 (2.0) | 0 (0.0) | | |
| Non-working | 14 (28.0) | 17 (34.0) | | |
| Retired | 16 (32.0) | 9 (18.0) | | |
| Housewife | 8 (16.0) | 9 (18.0) | | |
| Other Job | 3 (6.0) | 5 (10.0) | | |
| **Living Situation** | | | | |
| Live Alone | 2 (4.0) | 0 (0.0) | 7.097 | 0.029 |
| Live with Family Members | 48 (96.0) | 50 (100.0) | | |

*P-value was calculated using the Chi-square test ($\chi^2$); NS=non-significant difference (p≥0.05)*

Table 3 showed that there were no statistically significant differences found between the study and control groups regarding most personal data characteristics, except for living situation, which showed a statistically significant difference ($p$=0.029).

***Table 4: Medical History of Study and Control Groups (n=100)***

| Variable | Study Group (n=50) n (%) | Control Group (n=50) n (%) | Fisher's Exact Test | *P*-value |
|---|---|---|---|---|
| **Medical History** | | | | |
| 1- Hypertension | 38 (76.0) | 37 (74.0) | 0.053 | 0.818 |
| 2- Cardiovascular Disease | 19 (38.0) | 22 (44.0) | 0.368 | 0.544 |
| 3- Dyslipidemia | 28 (56.0) | 30 (60.0) | 0.163 | 0.687 |
| 4- DM | 45 (90.0) | 42 (84.0) | 0.788 | 0.375 |
| 5- Smoking | 13 (26.0) | 12 (24.0) | 0.053 | 0.818 |
| 6- Obesity | 12 (24.0) | 13 (26.0) | 0.053 | 0.818 |

*DM=Diabetes mellitus; Data was analyzed using Fisher's exact test; NS=non-significant difference (p≥0.05)*

Table 4 reveals that over two-thirds of both the study and control groups had hypertension (76.0% and 74.0%, respectively), and a large portion of both the study and control groups had DM (90.0% and 84.0%, respectively).

***Table 5: Preoperative Limb Ischemia Severity by Group (n = 100)***

| Stages | Study Group (n=50) | Control Group (n=50) | *p*-value |
|---|---|---|---|
| | Preoperative Day | | |
| | n (%) | n (%) | |
| Stage 4 | 3 (6.0) | 2 (4.0) | (NS) 0.591 |
| Stage 5 | 24 (48.0) | 29 (58.0) | |
| Stage 6 | 23 (46.0) | 19 (38.0) | |

*NS=non-significant difference (p≥0.05)*

Table 5 illustrates there was no statistically significant difference that was observed between the study and control groups on the preoperative day in relation to CLTI severity ($p$=0.591).

***Table 6: Postoperative CLTI Severity by Group Over Time (n=100)***

| Follow-up/Effect | Study Group Mean ± SE (95% CI) | Control Group Mean ± SE (95% CI) | *p*-value | Effect size (Partial $\eta^2$) |
|---|---|---|---|---|
| 1 month | 5.26 ± 0.16 (4.93–5.59) | 6.28 ± 0.08 (6.12–6.44) | — | — |
| 6 months | 2.76 ± 0.25 (2.27–3.25) | 5.60 ± 0.13 (5.33–5.87) | — | — |
| Within-Group Repeated-Measures ANOVA | F (1.49)=165.541 | F (1.49)=45.534 | <0.001 | Study=0.772 Control=0.482 |

*P-value was calculated using repeated-measures analysis of variance (RM-ANOVA); Statistical significance was considered at p<0.05; Effect size was estimated using partial eta squared (Partial η²); SE=Standard Error; CI=Confidence Interval; RM-ANOVA=Repeated-Measures Analysis of Variance*

Table 6 demonstrated a significant improvement in postoperative CLTI severity over time in both groups. The study group showed a greater reduction in CLTI severity compared with the control group at the 6-month follow-up. The time effect was statistically significant in both groups ($p$<0.001), with a large effect size (Partial $\eta^2$=0.772 and 0.482, respectively).

***Table 7: Physical Functional Health Status Scores by Group Over Time (n=100)***

| Follow-up/Effect | Study Group (n=50) Mean ± SD (95% CI) | Control Group (n=50) Mean ± SD (95% CI) | *p*-value | Effect Size (Partial $\eta^2$) |
|---|---|---|---|---|
| Preoperative | 74.24±8.80 (71.74–76.74) | 72.28±6.12 (70.54–74.02) | 0.203 | — |
| 1 month postoperative | 42.30±14.29 (38.23–46.37) | 65.30±13.67 (61.41–69.19) | <0.001 | — |
| 6 months postoperative | 38.18±14.98 (33.92–42.44) | 64.96±14.10 (60.95–68.97) | <0.001 | — |
| Within-group repeated-measures ANOVA (time effect) | F (2.98)=308.847 | F (2.98)=18.341 | <0.001 | 0.863/0.272 |
| Post hoc comparison: Preoperative vs 6 months | Mean difference=36.04 (95% CI: 31.49–40.59) | Mean difference=7.32 (95% CI: 3.11–11.53) | <0.001 | — |

*P-value was calculated using repeated-measures analysis of variance (RM-ANOVA) with post hoc pairwise comparisons based on estimated marginal means; SD=Standard Deviation; CI=Confidence Interval; η²=Partial Eta Squared; p<0.001 indicates a highly statistically significant difference, while p≥0.05 indicates a non-significant difference*

Table 7 demonstrated a significant improvement in physical functional health status over time in both groups ($p$<0.001). The study group showed a greater improvement compared with the control group, with a larger effect size (Partial $\eta^2$=0.863) compared with the control group (Partial $\eta^2$=0.272).

## DISCUSSION

CLTI is a dangerous form of PAD that affects adults, significantly affecting their quality of life and physical abilities and causing an elevated morbidity rate (Saad *et al*., 2025). In this study, the addition of warm compression therapy to structured lower-limb exercise resulted in significant improvement in CLTI severity and physical functional health status compared with routine hospital care. Exercise therapy is an established component of conservative management for patients with PAD and CLTI (Mazzolai *et al.,* 2024). These findings suggest that the combined application of exercise and warm compression therapy may provide additional clinical benefits beyond standard management by supporting symptom improvement and functional recovery. However, the individual contributions of each intervention component could not be determined separately due to the combined nature of the interventions.

In the present study, more than half of the patients in both groups were classified as stage 5 during the preoperative phase, indicating advanced ischemic severity at baseline. At the six-month follow-up, the study group showed marked improvement, whereas more than half of the control group remained at stage 5.

A statistically significant difference was observed between the two groups at both one-and six-month postoperative follow-ups regarding CLTI stage severity. The improvement observed among patients in the study group may be attributed to the integrated supportive intervention program, which included structured exercise and warm compression therapy. This combined approach may have contributed to improved

peripheral circulation, tissue perfusion, and functional outcomes. However, because both interventions were administered concurrently, the individual contribution of each component to the observed improvement cannot be determined. Lee *et al.* (2022) reported similar outcomes, revealing that over half of the patients achieved stage 0 after six months.

Gueifão *et al*. (2025) found that patients presenting with rest pain or an infra-popliteal anatomical disease pattern more frequently underwent endovascular procedures. Cieri *et al.* (2025) reported that patients classified within stages 4–6 experienced significantly higher rates of amputation and mortality compared with those in lower stages (0–3). These findings emphasize the importance of early identification and implementation of effective therapeutic interventions to improve limb salvage and survival outcomes. Therefore, the clinical staging system remains a clinically relevant tool for assessing disease severity and guiding individualized management strategies in patients with CLTI.

Regarding overall physical functional health, most participants in both groups were classified as functionally dependent prior to the intervention. At the six-month follow-up, over two-thirds of the study group attained functional independence, whereas approximately half of the control group continued to exhibit partial dependence. These findings are consistent with Banaś *et al*. (2022), who found that patients with CLTI had the lowest physical functioning scores prior to intervention.

A recent systematic review and meta-analysis reported that exercise interventions significantly improved pain-free and maximal walking distances in patients with PAD, indicating measurable gains in overall functional independence compared with non-exercise controls (Xu *et al*., 2025). In addition, clinical consensus documents recommend supervised and structured exercise therapy as a first-line intervention for symptomatic PAD, highlighting consistent improvements in walking performance and functional status across randomized controlled trials (Naveh *et al*., 2025).

The mean age of participants in the study and control groups was 59.60±6.46 and 58.44 ± 6.41 years, respectively, indicating that most patients were in the late middle-age category. Age-related vascular changes, including arterial stiffening, reduced vasodilation capacity, and decreased vascular elasticity, may contribute to impaired blood flow in the lower extremities (Castelli *et al*., 2023). These findings are consistent with Bączyk *et al*. (2025), who reported a mean age of approximately 69 years among both male and female participants.

With respect to gender distribution, males represented the majority of participants in both the study and control groups. The higher prevalence of smoking among men, recognized as a major modifiable risk factor for PAD, may explain this predominance. This predominance may be attributed to the higher prevalence of smoking among men, which is recognized as a major modifiable risk factor for PAD. Several previous studies, including those by Ferreira *et al.* (2024), Haga *et al.* (2024), and Shatnawi *et al.* (2023), consistently reported that males represent the majority of patients with PAD, reflecting the higher burden of modifiable cardiovascular risk factors in men.

Concerning educational level, more than half of both groups had at least a secondary level of education. Lower educational attainment is often associated with limited health literacy and reduced health-related knowledge. However, this finding differs from previous studies. Saad *et al.* (2025) reported that most participants were illiterate. Similar findings were reported by Ying *et al.* (2022) and Hassan *et al.* (2020). Regarding medical history, hypertension and DM were the most prevalent comorbidities among participants in both groups. These findings are biologically plausible, as hypertension promotes atherosclerotic plaque formation and progressive arterial narrowing, whereas DM impairs endothelial function and vascular elasticity, thereby compromising peripheral circulation (Piechocki *et al.,* 2024).

The findings are consistent with those of Gofio *et al.* (2025), who identified hypertension and DM as the predominant comorbidities among patients with CLTI. Similarly, Mohamer *et al.* (2022) and El-Sayed *et al.* (2021) reported that smoking, hypertension, and DM are the major risk factors associated with CLTI progression and increased disease severity. The findings suggest that the integrated intervention program, combining structured exercise, warm compression therapy, and patient education, may provide additional benefits beyond routine hospital care by improving functional outcomes and reducing CLTI-related symptoms.

These findings support the research hypothesis, as patients who received the integrated intervention program demonstrated greater improvement in CLTI severity and physical functional status compared with the control group receiving routine hospital care. However, the individual contributions of each intervention component could not be determined separately due to the combined nature of the intervention.

This study presents several methodological strengths. The implementation of a combined structured exercise and warm compression therapy program enabled evaluation of the overall effect of this intervention package on CLTI severity and physical functional status. Baseline equivalence between groups enhanced internal validity, while standardized objective measures ensured reliability and clinical relevance.

Nurses play a pivotal role in educating patients about the benefits and techniques of exercise and warm compression. Teaching patients how to perform these safely at home can enhance adherence and encourage self-care, potentially reducing hospital readmission and complications. This holistic approach supports tissue perfusion, promotes healing, and improves patients' outcomes.

### Limitations

The single-center design and relatively small sample size may restrict generalizability. Partial reliance on self-reported adherence to exercise could introduce bias in reporting. Additionally, since exercise and warm compression therapy were delivered as a combined intervention, the separate effect of each component could not be isolated. Future studies using separate intervention groups may help determine the specific contribution of each component. Furthermore, the lack of follow-up beyond six months limits conclusions about the long-term sustainability of the observed benefits. Despite these limitations, the findings provide strong evidence supporting nursing-led interventions, patient education, and exercise programs to improve functional outcomes in CLTI patients.

### Future Scope

Future studies could explore larger patient populations, incorporate advanced imaging techniques, and investigate long-term effects of exercise and warm compression therapy on circulatory health to further validate and expand the findings of this study.

## CONCLUSION

Considering the current study findings, the combined application of exercise modalities (including walking, treadmill training, BAE, resistance training, and ROM exercises) with warm compression was associated with improved postoperative CLTI stage severity and physical functional health status. Hence, this expanded scope may help reduce disease severity and improve patients' clinical and functional status. These suggestions for further research and practice can be made considering the current study's findings: The hospital routine care may consider incorporating a combined exercise and warm compression program as an integral part of the care of patients with CLTI. Continuous educational and training programs are necessary to provide patients with PAD on a regular basis to enhance their standard of living and physical and mental well-being.

### CRediT Authorship Contribution Statement

N.H.A.: Conceptualization, methodology, data curation, formal analysis, writing – original draft, writing – review and editing. S.Z.A.: Methodology, supervision, validation, review and editing. H.A.H.: Investigation, clinical supervision, validation, review and editing. G.H.A.: Investigation, clinical supervision, validation, writing – review and editing.

### AI Assistance Declaration

The authors declare that generative AI tools (such as ChatGPT and Microsoft Copilot) were used only for language enhancement and grammar correction during the preparation of this manuscript. The authors carefully reviewed and revised the content and take full responsibility for the final version of the manuscript.

## Conflict of Interest

The authors disclose that they do not have any competing interests.

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