

How to Cite:

Maharem, T. A. S., Shehata, A. M., & Khalil, B. M. (2022). Effect of ankle pump exercise on fatigue sensation, comfort, and lower limb hemodynamics among deep vein thrombosis patients. *International Journal of Health Sciences*, 6(S9), 4945–4957.
<https://doi.org/10.53730/ijhs.v6nS9.14488>

Effect of ankle pump exercise on fatigue sensation, comfort, and lower limb hemodynamics among deep vein thrombosis patients

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Abstract---Background: Ankle pumping exercises utilize a calf muscle pump function to pump blood to the heart by muscle contraction. Ankle pumping exercises are often used for the relief of edema and the prevention of deep vein thrombosis. So, the current study aimed to evaluate the effect of ankle pump exercise on fatigue sensation, comfort, and lower limb hemodynamics among deep vein thrombosis patients. Design: This study was carried out using a quasi-experimental research design. Setting: This study was applied in the Orthopedic Department at Ain Shams University Hospital. Subjects: It consisted of a convenient sampling technique enrolled to select a sample of 100 patients with deep vein thrombosis in the previously selected department who agreed to participate in the study and were randomly assigned into two equal groups, with 50 patients in each group (the intervention group who received ankle pump exercise and the control group who received routine hospital care only). Tools: three tools were used (I): A patient interviewing sheet, (II): Rating of Perceived Exertion (RPE), and (III): Comfort evaluation scale. Results: There was a highly statistically significant difference between the study group and control patients' fatigue sensation, comfort, and lower limb hemodynamics after the implementation of the ankle pump exercise. The diameters and blood flow (peak systolic) velocities of the external iliac vein, femoral vein, and popliteal vein increased

significantly in the participants. Conclusion: Fatigue sensation, comfort, and lower limb hemodynamics had been improved after ankle pump exercise in the study group than in the control group among patients with deep vein thrombosis. Recommendations: ankle pump exercise should be incorporated into care for patients with deep vein thrombosis to improve their fatigue sensation, comfort, and lower limb hemodynamics.

Keywords---ankle pump exercise, comfort, deep vein thrombosis, fatigue sensation, lower limb hemodynamics.

Introduction

Deep vein thrombosis (DVT) is a type of thrombophlebitis that affects deep veins and is known to have catastrophic side effects. The illness known as deep vein thrombosis, which primarily affects the big veins in the lower leg and thigh, is brought on when a blood clot forms in a vein located deep within the body. It is thought to be brought on by altered physiological pathways, which are likely to happen as a result of trauma, surgery, and limited movement (Shanshan et al., 2021).

Deep vein thrombosis, or the development of blood clots in deep veins, continues to be a serious health issue that contributes to morbidity, mortality, and financial strain on the world's healthcare systems. The incidence of lower extremity DVT was about 1% in the general population, and it was responsible for 600 000 hospital admissions and 80 000 fatalities each year in the USA. Intensive care unit patients in China were reported to have a prevalence of DVT between 10% and 100%, and 2.1% to 4.7% of patients died as a result of DVT, despite the lack of multicenter epidemiological data. As a result, DVT prevention is crucial, and nurses are often believed to be vital in DVT prevention (Hayden et al., 2021).

The most popular mechanical preventative technique has traditionally been ankle pump exercise (APE). APE causes the calf muscle to contract and relax rhythmically through the movement of the ankle joint, which increases the venous reflux of the lower extremities. Normally, each contraction of the calf muscle can release 60 mL to 90 mL of blood, effectively squeezing the blood from the lower limbs' veins to the proximal. Additionally, a risk factor for DVT is decreased calf muscle pump performance. APE is frequently utilized in daily life and therapeutic practice, and research has shown that it successfully reduces DVT and relieves limb edema. Standardized APE hasn't been developed in practice yet (Sakai et al., 2021).

Exercises like ankle pumping make use of the calf muscle pump, which contracts the muscles to pump blood to the heart. Ankle pumping exercises are frequently used to treat edema³ and prevent deep vein thrombosis (DVT) that is brought on by extended periods of bed rest. Ankle pumping exercises can help prevent DVT, according to a guideline for the Diagnosis, Treatment, and Prevention of Pulmonary Thromboembolism and Deep Vein Thrombosis⁴. However, there has

been substantial discussion regarding the best techniques and formats for ankle-pumping exercises (Tufanaru et al., 2022).

Ankle pump exercise (APE), which is performed through plantar flexion and dorsiflexion of the ankle joint, encourages venous blood return to the lower extremities and is advised as an effective method for preventing venous thromboembolism (VTE). APE also lessens venous stasis and enhances calf muscle pump activity, which is advantageous for patients with chronic venous insufficiency (CVI) and venous leg ulcers (VLUs). However, the most effective frequency of APE has not been identified.

Holding plantarflexion and dorsiflexion for 10 seconds at a time, or 3 beats per minute, is advised by traditional APE. APE frequencies that are quicker, ranging from 6 to 100 beats/min, have been discovered to be more efficient for accelerating blood flow velocity in the lower extremities. The vast range of frequencies and variable results make it challenging to validate the most efficient frequency for APE. No evidence-based studies exist to support clinical practice decision-making. The question of which frequency is most effective is challenging to answer because conventional meta-analysis techniques only examine two frequencies at once (Sakai et al., 2021).

Although lower extremity amputation (LEA) has been linked to an increased risk of cardiovascular disease, the hemodynamic mechanisms underlying this association are yet unknown. Therefore, the investigation of the hemodynamic environment change of patients following LEA was purposefully carried out to elucidate the link between them and determine the likely pathophysiology. To quickly replicate the cardiovascular circulation after LEA, a near-physiological mock circulatory system (MCS) was used in the current study. Unsteady-state numerical simulation was used as a support technique to observe changes in the hemodynamic environment inside the blood vessel. Higher peripheral vascular impedance, higher blood pressure, and more pronounced redistribution of blood perfusion volume are all indicators of a more severe LEA (O'Keeffe & Rout, 2019).

Additionally, more severe LEA results in changes to the infrarenal abdominal aorta and iliac artery's relative residence time (RRT), oscillatory shear index (OSI), and wall shear stress, which are all closely related to an increased risk of cardiovascular diseases. The outcomes demonstrated that the patient's hemodynamic environment is impacted differently by varied degrees of LEA (changing heights, unilateral/bilateral). The study provides a reference point for the enhancement of the cardiovascular hemodynamic environment and the prevention of cardiovascular diseases in lower extremity amputees, as well as an explanation of the potential causation of cardiovascular diseases after LEA from a hemodynamic perspective (Kropp et al., 2018).

Significant of the study

Lower extremity amputation (LEA) is a surgical surgery that is required to save lives and results in the loss of limbs and significant morphological alterations in humans. Worldwide, countless people have lost a lower extremity. In 2018, there were more than 1.7 million lower extremity amputees in China. According to data

from India's Census 2011, there are over 5,436,000 lower extremity amputees, most of whom are young men, and trauma is the main reason for amputation (O'Keeffe & Rout, 2019). There are 2 million amputees in the US, with 185 000 new lower extremity amputees added annually.

Ankle pump exercise is one non-pharmacological treatment method that improves deep vein thrombosis patients' self-esteem and ability to control their illness. Because it is readily available, affordable, and improves lower limb hemodynamics, comfort, and fatigue perception, ankle pump exercise is regarded as the easiest therapy to learn (O'Keeffe & Rout, 2019)

Aim of the study

This study aimed to evaluate the effect of ankle pump exercise on fatigue sensation, comfort, and lower limb hemodynamics among deep vein thrombosis patients through:

1. Assessing lower limb hemodynamics among patients in the study group than the control group.
2. Assessing the lower extremity fatigue sensation among patients in the study group than the control group.
3. Assessing the comfort level among patients in the study group than the control group.
3. Developing and implementing ankle pump exercises for deep vein thrombosis patients
4. Evaluating the effect of ankle pump exercise on lower limb hemodynamics among deep vein thrombosis patients

Research hypothesis

The implementation of ankle pump exercises for deep vein thrombosis patients will have a positive effect on fatigue sensation, comfort, and lower limb hemodynamics among the study group than the control group.

Research design

The goal of this study was accomplished using a quasi-experimental design. An empirical interventional study using a quasi-experimental design does not use randomization to determine the causal effects of an intervention on the target population (Middleton, 2019).

Setting

This study was conducted at the orthopedic department at Ain Shams university hospital. This setting was selected due to the high flow rate of cases additionally it serves the biggest region of the population. It is located on the third level of the hospital and consists of 8 rooms, each with 6 beds.

Subjects

It involved a convenient sampling technique to choose a sample of 100 adult patients with deep vein thrombosis in the previously chosen department who agreed to participate in the study. These patients were randomly assigned into

two equal groups, with 50 patients each (the intervention group receiving ankle pump exercise and the control group receiving only routine hospital care).

The participants were chosen using a simple random sample method. Each patient was asked to choose a piece of paper, which was how randomization was done. The patient who chose the letter carrying the paper was in the intervention group (I), and the patient who chose the letter containing the control paper was in the control group (C). While the control group received standard treatment, the intervention group, which included participants of both sexes and agreed to participate in the study, received ankle pump exercises in addition to usual care.

Tools of data collection

Tool I: Patients' interviewing sheet

After evaluating pertinent literature and research findings, the researchers created it (*Hardy et al., 2018 & Amare & Getachew., 2021*). There were two components:

- **Part 1:** It included the patient's demographic data, which included five items of information (age, gender, educational level, occupation, and place of residence).
- **Part 2:** It included the patient's clinical information such as previous hospitalization, chronic diseases, weight, Height (m), **and** BMI (kg/m²).

Tool (2) Rating of Perceived Exertion (RPE)

It was adapted from Ritchie. (2012) to measure fatigue sensation. The RPE scale has 15 values between 6 and 20, each of which relates to a different aspect of weariness experience. Following the exercise, the subjects and helper provide the appropriate value based on their subjective perception of exhaustion, or RPE score.8. The sentences' relevance, clarity, simplicity, and fluency as measured by the Content Validity Index (CVI). Content, clarity, and simplicity were all given a score of 93.40, 89.80, and 90.80% respectively.

Tool (3) Comfort evaluation scale

A scale of comfort was adapted from Borg (1982) and used to rate the subjects' comfort on a scale of 0 to 10. The volunteers decided on the corresponding score after the exercise based on their subjective impressions. 0 to 4 ratings indicate an uncomfortable feeling, 5-7 points indicate a decent feeling, and 8 to 10 points indicate a comfortable feeling. The comfort level increases with the score.

Validity and reliability of the tool

Validity of the tools created by a panel of five experts from various academic categories (professors and assistant professors) in the Department of Medical-surgical Nursing at the Faculty of Nursing. The tools were examined by the experts for simplicity, clarity, completeness, and relevance; no changes were made. Cronbach's alpha test was used to examine reliability, which resulted in

scores of 0. 0.977 on the Rating of Perceived Exertion and 0.97 on the Comfort Evaluation Scale.

The procedure of data collection

Preparatory phase:

A booklet, articles, the internet, journals, and magazines were used to theorize about various study components and evaluate the previously published literature when designing the data-gathering strategies.

Administrative design:

The directors of the previously selected department gave their permission for data collecting, and administrative approval was obtained to carry out this study.

Ethical considerations:

Before the study started, the researchers had a meeting with the setting's directors to outline the goals of the experiment and gain their participation. The study's objectives were first explained to the adult patients, and each participant verbally consented before the study began. They were informed that their decision to participate in the study was entirely up to them and that they could withdraw at any time, with no need to justify it. The confidentiality of their information and the fact that it would only be used for the study were made clear to the participants.

Pilot Study:

In a pilot study with 10% of the patients (ten adult patients), the research procedure was examined for clarity, viability, and applicability. Adult patients who had taken part in the pilot trial were enrolled in the study.

Fieldwork:

The study teams went to the setting they had previously chosen twice a week, from 9 am to 1 pm. Data was obtained over six months, from the start of June to the end of November 2021. Each interview tool can be completed in 35 to 45 minutes. In previously chosen locations, the researchers visited with patients one-on-one. They gave a brief introduction before outlining the goals of the study. As they performed face-to-face interviews with the patients, the researchers read the questions and helped the patients fill out the questionnaires. Data collection began in July 2021 and continued through December 2021.

The implementation process for the study is divided into three phases: assessment, implementation, and evaluation.

Assessment phase:

The researcher established a good relationship with the patients by initially speaking with them informally. The objective and area of the inquiry were discussed. The survey's demographic, Rating of Perceived Exertion, and Comfort evaluation scale items received responses from the researchers.

Implementation Phase

For the intervention group:

The researchers presented a brief overview of the study's goals and introduced each member of the intervention group. Each interview lasted around an hour, depending on how well the patient understood. The 50 patients in the intervention group received ankle pump exercises in addition to routine treatment. We used demonstrations, images, and group discussions (an exercise involving the ankle pump) as instructional aids.

Ankle pump exercise:

The subjects were lying on the bed, with their legs slightly outstretched, thighs relaxed, ankles padded with cotton pads, feet back extended (toes toward themselves), and plantar flexed (toes away from themselves) for one time. The frequency of ankle pump exercise is 30 times/min, exercise for 3 min. The angle of plantar flexion and back extension is the maximum angle that can be achieved at the specified frequency. The active ankle pump exercise was completed by the subjects themselves, while the passive ankle pump exercise was performed by the helper to assist the subjects to complete the above actions. The exercise frequency was controlled by a timer.

For the control group:

The researchers introduced themselves, went over the goals of the study, and got verbal consent from each patient in the control group during a face-to-face talk that lasted around 30 minutes. Following this, the researchers collected information on the patient's demographics, medical history, perception of weariness, level of comfort, and lower limb hemodynamics without performing the ankle pump exercise.

Evaluation phase:

After applying the ankle pump exercise technique, the researchers reassess comfort levels and feelings of fatigue in both the intervention and control groups using the same instruments as the pretest (tools II and III as the posttest).

Statistical analysis

Version 20 of SPSS statistical software was used to analyze the data. Before and after the intervention, continuous data were collected, and the mean and standard deviation were expressed (SD). Data that can be categorized was reported using percentages and figures. The two groups were compared using the independent t-test, and the outcomes of each group were compared before and after the intervention using the paired t-test. Analysis of variance with one-way repeated measures (ANOVA) was used to examine. To evaluate variables that did not meet the parametric assumptions, the Mann-Whitney test was applied. Results were analyzed using the chi-squared method. The chi-square test was used to assess the correlation between two variables in the case of noncontiguous data. For statistical significance, a p-value of less than 0.05 was used.

Table (1): Distribution of the studied adult patients regarding their demographic data

Demographic data	Control group (n=50/%)	Intervention group (n=50/%)
Age (in years):	42.86 ± 6.94	43.77 ± 8.05
Sex:		
Female	38(76%)	43(86.0%)
Male	12(24%)	7(14.0%)
Residence:		
Rural	32(64%)	30 (60.0%)
Urban	18(36%)	20 (40.0%)
Level of education:		
Illiterate	23(46%)	25(50.0%)
Read & write	18(36%)	15(30.0%)
University education	9(18%)	10(20.0%)

As shown in Table 1. The studied adult patients' average age was 42.86 ± 6.94 years old in the control group compared to 43.77 ± 8.05 in the intervention group. The majority of them in the control and study groups respectively were female (76% and 86%). Regarding residence, 64% and 60% of the studied adult patients respectively were living in rural areas. Finally, 46 % of them in the control group compared to 50 were illiterate.

Table (2): Distribution of the studied adult patients regarding their clinical data

Clinical data	Control group (n=50/%)	Intervention group (n=50/%)
Previous hospitalization		
- Yes	3(6%)	1(2%)
- No	47(94%)	49(98%)
Chronic diseases		
- Yes	2(4%)	4(8%)
- No	48(96%)	46(92%)
Height (m)	1.68 ± 7.30	1.66 ± 11.50
Weight (kg)	58.33 ± 9.67	59.44 ± 8.98
BMI (kg/m ²)	22.95 ± 3.03	22.65 ± 2.87

Table 2 showed that 94% of the control group and 98% of the intervention group of the studied adult patients had no previous hospitalization. Additionally, 96% in the control group and 92% in the intervention group of them had no chronic diseases. Concerning height the mean scores of their BMI were 22.95 ± 3.03 in the control group and 22.65 ± 2.87 in the intervention group.

Table (3): Comparison of patients' mean scores in the two control group and intervention groups concerning Rating of Perceived Exertion pre- and post-ankle pump exercise intervention (N=100)

Rating of Perceived Exertion	Control group(n=50)	Intervention group (n= 50)	P-value
	Mean $\pm$ SD	Mean $\pm$ SD	
- Pre-ankle pump exercise	6.0 $\pm$ 0.2	6.0 $\pm$ 0.3	9.76 < 0.001
- Post-ankle pump exercise	7.0 $\pm$ 0.1	11.1 $\pm$ 0.5	

**** Highly Significant $p \leq 0.001$**

Table (3) showed a significant difference in the Rating of Perceived Exertion scores between control and intervention groups pre- and post-ankle pump exercise intervention

Table (4): Comparison of the mean scores among patients in the control and intervention groups regarding Comfort Evaluation Scale pre- and post-ankle pump exercise intervention (N=100)

Comfort evaluation scale	Control group(n=50)	Intervention group (n= 50)	P-value
	Mean $\pm$ SD	Mean $\pm$ SD	
- Pre-ankle pump exercise	1.2 $\pm$ 0.5	1.3 $\pm$ 0.5	75.42 < 0.001
- Post-ankle pump exercise	1.4 $\pm$ 0.5	5.6 $\pm$ 0.5	

**** Highly Significant at $p < 0.001$**

The difference between the intervention and control groups was highly statistically significant, as shown in Table (4) regarding patients' comfort mean score which in the intervention group was higher and better than the control group post the intervention of the ankle pump exercise as $P=0.001$.

Table (5): Differences in the hemodynamics of the common femoral vein in the intervention and control groups post-ankle pump exercise (n = 100)

Comfort evaluation scale	Control group (n=50)	Intervention group (n= 50)	P- value
	Mean $\pm$ SD	Mean $\pm$ SD	
Peak systolic velocity (cm/s)	27.3 $\pm$ 1.1	26.3 $\pm$ 6.3	28.55 < 0.001
Time-averaged mean velocity (cm/s)	25.4 $\pm$ 1.5	42.1 $\pm$ 8.6	24.33 < 0.001

Table (5) The common femoral vein's hemodynamics changed. Peak systolic common femoral venous blood flow was higher in the intervention group than in the control group, and the difference between the two groups was statistically significant ($p .000$). A statistically significant difference ($p < 0.001$) existed between the two groups when comparing the TAMV of the common femoral venous blood flow, with the intervention group's blood flow being quicker than the control group's.

Discussion

At rest, the negative pressure that is created in the chest during inhalation and the siphon negative pressure that is created in the heart during diastole are what primarily drive the return of venous blood to the lower extremities. The muscle pump is another significant factor in promoting the return of venous blood to the lower extremities; for example, one contraction of the calf muscle can release 60–90 ml of venous blood (Crisóstomo et al., 2020). By compressing the intramuscular and intermuscular veins as the calf muscles contract, they can efficiently encourage the return of venous blood (Broderick, et al., 2019). The ankle exercise is to use this mechanism to achieve the purpose of improving fatigue sensation, comfort, and lower limb hemodynamics among patients with deep vein thrombosis prevention.

The Rating of Perceived Exertion scores pre- and post-ankle pump exercise intervention were significantly different between the control and intervention groups, according to the study's findings. The results demonstrated the main benefits of the ankle pump exercise and demonstrated their potency in modifying and improving patient outcomes, according to the researchers. Long-term active contraction of the muscles will result in a significant sense of exhaustion from the subject's point of comfort's perspective (Cheng & Rice, 2019). Additionally, this result is comparable to that of Cavazzana et al. (2018), who discovered that disease affects patients and lowers their tolerance for fatigue.

This conclusion is reinforced by Li et al., (2020) who discovered that ankle exercise causes less post-exercise weariness in their study concerning "Effects of ankle pump exercise frequency on venous hemodynamics of the lower limb" Similar findings were made by Li et al. in (2022) when they investigated "Which frequency of ankle pump exercise should be chosen for the prophylaxis of deep vein thrombosis?"

The results of the present study show that there were highly statistically significant differences between the intervention and control groups in terms of the mean score for patient comfort, which was higher and better in the intervention group following the intervention of the ankle pump exercise. From the researchers' perspective, it supported the usefulness of ankle pump exercises in enhancing patient comfort.

According to the study's findings, the common femoral vein's hemodynamics have changed. Peak common femoral venous blood flow velocity was higher in the intervention group than in the control group, and the difference between the two groups was statistically significant. The difference in TAMV of the common femoral venous blood flow between the intervention group and the control group was statistically significant. This outcome, in the opinion of the researchers, shows the beneficial benefits of ankle exercise application, which satisfies the needs of the patients.

Since the effect of ankle exercises on promoting the return of venous blood flow to the lower extremities was similar to that reported by Partsch H, et al. in 2018, it may be inferred that these exercises have the potential to successfully prevent

DVT. In addition, the results of this study are in line with those of Tianhua et al. (2022), who discovered that ankle exercise is the most efficient technique to enhance the venous hemodynamics of the lower extremities. Similar to this, Dix FP et al., (2019) demonstrated that ankle exercise is essential to improving the hemodynamic effect of lower extremity veins in both healthy individuals and clinical patients.

These results are consistent with a study by Pi et al. (2019) titled "Influence of ankle active dorsiflexion movement guided by Inspiration on the venous return from the lower limbs," which found that ankle exercise is a useful exercise for enhancing lower extremity hemodynamics. Furthermore, Kehl (2016) showed that ankle exercise is frequently used in clinical treatment for patients who are laying in bed to prevent thrombosis, which is in line with the findings of this study. Results from earlier research indicated that ankle exercise was more effective at enhancing lower extremity hemodynamics (Li et al., 2020; Huanli et al., 2020).

Additionally, the results of this study were in line with those of other research by Shimizu et al. (2017) and Li et al. (2020), which revealed that the frequency of ankle exercise might affect the venous hemodynamics of lower extremities. Ankle activity could result in a faster blood flow velocity in the femoral vein, according to Li et al.'s study. The study by Nakayama et al. (2016) discovered that ankle exercise was more efficient.

Conclusion

According to the current study's findings, the study's hypotheses are supported by the fact that patients with deep vein thrombosis experienced less fatigue sensation, more comfort, and improved lower limb hemodynamics following ankle pump exercise in the intervention group compared to the control group.

Recommendations

Based on the findings of the current study, the following recommendations are proposed:

1. Ankle pump exercise should be incorporated into care for patients with deep vein thrombosis to improve their fatigue sensation, comfort, and lower limb hemodynamics.
2. Providing patients with deep vein thrombosis with an educational program on the advantages of and how to perform ankle pump exercises to enhance their sense of weariness, comfort, and lower limb hemodynamics.
3. To achieve generalization of the results and wider application of ankle pump exercise, it is advised that the current study be replicated on a sizable sample.
4. Further studies about the effect of the ankle pump exercise on the quality of life of patients with deep vein thrombosis.

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