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Systematic Review

Effect of Leg Exercise on the Lower Limb Circulation of Patients with Diabetes Mellitus: A Systematic Review

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ABSTRACT

Introduction: Hyperglycemia is one of the typical symptoms of patients with diabetes mellitus. This condition makes the patient very vulnerable to circulatory disorders in the lower extremities, especially in the legs. A lack of exercise of the feet can cause an increased risk of foot ulcers. This systematic review aims to systematically review the research evidence related to the effects of leg exercise on increasing the value of the ankle-brachial index in patients with diabetes mellitus.

Methods: This study used a systematic review with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach. We identified 85 articles from Scopus, 34 from Pubmed and 401 from ProQuest. The keywords used in the search were "Foot Exercise", "Buerger Allen Exercise" and "Diabetes Mellitus". The inclusion criteria for this study were 1) Interventions with a focus on the Buerger Allen Exercise and 2) papers published in English. The deadline for publication was between 2014 and 2019.

Results: After going through the selection process, 8 articles were deemed to be relevant for inclusion in this systematic review. One effort to overcome the interference of lower limb circulation is through physical exercise in the form of leg exercises. The exercises that can be applied are Buerger Allen Exercises. The simplest examination that can be done to detect any interference with lower limb circulation is to measure the value of the Ankle Brachial Index (ABI).

Conclusion: The advantage of this exercise is that it does not involve expensive costs and the risk of injury is low when doing exercises at home.

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KEYWORDS

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INTRODUCTION

Diabetes mellitus (DM) refers to a group of metabolic diseases with the characteristic of hyperglycemia that occurs due to abnormalities in insulin secretion, insulin action or both. Hyperglycemia is a condition where there is an elevated level of glucose in the blood that exceeds normal limits. This condition is one of the typical signs of diabetes, although it may also be found in another state (PERKENI, 2015). In 2015, the prevalence of diabetes in the world totals as many as 415 million people. This number is expected to increase in 2040 up to 642 million. The prevalence of DM in Southeast Asia may total as many as 87 million people. Indonesia is one country in Southeast Asia where the prevalence of diabetes in 2015 amounted to 10 million people, ranked 7th in the world (IDF, 2015).

An increase in blood glucose that is not managed in a long time led to patients with diabetes mellitus impaired blood flow. This condition will affect the blood platelet function so then the patients are more at risk of developing peripheral arterial disease. This often affects the lower extremities, usually the feet (Debra Kohlman-Trigoboff, MS, 2013). Peripheral arterial disease is one of the causes

of diabetic ulcers on the feet (F. Aguilar Rebolledo, 2011). The prevalence of patients with diabetic ulcers on the feet around the world is around 15%. The risk of amputation is 30% and the mortality rate is 32% (IDF, 2015). Indonesia's health profile data based on Indonesia's 2011 DM survey of those with diabetic ulcer complications was ranked 6th out of the 10 major illness of both outpatients and inpatients in the hospitals in Indonesia. The mortality rate ranges from 17 - 23% due to ulcers. The amputation number ranges from 15 -30% and there is a 1-year mortality rate post-amputation for 14.8% of patients (Kementrian Kesehatan Republik Indonesia, 2012).

The risk of lower extremity amputation is 46 times greater in patients with diabetes than those without diabetes. Injuries and other problems in the feet are a major cause of illness (morbidity), disability (disability) and death (mortality) in patients with diabetes(Armstrong, 1998). Investigations that can be done to detect the peripheral circulatory disorder include assessing the Ankle Brachial Index (ABI). The ABI examination is one of the non-invasive methods used to identify arterial insufficiency and it is recommended as a part of the assessment of individuals at risk of disease (Migliacci, Nasorri, Ricciarini, & Gresele, 2008). The ABI measurement is conducted by comparing the ratio of systolic blood pressure of the foot (ankle) and the systolic blood pressure arm (brachial) (Lippincott Williams and Wilkins, 2012). The ABI examination has a sensitivity of 79% and a specificity of 96% in the diagnosis of peripheral arterial disease(Hamonanganl, 2014).

Leg exercises are one of the activities that can be performed by patients with diabetes to prevent the occurrence of peripheral arterial disease. Leg exercises that can be done include the Buerger Allen exercise. The Buerger Allen exercise is a combination of postural changes (leg elevation 45°. decreased feet. and sleeping on your back) as well as muscle pumping of the ankle which consists of two movements, namely dorsiflexion and plantarflexion (Chyong-fang Chang, Chang, & Chen, 2015). Muscle pumping in the form of dorsiflexion and plantarflexion is done actively by moving the skeletal muscles actively, causing the muscles to stimulate blood vessel pressing (Yollanda & Widayati, 2016). Muscle pumps can stimulate the endothelium to secrete or release nitric oxide (NO) which will send a signal in the form of vascular smooth muscle relaxation. At the time there is smooth muscle cell relaxation in the blood vessels, the blood flow in the vasodilatation of the peripheral legs will become smooth(Nurkhalis, 2014). This study aims to systematically review the research evidence related to the effect of leg exercises on increasing the value of the ankle-brachial index in patients with diabetes mellitus.

MATERIALS AND METHODS

Search Strategy

This study used a systematic review with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach. The search for article sources used the Scopus, Pubmed, and ProQuest databases. The search focused on studies in English published between 2014 and 2019. The process of searching for articles was carried out from October 5th through to December 25th 2019. The keywords used in the search were "Leg Exercise", "Buerger Allen Exercise" and "Diabetes Mellitus" to search for the relevant articles. We looked up the references in Google Scholar to filter the references taken into account. The broad search strategy was used to get all of the potential and relevant studies ready to review.

Study Criteria

The reviewers independently filtered the full text of the selected references without exception by title and abstract. This was to get as many articles as possible that were relevant. The inclusion criteria for this systematic review were 1) an intervention focused on the Buerger Allen Exercise and 2) papers published in English. The selection was not limited by the methodological quality, population and yield.

Data Extraction

The reviewers extracted the data that contains information about 1) the first author, 2) the year of publication, 3) country of study, 4) the research location, 5) the time needed during the study, 6) the research sample, 7) the population characteristics used in the research, 8) the variables studied and 9) the characteristics of the intervention and the results. This was used to check the accuracy of the data extraction results.

Data Synthesis

The data synthesis contains information about the population used for the research, the applied interventions, the research designs and the research results summarized using narrative and tabular synthesis. The data limitations and the use of divergent variables in the research did not involve meta-analysis.

RESULTS

Study Search

Based on the results of the study search, as many as 520 potentially relevant articles were identified according to the established criteria. A total of 8 articles were systematically identified using the electronic database search and they fulfilled the inclusion criteria (Figure 1). The articles identified consisted of 3 prospective control groups (Lin et al., 2020)(Lin et al., 2018)(Chen et al., 2017), 2

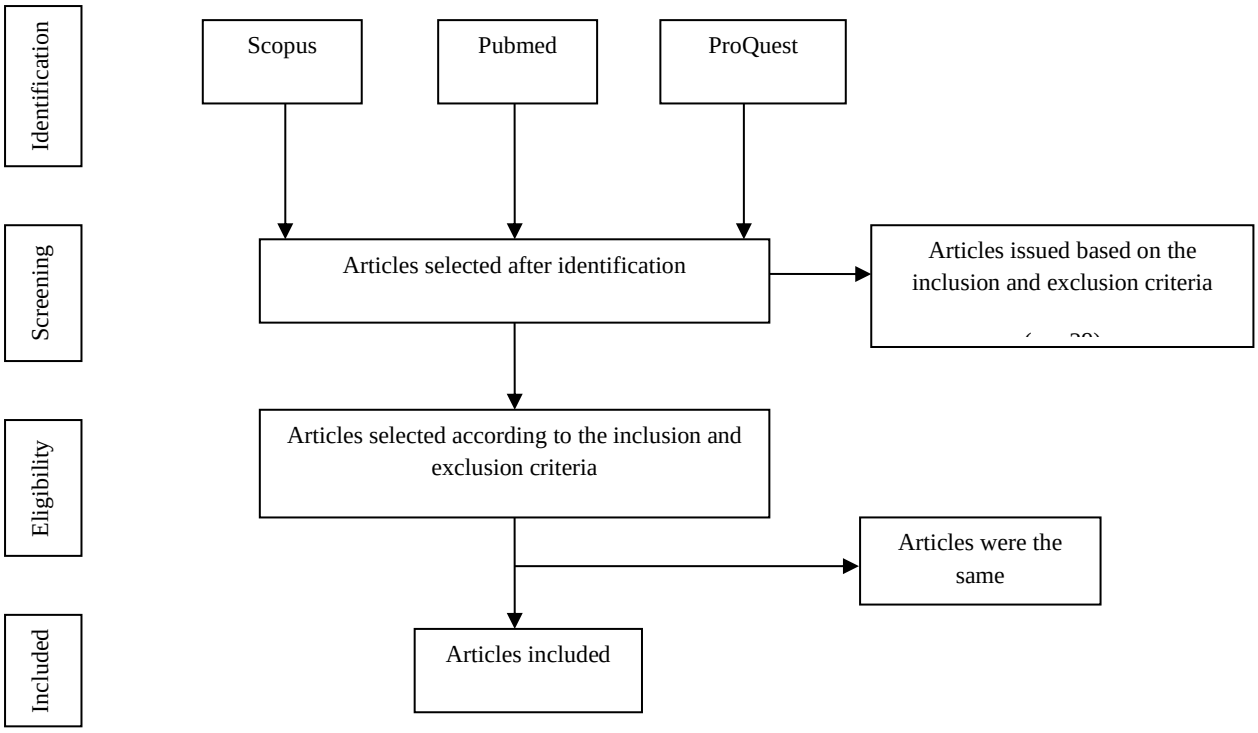

Figure 1 – Flowchart of the Inclusion Process

qualitative (Huang, Chang, Lin, Lin, & Member, 2017)(Chang-cheng Chang et al., 2016)and 3 experimental queries (Chyong-fang Chang, Chang, & Hwang, 2015)(Vijayabarathi & Hemavathy, 2014)(Mellisha & Sc, 2016). The search articles were in the range of 2015 – 2020 for publication. To be specific, 6 articles were conducted in Taiwan and 2 articles were conducted in Chennai. The articles were published in English. The study was conducted in various places such as Chang Gung Memorial Hospital, Chia-Yi Branch, among the rural Chiayi County community residents and at Rajiv Gandhi Government General Hospital, Chennai.

Study Characteristics

A total of 8 articles have been identified involving a total of 340 patients. The patients were divided into 3 groups including group A (no peripheral arterial disease [PAD]), group B (PAD without angioplasty) and group C (PAD with angioplasty) (Lin et al., 2020). Patients without percutaneous transluminal angioplasty (PTA) and those previous percutaneous experience (group A1) were paired with the previous PTA patients (group A2) (Lin et al., 2018). Group A arterial occlusive disease (PAOD) with or without percutaneous transluminal angioplasty (PTA) and Group B non-PAOD (Huang et al., 2017) also involved patients with unilateral or bilateral diabetic ulceration (Chang-cheng Chang et al., 2016)(Chyong-fang Chang, Chang, & Hwang, 2015)(Vijayabarathi & Hemavathy, 2014)(Mellisha & Sc, 2016) (Table 1).

Measurement

The measurement variations from the selected studies aim to assess Buerger's exercise regarding some of the physiological responses or clinical symptoms. The physiological indicator variables measured include tissue blood volume (HbT) (Lin et al., 2020)(Lin et al., 2018)(Huang et al., 2017), oxyhemoglobin (HbO2) (Lin et al., 2020)(Lin et al., 2018)(Chen et al., 2017), deoxyhemoglobin (Hb) (Lin et al., 2020)(Chen et al., 2017) and tissue oxygen saturation (StO2) (Lin et al., 2020)(Huang et al., 2017). The indicator variables measured for the clinical symptoms include foot necrosis (in years) (Lin et al., 2018), the degree of swelling, pain (Wong-Baker Facing Pain Value Scale, Numerical Pain Value Scale) (Mellisha & Sc, 2016), the ABI of the foot (Chyong-fang Chang, Chang, & Hwang, 2015), promoting health behaviors (Chyong-fang Chang, Chang, & Hwang, 2015), MNSI values (Chyong-fang Chang, Chang, & Hwang, 2015) and the symptoms of foot discomfort (Chyong-fang Chang, Chang, & Hwang, 2015) (Table 1).

Intervention Characteristics

Some studies do not have a comparison group. All of the patients are collected and grouped according to the diagnosis of the disease. All patients were given the Allen Buerger exercise and the results were documented. This study aims to compare the interventions but using different participant characteristics. However, several other studies involve 2 groups, namely an intervention group and a comparison group. The study aimed to assess the benefits of the Buerger Allen exercise compared to the usual care. One study compared it with arterial reconstruction. The time of the intervention (period) of the selected study ranged from 5 days (Mellisha & Sc, 2016), 1 month (Chyong-fang Chang, Chang, & Hwang, 2015), 2 months (Lin et al., 2018)(Chang-

cheng Chang et al., 2016), 3 months (Huang et al., 2017), 7 months (Chen et al., 2017) and up to 1 year (Lin et al., 2020) (Table 2). The 8 studies contained an Allen Buerger exercise program which included intensity, duration, frequency and procedure. The exercise can be done every day (n = 6) and the intensity ranges up to 3 times a day at 4-hour intervals (8 am, 12 noon, and 4 pm) with each section repeated 3-6 times each session (Mellisha & Sc, 2016). The Buerger Allen training procedure is inconsistent within each study. For example, referring to the angle of the leg, the duration of each step and each section.

DISCUSSION

Patients with DM are at risk of having impaired lower limb circulation, which is one of the causes of foot ulcers (F. Aguilar Rebolledo, 2011). This is due to the reduced sensation of local pain (neuropathy) making the patient unaware even to the point of ignoring the wounds that occur because they do not feel it. Spontaneous ulcers arise often due to trauma, for example sand intruding, prickly thorns, blisters from the use of shoes, narrow sandals and hard materials. Initially the ulcers are only small but then they expand. The wound will become ulcerated and produce an odor called gangrene (Efa Trisna & Musiana, 2020). Leg exercises are one form of physical exercise that focuses on the lower extremities that can be done by the diabetic patients to prevent the occurrence of peripheral arterial disease. The leg exercises that can be done include the Buerger Allen Exercise. This exercise was first described by Buerger in 1926 and it was later modified by Allen in 1930(Mellisha & Sc, 2016)(ARTHUR, 1928). The duration of each movement of this exercise varies according to the patient's ability in terms of application and the speed of the color change(Bottomley, 2007). Leg exercises actively stimulate the vascular endothelium to secrete or release nitric oxide. Nitric oxide stimulates guanylate soluble cyclase (SGC) which causes an increase in the synthesis of cyclic GMP from guanosine triphosphate (GTP)(Isral & Sulastri, 2014). The increase in cyclic GMP will cause vascular smooth muscle relaxation. At the time of smooth muscle cell relaxation, the blood flow concerning the vasodilatation of the peripheral legs will become smooth(Nurkhalis, 2014).

This exercise has been used for 80 years as a strategy conducted to improve peripheral circulation (Mellisha & Sc, 2016)(ARTHUR, 1928). However, little evidence has shown the effects of the Buerger Allen exercise on the peripheral circulation improvement or healing DFU. Previous research suggests that exercise is beneficial for the patients in group A (no peripheral arterial disease [PAD]). Group B (PAD without angioplasty) and group C (PAD with angioplasty) (Lin et al., 2020) involve patients without percutaneous transluminal angioplasty (PTA). Percutaneous previously (Group A1) was found among the previous PTA patients (Group A2)(Lin et al., 2018), which refers to the group with arterial occlusive disease (PAOD) with or without percutaneous transluminal angioplasty (PTA). Group B were non-pAOD(Huang et al., 2017). The Buerger Allen exercises are an active postural exercise of the legs used to prevent peripheral vascular disease and to improve the circulation of the lower extremities(Mellisha & Sc, 2016). This exercise is a combination of postural changes (leg elevation 45°, decreased foot position and sleeping on your back) as well as the muscle pumping of the ankle which consists of two movements, namely dorsoflexion and plantarflexion (Chyong-fang Chang, Chang, & Hwang, 2015). This exercise should be continuously and repeatedly conducted to increase the muscle microvascular blood flow circulation(Rosales-velderrain, Padilla, Choe, & Hargens, 2013).

Changes in gravity cause the emptying of the veins and an increased flow in the right atrium. This means that cardiac output can be increased (Chang-cheng Chang et al., 2016). This change will affect the distribution of fluids in the body by helping, in turn, to empty and fill the veins with blood. This can increase the rate of blood transportation through the blood vessels. Ankle movements can strengthen the distal circulation due to the strength of the muscle contractions. Movements in the form of dorsoflexion and plantarflexion can also help to avoid the use of the Achilles' tendon contracture or stiffness in the joints which can cause foot deformities (Chang-cheng Chang et al., 2016). The movement of the ankle can increase muscle strength and the ankle joints can increase the contraction of the small muscles in the calf veins, causing the pumping to increase the venous return to the heart. A contraction that occurs in the small muscles of diabetes can increase the supply of oxygenated blood and nutrients in the circulation of the patients with ulcers in the feet(Piergiorgio Francia, Roberto Anichini, Alessandra De Bellis, Giuseppe Seghieri, Renzo Lazzeri, Ferdinando Paternostro, 2015). Lying in the supine position may improve the perfusion of the foot when the effect of gravity is withdrawn(Chang-cheng Chang et al., 2016). This method effectively improves the hemodynamic status of the patients experiencing foot problems in the lower extremities(Tota Kawasaki, Tetsuji Uemura, Kiyomi Matsuo, Kazuyuki Masumoto, Yoshimi Harada, Takahiro Chuman, 2013).

The Buerger Allen exercise involves a variety of active movements especially in the area of the lower extremities and plantar area by applying the force of gravity. This is so then each phase of the movement must be done properly and regularly (Jannaim, Ridha Dharmajaya, 2018). This exercise consists of several stages. (1) The patient performs exercises in the supine position. (2) The foot is lifted at an angle of 45 ° and 60 ° using a pillow for 3 minutes. Elderly patients who cannot tolerate an altitude of 45 ° can elevate the feet to the maximum possible until the legs look pale(Chang-cheng Chang et al., 2016). (3) The patient sits on the edge of the bed with their feet

hanging off the bed. (4) Exercising the legs using dorsoflexion and plantarflexion, and moving the legs in and out for 3 minutes. (5) The patient lying in the supine position with a blanket for 3 minutes(Lin et al., 2020). The whole training cycle is repeated 3 to 6 times each session and each session is repeated at least 3 times a day [18].

The indications of the Buerger Allen exercise include: 1) patients with type 2 diabetes mellitus both male and female; 2) age over 35 years; 3) patients with diabetes mellitus have a low risk of diabetic foot ulcers (class 0-1 according to the Wagner classification system); 4) no people who have diabetes mellitus with foot ulcers and gangrene which chronicles 5) people who do not have neurological diseases and poor cardiology (Vijayabarathi & Hemavathy, 2014). Contraindications in the clients who have a change of physiological function such as dyspnea or chest pain, depression, worry or anxiety, the patients whose activity of daily living (ADL) is poor or dependent and the patients with foot wounds who are a diabetic who are not able to perform a range of motion (ROM) actively or independently were excluded(Chyong-fang Chang, Chang, & Chen, 2015).

Impaired blood flow in the legs can be detected by measuring the ankle-brachial index (ABI). ABI is a diagnostic examination procedure of the lower extremity circulation in order to detect the presence of peripheral artery disease (PAD) by comparing the highest systolic blood pressure of the ankle and the arm(Ruth Bryant, 2006). This check is done by measuring the blood pressure in the ankle region (foot) and in the brachial (arm) region. This requires a doppler probe(Hamonanganl, 2014). ABI has high sensitivity and it is both specific and accurate for LEAD diagnosis (Hirsch et al., 2005)(Grenon, Gagnon, & Hsiang, 2013). The tools used to examine the ABI include a doppler probe and pressure cuff sphygmomanometer in order to measure systolic pressure and the ankle pressure (Claudia Rumwell, 2009)(Grenon et al., 2013). The extremity systolic pressure measurement and the calculation of ABI is a standard non-invasive assessment of the severity of the vasculopathy of the lower limbs. However, arterial stiffness-associated medial calcifications may interfere with the ankle pressure measurement(Brooks et al., 2001)(Tsai, Tulsyan, Jones, Castronuovo, & Carter, 2000)(Quigley, Faris, & Duncan, 1991). In patients with circulatory disorders of the foot, it will be found that the limb blood pressure is lower than the arm blood pressure, which can be seen from the ABI score(Pessinaba et al., 2012). The abnormal condition can be obtained when the ABI value is between 0.41 and 0.90, which indicates that there is a high risk of injury in the leg and that the patients will need follow-up treatment. An ABI <0.4 indicates a necrotic foot, gangrene, ulcers and ulcers that need multi-disciplinary treatment(PAPDI, 2007). The low value of the ABI score shows that the patient is at risk of foot ulcers. Ulcers affect the severity of the condition of the patient (Kristiani et al., n.d.). Delays in early diagnosis can increase the risk of serious complications including disability and amputation (James F. McKinsey, 2012).

The different stages of the exercise involve various joint movements or stretches that can increase the blood flow to the lower extremities in order to prevent peripheral arterial disease (Kevser Bayraktar, Benjamin A Lipsky , Bulent M Ertugrul, 2015). These exercises are easy to learn and they can be done at home via media images, a video or a live demonstration (Chang-cheng Chang et al., 2016). The exercises are easy to teach which will enhance the independence of the patient when performing physical exercises and resolving any complaints that may arise from DM(Sandra Pebrianti, 2017). This exercise does not incur a high cost and the physical activity has a lower risk of injury. The majority of diabetic patients can thus do the exercise at home.

This systematic review is an attempt to synthesize the evidence showing that the Buerger Allen exercise can improve the circulation of the lower extremities. The studies reviewed varied including the participants, interventions, samples, methods, measurements and outcomes. The limitation of this systematic review is that the results may be biased by only displaying publications in English. Studies in other languages may be missed as a result.

Several research articles show that many diabetes mellitus patients suffer from diabetic foot ulcers, thus they are at risk of amputation. Diabetes treatment through foot exercises such as the Buerger exercise will benefit the diabetic patients who have peripheral circulatory insufficiency characterized by a ankle-brachial index <0.9 or a Michigan Neuropathy Screening Index > 2. Thus it is necessary to research the effects of the Buerger exercise on peripheral disorders related to diabetes mellitus through evidence-based studies.

CONCLUSION

Some of the studies chosen did not exclusively focus on diabetes mellitus patients with ulcers. In this review, the Buerger exercise can be beneficial for PAD patients, for PAD patients without angioplasty and for the PAD patients without percutaneous transluminal angioplasty (PTA). This includes previous percutaneous PTA before arterial occlusive disease (PAOD) with or without percutaneous transluminal angioplasty (PTA) and non-PAOD patients with unilateral or bilateral diabetic ulceration. Although this study involved methodological limitations, we have tried to gather evidence supporting the benefits of the Buerger-Allen exercise.

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APPENDIX

Table 1.Characteristics of the Main Results

No.	Author and Title	Country, Study Design, Setting and Sample Size	Design	outcomes	Result
1	Wireless Using Near-Infrared Spectroscopy to Predict Wound Prognosis in Diabetic Foot Ulcers (Lin et al., 2020)	Taiwan. N = 50 patients were divided into 3 groups. Group A (no peripheral arterial disease [PAD]), group B (PAD without angioplasty), and group C (PAD with angioplasty).	Prospective control group	Tissue blood volume (HBT), oxyhemoglobin (HbO2), deoxyhemoglobin (Hb) and tissue oxygen saturation (StO2).	NIRS may prove valuable for predicting wound healing by identifying the risk factors for poor injury prognosis such as decreased hemoglobin and blood volume tissue after exercise.
2	The assessment of Buerger's exercise on the dorsal foot skin vasculopathy circulation in Patients with diabetic foot ulcers by using wireless near-infrared spectroscope: a prospective cohort study (Lin et al., 2018)	Taiwan. N = 14 patients were divided into 2 subgroups: 8 patients without percutaneous transluminal angioplasty (PTA) and a previous percutaneous experince (Group A1) and 6 patients previously PTA (Group A2).	Prospective control group	The condition of the injured patients, follow-up time and the concentration of HbO2 and total hemoglobin (HBT).	HbO2 and HBT concentration increased significantly after the rehabilitation program consisting of sports training in group A (p = 0.024 in HbO2, in the HBT p = 0.02, n = 14) and group A2 (p = 0.021 in HbO2, p = 0.028 in the HBT, n = 6). The concentration in the A1 group had a significance limit that increased after exercise (p = 0.055 in HbO2, in the HBT p = 0.058, n = 8). Most of the ulcers were completely healed (11/14 = 78.57%) or improve (3/14 = 21.43%).
3	Quantitative Evaluation of Rehabilitation Effect on Peripheral Circulation of Diabetic Foot (Huang et al., 2017)	Taiwan. N = 30 patients were classified into 2 groups, namely Group A with arterial occlusive disease (PAOD) with or without percutaneous transluminal angioplasty (PTA) and Group B with no pAOD.	Quantitative	The concentration of total hemoglobin (HBT) and the relative and tissue oxygen saturation (StO2)	The results showed that the relative concentrations of HBT and StO2 following the different groups are significant. Besides, using RBFNN with the input of the relative concentrations of HBT and StO2 can effectively distinguish between the healthy group and diabetic group.
4	The Application of Wireless Near Infrared Spectroscopy on Detecting Peripheral Circulation in Patients With Diabetic Foot Ulcer When Doing Buerger's Exercise (Chen et al., 2017)	Taiwan. N = 30 patients with diabetic foot ulcers (DFU) were treated in the wound care center. They were divided into 2 sub-groups based on duplex ultrasound or angiography. Patients with DFU (Group A) were enrolled in the study: 9 patients were in Group A1 and 21 patients were in Group A2.	Prospective control group	Peripheral HbO2 and Hb total circulation in patients with diabetic foot ulcers.	HbO2 concentration increased in the post-exercise phase for all groups (P¼0.006 in Group A1, P¼0.223 in Group A2, P¼0.03 in Group B). However, there are significant differences both before and after the exercise phase (P¼0.001 and P¼0.01, respectively) between groups A and B.
5	A quantitative real-time assessment of Buerger exercise on foot dorsal skin peripheral circulation in patients with diabetic foot (Chang-cheng Chang et al., 2016)	Taiwan. N = 30 patients with unilateral or bilateral diabetic ulceration at Chang Gung Memorial Hospital, Chia-Yi Branch	quantitative	SPP real-time measurement	The Buerger-Allen exercise significantly increased the level of tuition by more than 10 mm Hg (n = 46, 58.3 vs 70.0mmHg, P <0.001).
6	Combined Effects of Buerger Exercise	Taiwan. N = 66. Patients with type 2 diabetes in the rural	Quasi-experimental	ABI of the foot and promoting healthy	After 12 months, the same number of participants (n =

	Program on Health-Promoting Peripheral Neurovasculopathy Among Community Residents at High Risk for Diabetic Foot ulceration (Chyong-fang Chang, Chang, & Hwang, 2015)	community who were residents Chiayi County.	one-group pretest-posttest	behaviors, values MNSI and the symptoms of leg discomfort.	25, 80.6%) reported a reduction in their discomfort.
7	Buerger Allen Exercise for Type 2 Diabetes Mellitus Foot Ulcer Patients (Vijayabarathi & Hemavathy, 2014)	N = 60. Type 2 diabetes mellitus patients with foot ulcers in the Government General Hospital Rajiv Gandhi, Chennai.	Quasi-experiment	Pre-assessment was done using the Wagner wound assessment scale and the characteristics of the foot ulcer wounds had been previously assessed with the aid of a wound assessment examination in both the experimental group and the control on the first day.	On average in the experimental group, the patients with diabetes showed a 24.6% improvement in wound healing whereas the control group, on average, showed that the patients with diabetes had wound healing only up to 5.3%.
8	Effectiveness of Buerger Allen Exercise on Lower Extremity Perfusion and Pain among Patients with Type 2 Diabetes Mellitus in Selected Hospitals in Chennai (Mellisha & Sc, 2016)	N = 60. Type 2 diabetes mellitus patients with foot ulcers in the Government General Hospital Rajiv Gandhi, Chennai.	Quasi-experiment	The level of pain and lower limb perfusion	The comparison of the pre- and post-test findings showed that in the experimental group, the average score of lower extremity pain level was reduced from 4.33 to 1.30. Pain reduction showed a statistically significant difference at the 1% level of significance (p = 0.001). The average score of the lower limb perfusion level increased from 44.50 to 52. This I shows a statistically significant difference at a significance level of 1% (p = 0.001).

Table 2 Characteristics of the Buerger-Allen Exercise

No.	Author and Title	Length	Angle / Degree	Intensity / Frequency	Procedure and Duration
1	Wireless Using Near-Infrared Spectroscopy to Predict Wound Prognosis in Diabetic Foot Ulcers (Lin et al., 2020)	1 year	45 ° and 60 °	Every movement in the Buerger-Allen exercise is carried out for 3 minutes.	First, the patients do exercises in the supine position. Then their feet are raised between 45 ° and 60 °, supported by pillows for 3 minutes. In the third stage, the patient sits on the edge of the bed with their legs hanging off the bed. In the fourth phase, the patients perform leg exercises with alternate dorsiflexion and plantarflexion positions. They then move their legs in and out for 3 minutes. At the end of the fifth stage of the exercise, the patient lies in the supine position with a blanket for 3 minutes.

2	The assessment of Buerger's exercise on the dorsal foot skin vasculopathy circulation in Patients with diabetic foot ulcers by using wireless near-infrared spectroscope: a prospective cohort study (Lin et al., 2018)	8 weeks	45 ° - 60 °	3 times a day at home for at least 8 weeks	The Buerger-Allen exercise contains 3 steps and 5 phases (phase 1: the supine position; stage 2: elevating the foot at 45 ° - 60 ° is supported by the object for 3 minutes; stage 3: sitting on the edge of the bed with legs dangling; stage 4: repeat feet flexion/extension and then pronation/supination for 3 minutes; stage 5: lieing on the back and resting the feet on a warm blanket for 5 minutes).
3	Quantitative Evaluation of Rehabilitation Effect on Peripheral Circulation of Diabetic Foot (Huang et al., 2017)	3 months	45 ° - 60 °	Every movement in the Buerger Allen exercise was carried out for 3 minutes.	There are three steps to the Buerger Allen exercises. The patients start from a the supine position with their feet elevated at 45 ° - 60 °. Second, they perform leg exercises with dorsiflexion and plantar flexion, and move their legs in and out, lasting for 3 minutes in a sitting position. The final step is to lie down.
4	The Application of Wireless Near Infrared Spectroscopy on Detecting Peripheral Circulation in Patients With Diabetic Foot Ulcer When Doing Buerger's Exercise (Chen et al., 2017)	January to August 2015	45 ° - 60 °	Every movement involved in the Buerger Allen exercises is carried out for 3 minutes.	All of the participants were taught to do the Buerger – Allen exercises by trained research assistants. The subjects started in a supine position in the beginning (pre-exercise) followed by foot elevation at 45 ° - 60 ° using a support cushion for 3 minutes in the second stage. In the third phase, the participants sat down at the end of the bed with the lower legs hanging down and then they do dorsi- and plantar-flexion along with a movement in and out for 3 minutes.
5	A quantitative real-time assessment of Buerger exercise on foot dorsal skin peripheral circulation in patients with diabetic foot (Chang-cheng Chang et al., 2016)	October 2012 to December 2013	45 °	Every movement in the Buerger Allen exercise is carried out for 3 minutes.	The Buerger Allen exercises were taught to the patients in the clinic. First, the lower extremities are elevated to an angle of 45 ° and they are supported in this position until the skin becomes pale. Second, the patient sits in a relaxed position with the legs and feet resting below the level of the remaining body parts. They conduct flexion/extension exercises and then individual foot pronation/supination for 3 minutes until redness appears. Finally, the patient lays still for 5 minutes with both feet placed on the bed with a warm blanket for a few minutes.
6	Combined Effects of Buerger Exercise Program on Health-Promoting Peripheral Neurovasculopathy Among Community Residents at High Risk for Diabetic Foot ulceration (Chyong-fang Chang, Chang, & Hwang, 2015)	March 2012 to April 2013	45 ° - 60 °	The whole training cycle was repeated 3 to 6 times each session. Each session was repeated at least 3 times a day. If diligently followed, this regime will result in a total exercise time > 81 (3 × 3 ×	The three steps for the Buerger exercises are based on the previous interventions (Allen, 1930; Bottomley, 2007): The patient (a) maintains a supine position with both legs elevated at 45 ° - 60 °, supported by pillows, the table or wall for 3 minutes; (B) sits on the edge of a bed or chair with the legs hanging down doing exercises involving dorsiflexion and plantar flexion position, moving the feet inward and outward, and then flexing and extending toes for 3 minutes; and (c) lays on his back for 3

			3 × 3) minutes per day.	minutes. If at any time the patient feels discomfort (i.e., Blanched), stopping the exercise or changing position is an option.
7	Buerger Allen Exercise for Type 2 Diabetes Mellitus Foot Ulcer Patients (Vijayabarathi & Hemavathy, 2014)	15 days	Rate cuts are done every fifth day during the intervention period. Post-foot ulcer wound assessment was carried out using the same checklist on the fifteenth day.	Pre-wound assessment was done by using a rating scale and the characteristics of the foot ulcer wounds were assessed on the first day. The control group received routine care. Rate cuts were done every fifth day during the intervention period.
8	Effectiveness of Buerger Allen Exercise on Lower Extremity Perfusion and Pain among Patients with Type 2 Diabetes Mellitus in Selected Hospitals in Chennai (Mellisha & Sc, 2016)	5 days	Exercise done for 3 times a day at intervals of 4 hours (8 am, 12 noon and 4 pm) for 5 days under the supervision of the investigators.	For the experimental group, the researchers were shown the Buerger Allen exercises and they were asked to exercise 3 times a day at intervals of 4 hours (8 am, 12 noon and 4 pm) for 5 days under the supervision of investigators.